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PUGET SOUND RESEARCH '91

PROCEEDINGS

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PUGET SOUND

RESEARCH '91

TOXIC CHEMICALS: SOURCES AND EFFECTS

Session Chair:

Bruce B. McCain, NOAA/NMFS

INTRODUCTION

Bruce B. McCain [1]

The following papers address two general topics: the introduction and fate of chemical contaminants in the marine environment, and the characteristics of bioindicators that can be used to assess the toxic effects of selected chemical contaminants.

The first two talks, as well as the last, are concerned with the introduction and fate of contaminants. Smayda & Harper discuss how circulation patterns in Mats Mats Bay could affect the distribution of pollutants in that bay. Crecelius & Maykut present data which characterizes the seasonal variability of atmospheric inputs into Puget Sound of selected contaminants from a major urban center. And Smith & Lucchetti give a historical overview of oil spills in Puget Sound. On a closely related topic, Denovan & Word discuss the degradation of Alaska North Slope crude oil, the type of oil spilled in the *Exxon Valdez* spill.

Of the remaining two papers, Word et al. present the results of their studies of how various test conditions affect the responses of the amphipod, *Repoxynius abronius*, to chemically contaminated sediments (*R. abronius* is an important test animal used in a commonly applied sediment toxicity bioassay), and Ellis & Alvarez describe relationships between seawater levels of tributyltin and aberrant sexual characteristics in sea snails (abstract only).

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CIRCULATION AND WATER QUALITY OF MATS MATS BAY

Thomas Smayda and Martin E. Harper[1]

INTRODUCTION

An oceanographic survey to document existing environmental conditions and to evaluate sensitivity to urbanization was conducted in Mats Mats Bay, Washington during the summer of 1989. The focus was on water circulation and flushing, as well as water quality. Water was sampled from two bay stations, Mats Mats channel, a background station in Admiralty Inlet, and three inflow creeks. Oyster tissue was also sampled.

Mats Mats Bay has a unique configuration, with a narrow channel through which all tidal exchange occurs. Channel samples collected on rising and falling tides and combined with creek data permitted mass balance evaluation of internal loading. A bathymetric map was prepared to calculate flushing and circulation characteristics of the bay, and drogue studies were performed to further evaluate the circulation regime.

STUDY AREA

Mats Mats Bay is a Class AA (WAC 173-201) tidal basin located on Washington State's Olympic Peninsula, two miles due north of Port Ludlow (Figure 1). The bay is a small, sheltered basin isolated from Admiralty Inlet by a narrow, doglegged channel. Rolling hills rise to elevations of 600 feet and surround the bay. The hilly terrain, small fetch, and angled channel combine to reduce wind and wave action within Mats Mats Bay. The catchment area is approximately 2.4 square miles and annual rainfall is on the order of 24 inches. Runoff from this catchment enters the bay via three small creeks.

Approximately 85% of the catchment is vegetated, 10% bay surface, and 5% cleared for small farms, residences, roadways, and the Mats Mats quarry. Predominant tree species are Douglas fir, western red cedar, red alder, western hemlock, and big leaf maple, with associated understory. Soils in the catchment are dominated by Alderwood gravelly sandy loams and Cassolary sandy loams with 0-15% slopes. Bedrock is basalt. A herring bait facility maintains floating net pens which hold approximately 2.7 million herring annually. A commercial oyster bed has been located at the north end of Mats Mats Bay. The bay is a well protected anchorage. During summer 1989 approximately 20 permanently moored boats and 3 live-aboards were observed. More than 20 live-aboards may gather during peak use weekends.

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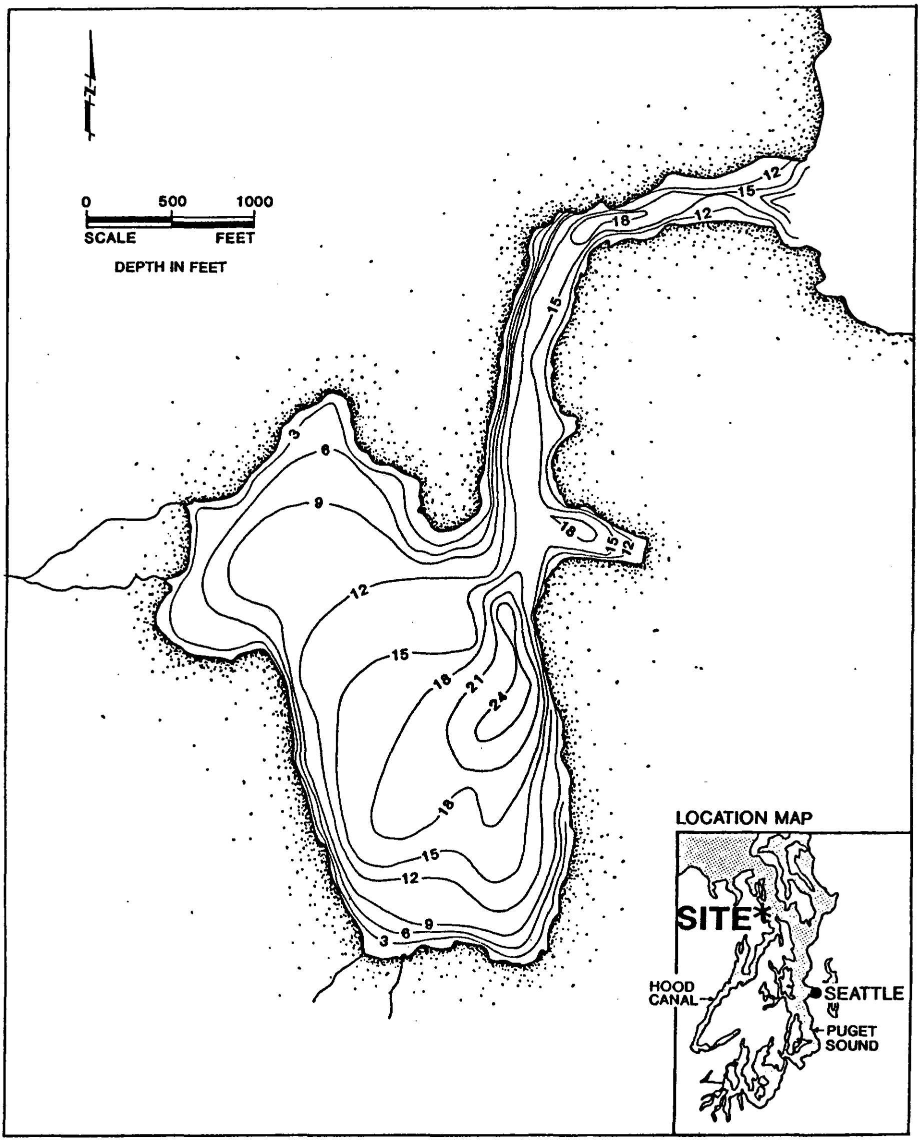

Figure 1.
LOCATION AND BATHYMETRIC MAP OF MATS MATS BAY.

METHODS

Surface and deep seawater samples were collected from a background station in Admiralty Inlet, from within the channel, and from two stations located within the bay. Three creek stations were sampled and oyster samples were collected. Samples were collected at least once per month between July and October. "Worst case" conditions were targeted by the collection of bay samples during the last half of ebb tide and during minimal tidal ranges. Drogue studies of water motion were conducted once during a minimal tidal range and once during an average range. Samples were collected, preserved, transported and analyzed in accord with Puget Sound Protocols (PSEP, 1986). Groups of party balloons filled with fresh water were deployed as drogues. Significance was assessed with a Student's t test at a 95 percent confidence interval. Data quality, based upon precision, accuracy, completeness, representativeness and comparability, was deemed wholly satisfactory.

BASIN MORPHOMETRY

Mats Mats Bay is small, heart-shaped basin of about 133 acres. Maximum and mean depths are 24.7 and 9.9 feet and the volume is 57 million cubic feet (Table 1). The channel is long and narrow, about 3,300 feet by 300 feet, and also relatively deep, with maximum and mean depths of 15.7 and 9.5 feet respectively. At mean tide the volume of Mats Mats Bay plus the channel is 57.5 million cubic feet, of which about 77% is within the bay and 23% in the channel.

Table 1.
MORPHOMETRIC AND TIDAL CHARACTERISTICS OF MATS MATS BAY, WASHINGTON.

		MEAN HIGHER HIGH WATER	MEAN TIDE WATER	MEAN LOWER LOW WATER
Tidal Height	(ft)	9.9	5.8	0.0
Maximum Length	(ft)	4500	4333	4190
Maximum Depth	(ft)	28.8	24.7	18.9
Mean Depth	(ft)	12.9	9.9	6.0
Area	(mill.sq.ft)	6.36	5.80	4.50
Volume	(mill.cu.ft)	82.0	57.5	26.8
Water Residence	(d)	1.3	0.9	0.4

WATER EXCHANGE

The average ebb tide discharges 65% of the mean tide volume, an exchange of 1.3 times per day. Assuming complete mixing within the bay, water half-life is on average 0.32 d. Thus, even during periods of minimal flushing, considerable water exchange occurs in Mats Mats Bay.

The channel from Mats Mats Bay opens to Puget Sound between Olele and Basalt Points. Effectively, the channel opening is on a promontory which extends into the Admiralty Inlet portion of Puget Sound. This region of Puget Sound is known to be vigorously mixed, with current velocities on the order of 0.3 knots (Mofield and Larsen, 1984). Adjacent to Mats Mats Bay, prevailing currents flow northward, possibly on both ebb and flood tides, and mixing depth is generally on the order of 50 m (Harper-Owes, 1986). Thus, even in worst case conditions, water from the bay is likely swept from the channel mouth with only a small fraction available to re-enter the bay.

Creek input to Mats Mats Bay was found to be negligible. Combined flow was 0.32 ± 0.11 cfs. In contrast, based on data from Port Townsend, estimated evaporation from Mats Mats Bay during the same 152 day period was 20 inches, or 0.75 cfs. Evaporation apparently exceeded inflow, as confirmed by measurements which showed that the Admiralty Inlet station was slightly less saline than Mats Mats Bay stations. The small, volume of freshwater inflow and the negligible density difference between Mats Mats Bay and Admiralty Inlet are not perceived to have a strong influence on Mats Mats Bay circulation. Therefore, tidal prism and half-life calculation are thought to represent good estimates of water exchange.

In order to evaluate water exchange more fully, two drogue studies were performed, one during a minimal tidal exchange, the other during an average tidal cycle. During these studies predominant winds were from the north, but were very light, generally 2 to 5 knots. Surface currents moved in response to the wind, and drogue movement was generally southward, into the bay, regardless of tidal direction. In some instances balloons beached, an indicator of surface water downwelling. In other cases the balloons moved counterclockwise at the head of the bay. The picture which emerges is that even very light winds which prevail during summer and autumn serve to hold floating and near-surface objects within the bay despite the great tidal flushing rate.

Water column stability and small scale mixing (dispersion) are additional factors which exert important influences on water exchange. Mats Mats Bay had stable density stratification during July, August, and September. Complete vertical mixing was implicated during the October sampling. The upper mixed layer was 7 to 8 feet deep. The extent of mixing within this layer was determined by the rate which drogues separated from one another. Random

walk calculations indicate that horizontal dispersion was on the order of 10^4 cm^2/s which is relatively small but typical for bodies of water the size of Mats Mats Bay.

The channel was vertically well mixed. Peak observed flow rate during the average tidal exchange was 1.3 feet per second from the top to within 1 foot of the bottom. Flow through the channel apparently moves as a plug.

AVAILABLE LIGHT

Light, rather than nutrients, controls the rate of phytoplankton growth for much of the year in Puget Sound waters (Winter et al., 1975). Available light for photosynthesis depends upon incident solar radiation and water clarity. Based upon average daily solar radiation from Astoria, Oregon, and measured secchi depths, available light is deemed sufficient to support algal blooms between the months of March through September (>40 ly/d), but the winter months of October through February have too little ambient light to support rapid phytoplankton growth.

Critical depth (D_{cr}) is the depth where photosynthetic oxygen production in the water column is equal to the oxygen consumed by water column respiration (= 5 ly/d). The calculated critical depth in Mats Mats Bay was always well in excess of the water depth, and thus water column oxygen production is expected to exceed oxygen utilization all year long. A conclusion is that oxygen depletion is not anticipated to occur at depth in the water column. Oxygen demand of the sediments, however, could result in reduced oxygen levels near the sediment-water interface.

TEMPERATURE

Mats Mats Bay remained cool throughout the summer, 14.2 ± 1.1 °C near the surface and 12.9 ± 1.0 °C at depth (Table 2). Distinct thermoclines existed at 2.8 meters during July and August but were absent in September and October. Water which entered and exited through the channel was the same temperature as Mats Mats Bay bottom water and was significantly cooler than water above the thermocline. This information also indicates that water exchange occurred beneath the thermocline to a larger degree than above.

DISSOLVED OXYGEN

Dissolved oxygen (DO) concentrations within Mats Mats Bay were on average about 150% supersaturated and not significantly different from Admiralty Inlet values. In October, however, DO in bottom water was 5.1 mg/L and in the northern station was 6.3 mg/L, both less than the Class AA water quality

Table 2.
WATER QUALITY INDICATORS FOR MATS MATS BAY DURING THE SUMMER OF 1989. *Station 1 is in Admiralty Inlet, Station 2 in the channel, and Stations 3 and 4 in Mats Mats Bay.*

DATE	STA	SECCHI DEPTH	TEMP	SALINITY	DISSOLVED OXYGEN	AMMONIA	NITRATE + NITRITE	TOTAL KJELDAHL NITROGEN	TOTAL PHOSPHORUS	SOLUBLE PHOSPHORUS	FECAL COLIFORM	CHL a	PHAEOPHYTIN
		m	deg.C	ppt	mg/L	ug N/L	ug N/L	ug N/L	ug P/L	ug P/L	MPN/100ml	ug/L	ug/L
11-Jun-89	1T	4.3	13.0	29.10	10.4	52	95	467	76		< 2	8.20	1.50
	1B		11.8	30.00	8.4	58	143	208	75		< 2	2.30	0.40
10-Jul-89	2I	> 3.2	10.8	30.43	10.2	28	159	256	61	44	< 2	7.00	< 0.10
	2O	> 3.8	13.0	30.38	11.9	69	67	346	53	40	2	3.90	0.20
	3T	2.2	14.2	30.34	12.6	50	63	< 100	58	38	11	5.50	1.30
	3B		11.8	30.43	7.2	123	51	175	66	47	< 2	3.60	0.80
	4	0.7	13.7	30.29	12.8	23	70	211	61	40	< 2	13.40	3.19
	1T	5.8	11.9	29.82	10.1	55	140	< 100	63		< 2	3.50	< 0.10
	1B		11.7	29.89	6.6	58	168	< 100	73		< 2	1.70	< 0.10
07-Aug-89	2I	> 4.7	12.2	31.30		12	174	354	87	57	< 2	5.05	< 0.10
	2O	> 4.8	12.3	31.70	8.4	11	174	462	84	59	< 2	3.19	0.32
	3T	3.0	15.3	31.12	11.6	< 10	47	286	74	32	< 2	11.87	0.59
	3B		13.0	31.23	10.0	< 10	71	502	81	69	2	14.97	< 0.10
	4	> 1.6	15.5	31.52	12.6	12	59	585	80	40	< 2	10.06	0.50
	1T	8.8	14.5	30.69	9.9	46	160	584	78	49	4	6.30	< 0.10
	1B			31.41	6.9	29	211	327	91	66	< 2	3.00	< 0.10
06-Sep-89	2I	> 4.9	12.9	30.98	7.5	20	163	329	79	75	< 2	5.48	< 0.10
	2O	> 4.8	15.8	30.69	9.8	23	194	< 100	79	78	< 2	4.11	< 0.10
	3T	3.7	14.9	30.65	9.0	13	168	256	81	72	5	7.40	< 0.10
	3B		14.5	30.98	7.5	23	168	< 100	88	72	< 2	5.86	< 0.10
	4	> 2.8	13.6	30.32	7.6	26	164	199	86	71	< 2	6.51	< 0.10
	1T	7.6	17.0	31.23	7.5	25	154	< 100	83	79	< 2	6.00	< 0.10
	1B		13.0	31.16	6.0	35	183	< 100	83	84	< 2	5.00	< 0.10
07-Sep-89	2I1	> 4.8	13.0	30.54	9.5	23	195	284	81	77	< 2	4.04	0.67
	2I2	> 5.0	13.0	30.29	9.9	24	194	< 100	82	76	< 2	7.26	< 0.10
	2O1	> 4.7	13.2	30.87	9.6	17	214	148	81	76	< 2	2.95	< 0.10
	2O2	> 4.7	13.8	30.32	10.1	27	201	< 100	79	78	< 2	2.65	0.60
29-Sep-89	2I1	3.7	12.5	30.11	9.5	45	228	272	93	57	< 2	1.74	< 0.10
	2I2	> 5.1	12.5	30.93	9.3	70	506	216	145	57	< 2	2.00	0.10
	2O1	> 5.1	12.3	31.49	9.7	88	132	445	77	53	6	2.19	0.11
	2O2	> 3.5	12.6	30.50	11.0	71	119	173	93	56	4	3.24	< 0.10
05-Oct-89	2I	5.1	12.0	30.49	9.2	63	223	246	86	53	4	< 0.10	2.29
	2O	> 5.0	11.7	30.42	8.5	100	231	490	91	57	< 2	0.45	< 0.10
	3T	4.3	12.5	30.49	8.0	99	209	325	90	47	2	0.43	0.17
	3B		12.4	30.28	5.1	77	192	390	91	57	< 2	0.37	0.94
	4	> 1.9	12.2	30.45	6.3	103	206	205	93	53	7	1.34	< 0.10
	1T	7.9	12.5	29.82	7.0	67	178	557	77	55	< 2	0.80	0.30
	1B		12.0	30.56	5.8	63	225	557	92	67	2	< 0.10	< 0.10
AVERAGE	2I	4.6	12.4	30.63	8.1	36	230	257	89	62	2	4.08	0.45
	2O	4.8	13.0	30.85	9.6	50	214	288	87	62	2	3.26	0.14
	3T	3.3	14.2	30.65	10.3	43	122	242	76	47	4	6.30	0.54
	3B		12.9	30.73	7.5	58	121	292	82	61	2	6.20	0.49
	4	1.8	13.8	30.65	9.8	41	125	300	80	51	3	7.83	0.97
	1T	7.5	14.0	30.39	8.6	48	158	335	75	46	2	4.15	0.15
	1B		9.2	30.76	6.3	46	197	271	85	54	2	2.45	0.10

standard of 7.0 mg/L. Dissolved oxygen was also low offshore as a result of fall upwelling in Admiralty Inlet. The upwelling is largely responsible for the low DO levels. The extent of man's influence includes such sources as the respiration of herring stored in net pens and the increase in oxygen demand of sediments as a result of the introduction of organic materials to the bay. The

respiration of herring is considered to be very similar to that of their Atlantic allies, the menhaden: about 0.1% mg DO/g wet weight/h when not feeding (Durbin et al., 1981). Based on 2.7 million herring per year, 14 d holding time, 30 g per fish, and the above oxygen consumption rate, the fish consume 300,000 mg DO/h or about 0.1% of the incoming DO.

NUTRIENTS

Mats Mats Bay waters consistently had TN:TP and DIN:SRP ratios of approximately 5:1 and 4:1, respectively, indicating that N, rather than P, was in shortest supply for phytoplankton growth. Despite indications of N limitation, the absolute level of dissolved inorganic nitrogen remained high. Even during August when peak phytoplankton concentrations were observed, concentrations of DIN remained in excess of 47 µg N/L. Eppley et al., (1969) have shown that many coastal phytoplankters may grow at nearly maximal growth rates when DIN exceeds 15 µg N/L. Thus, with nitrogen always available in excess of demand, nutrient limitation is not thought to have occurred.

Mass balance data suggest that input of nutrients from Admiralty Inlet is by far the most important source. Creek input was negligible. Internal loading (Table 3), as found by difference of inflow to the bay, minus outflow, was not. Notable internal sources may include sediment release, groundwater and septage input, boater activity, and the herring net pen operation. Approximately 4% to 11% of the P which entered the Bay sedimented during July and August; no net exchange was noted in September. In October sediment P release contributed about 6% of the P load. This seasonality is consistent with known mechanisms governing P solubility and is frequently observed in Pacific Northwest lakes. TN was, on average, generated in the bay but no consistent trends were observed.

Table 3.
INTERNAL LOADING CALCULATED BY MASS BALANCE.

		10-Jul-89	07-Aug-89	06-Sep-89	05-Oct-89
INTERNAL LOADING					
Total Phosphorus	(kg/d)	11.24	4.78	0.08	-7.37
Soluble Phosphorus	(kd/d)	5.64	-3.07	-4.19	-5.93
Total Nitrogen	(kg/d)	3.00	-168.53	351.18	-377.97
Nitrate + Nitrite	(kg/d)	127.90	0.14	-43.73	-11.81
Ammonia	(kg/d)	-56.80	1.57	-4.24	-55.56
Chlorophyll a	(kg/d)	4.31	2.91	1.94	-0.60
Fecal Coliform	(10^6/d)	-10.94	0.38	0.97	52.89

PHYTOPLANKTON ABUNDANCE

In Mats Mats Bay, average chl a levels were 3.3 to 7.8 µg/L with a peak concentration of 14.97 µg/L. Mass balance calculation indicates that about 30% less chl a washed out of Mats Mats Bay than entered. Two theories which are not mutually exclusive may account for this. Either phytoplankton death exceeded growth because of zooplankton and oyster feeding, or the phytoplankton were able to adjust their vertical placement in the water column to avoid washout.

Paralytic shellfish poisoning may occur when toxic phytoplankton species are present, sometimes visible as red tides. Shellfish toxin levels are routinely monitored in Mats Mats Bay and at Olele and Klas rocks near the channel opening. These results indicate that dangerous levels of toxin occasionally occur (DSHS, 1988).

WATER COLUMN FECAL COLIFORM BACTERIA

Water column fecal coliform bacteria were not abundant in Mats Mats Bay. The maximum detected concentration was 11 MPN/100 ml, but 19 of 28 samples contained less than the detection limit of 2 MPN/100 ml. The geometric mean concentration was less than 2.5 MPN/100 ml, within the 14 MPN/100 ml geometric mean limit imposed on Class AA Waters (WAC 173-210-045). Low fecal coliform levels in Mats Mats Bay have been confirmed by other studies. A suite of 13 samples collected during May through July 1987 (Harper-Owes, 1986) had a geometric mean concentration of 4 MPN/100 ml. Four stations sampled 12 to 14 times each by Rubida (1989) had geometric means which ranged from 0.4 to 2.0 MPN/100 ml.

Despite low fecal coliform concentrations in bay water, the three creeks exceeded Class AA fresh water quality standards: fecal coliform organisms shall not exceed a geometric mean of 43 organisms/100 ml with not more than 10% of the samples in excess of 100 organisms/100 ml. Ten samples collected from the three creeks had a geometric mean of 121 MPN/100 ml and the estimated upper 10% was 920 MPN/100 ml.

SHELLFISH FECAL COLIFORM BACTERIA

Freshwater input typically represents a large source of fecal contamination to marine systems and, because freshwater tends to float, highest contamination levels often exist at the surface. Furthermore, surface water exchange in Mats Mats appears poor. Because oysters reside in the intertidal zone, they are in an area of high exposure to surface waters. As discussed previously, bay water had essentially undetectable fecal coliform bacterial concentrations, but the three inflow creeks contained relatively high concentrations.

The Food and Drug Administration has promulgated a guideline of 230 fecal coliform organisms per 100 ml of shellfish tissue which applies to commercial sales. Oysters in Mats Mats Bay exceeded this guideline in 5 of 6 samples, having a geometric mean of 333 MPN/100 ml and a maximum of 673 MPN/100 ml. Tissue samples collected immediately adjacent to inflow creeks displayed greater concentrations of fecal coliform than did oysters from a location distant from the creeks. Prior data (Jefferson County Department of Health, pers. comm.) include a shellfish sample from June 1985 with 20 MPN/100 ml and three during 1987 which showed levels of 20, 78 and 1300 MPN/100 ml.

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SIGNIFICANCE OF AIRBORNE CONTAMINANTS TO THE MARINE WATER QUALITY OF PUGET SOUND

Eric A. Crecelius[1] *and Naydene Maykut*[2]

INTRODUCTION

This paper arises from a study conceived by a technical advisory committee working through the Puget Sound Estuary Program (PSEP) to more fully understand the contribution of airborne toxics to water quality problems in Puget Sound (PSWQA, 1990). The PSEP is co-managed by the Puget Sound Water Quality Authority, the U.S. Environmental Protection Agency (EPA) Region 10, and the Washington State Department of Ecology. The Puget Sound Air Pollution Control Agency also contributed to the study.

The problem of the cross-media transfer of pollutants prompted the study. The deposition of airborne particles may be responsible for contributing specific heavy metals, polycyclic aromatic hydrocarbons (PAHs), and other organic compounds to Puget Sound. Deposition can occur directly as particles settle onto the water surface, or indirectly as they settle on land and are subsequently washed or blown into the Sound. These toxic chemicals are then added to the burden of chemicals in the sea-surface microlayer (the 50-micron boundary layer between the atmosphere and the ocean), the water column, and/or the sediments. This resultant increase in toxicity may affect aquatic life in the Sound.

STUDY PLAN

The study to determine whether the cross-media transfer of toxic pollutants is significant was conducted at Commencement Bay near Tacoma, Washington. The Commencement Bay area was chosen because it is well studied, it has a complex and diverse air pollution source matrix, high concentrations of lead and PAHs have been measured in the sediments and the sea-surface microlayer, and a heavy loading of air contaminants from industry has been documented there.

The Battelle Marine Sciences Laboratory, under contract from the Puget Sound Water Quality Authority, conducted field sampling and chemical analyses of atmospheric deposition samples collected over a 6-month period (July through December 1989) at five sites in the Commencement Bay area.

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RESULTS AND DISCUSSION

Results from this study were used to estimate the impact of metals and PAHs on the sea-surface microlayer and on water column concentrations in Commencement Bay. The following estimates are based on the mean contaminant deposition rates as reported by the Puget Sound Water Quality Authority (PSWQA, 1990). These results indicate that a higher deposition rate of metals and PAHs occurs at industrial sites on the Tacoma waterfront (Sea-Land) than at the Tyee Marina on Commencement Bay or at rural Riverside School near Puyallup.

The sea-surface microlayer contains contaminants derived from atmospheric deposition. The residence time of metals in the sea-surface microlayer was determined by Hardy and Apts (1983) to be on the order of 3 to 20 hours for urban air particulate matter (using a microlayer thickness of 50 microns and a wind speed of 3.6 m/s [average wind speed in Puget Sound]). The concentrations of metals in the sea-surface microlayer of Commencement Bay can be estimated using the mean deposition rates for the Sea-Land and Tyee Marina sites and using the assumptions of a thickness of 50 microns and a residence time of 3 or 20 hours.

The predicted concentrations (in µg/L) of chemicals in the sea-surface microlayer are presented in Table 1. Column 2 contains concentrations for the Tyee Marina site (representing the low end of the deposition rates) at a residence time of 3 hours. Column 3 contains concentrations for the Sea-Land site (representing the high end of the deposition rates) at a residence time of 20 hours. Column 4 contains literature values for actual chemical analyses of the sea-surface microlayer from Puget Sound urban bays (Hardy et al., 1987), while column 5 is a list of EPA chronic marine water quality criteria (EPA, 1986).

The estimates of contaminant concentrations from atmospheric deposition (Table 1, columns 2 and 3) indicate that the measured concentrations (column 4) may be high, due entirely to the cross-media transfer of these toxics from the air. Results for Puget Sound microlayer field samples analyzed by Hardy et al. (1987) are in the range of predicted concentrations. Marine water quality criteria (column 5) do not necessarily apply to the microlayer; however, 50 percent mortality of English and sand sole larvae was observed in bioassays when PAH concentrations exceeded 50 µg/L (Hardy et al., 1986). The marine chronic water quality criteria values are relatively low compared with the predicted and measured sea-surface microlayer concentrations of copper, lead, and zinc. Combustion polynuclear aromatic hydrocarbons (CPAH) (from flouranthene through benzo[g,h,i]perylene) do not have marine chronic water quality criteria. However, a marine acute criterion for PAH of 300 µg/L has been suggested by EPA based on lowest effect concentrations.

Table 1.
PREDICTED CONCENTRATIONS OF SPECIFIC CONTAMINANTS IN THE SEA-SURFACE MICROLAYER[a].

Contaminant	TM 3-hour (µg/L)	SL 20-hour (µg/L)	Literature Value Hardy et al. (1987) (µg/L)	EPA (1986) Marine Chronic Water Criteria (µg/L)
Arsenic	4.5	300	—[b]	36
Copper	144	2,470	51-3,200	2.9
Lead	87	10,800	38-650	5.6
Zinc	267	14,500	135-1,420	86
CPAH[c]	11	225	8-148	300[d]

(a) Concentrations assume a 50 micron-thick microlayer, 3-hour or 20-hour residence times, and deposition rates at Tyee Marina or the Sea-Land site.
(b) Data not available.
(c) Combustion polynuclear aromatic hydrocarbons.
(d) Lowest observable effects concentration.

The mass loading of contaminants to Commencement Bay from atmospheric deposition, point sources, and the Puyallup River is presented in Table 2. The atmospheric deposition rates are estimated using the mean deposition rates determined over a 6-month period at the Riverside School and Sea-Land sites. The area of Commencement Bay was assumed to be 10 km^2 (approximately 2 miles wide by 2 miles long). Data for mass loading of contaminants to Commencement Bay were taken from Tetra Tech (1988) and Paulson et al.(1989). The Tetra Tech (1988) mass loading data in Table 2 do not include sources along the Ruston shoreline because the arbitrarily chosen deposition area does not extend to that region of the bay. Data from Paulson et al. (1989) include municipal outfalls and the Ruston shoreline; this could explain why the values from Paulson et al. (1989) are about four times higher than those of Tetra Tech (1988). The Puyallup River contributes as much or more copper, lead and zinc as the point sources.

If the Riverside School deposition rates for metals are assumed to be typical for Commencement Bay, then atmospheric deposition contributes approximately 1 percent of the anthropogenic loading of metals. If the Sea-Land deposition rates are used, then atmosphere deposition could contribute 15 percent of the lead and zinc. However, because the high deposition rates for lead and zinc at Sea-Land apparently are caused by site-specific contamination from the metal ore offloading facility, the Sea-Land site is probably not typical of Commencement Bay. In addition, although adequate CPAH mass loading data were not available to make comparisons for Commencement Bay, based on an extrapolation of the Tyee Marina PAH deposition rate and previous

estimates by Romberg et al. (1984), atmospheric PAHs can account for less than 20 percent of the mass loading of PAHs to the central basin of the Sound.

Table 2.
CONTAMINANT MASS LOADING TO COMMENCEMENT BAY.

	Sources (metric ton/year)			
	Atmospheric Deposition			Municipal and Industrial
Contaminant	RS[a]	SL[b]	Point Sources Tetra Tech (1988)	Paulson et al. (1989)
Arsenic	0.007	0.07	5.2	—[c]
Copper	0.07	0.5	3.4	17
Lead	0.08	2.2	3.1	15
Zinc	0.1	3.1	8.4	21
CPAH[d]	0.013	0.055	—	—

(a) Predicted from Riverside School deposition samples.
(b) Predicted from Sea-Land deposition samples.
(c) Data not available.
(d) Combustion polynuclear aromatic hydrocarbon.

The atmospheric deposition data from the Riverside School site (representing low measured depositions) and the Sea-Land site (representing high measured depositions) were used to predict concentrations of contaminants in water quality of Commencement Bay (Table 3). The predictions were based on an assumption of the two conditions: a well-mixed, 10 m water column in Commencement Bay, and a 2-day residence time or flushing rate for Commencement Bay. (These assumptions are arbitrary and could change with time of year and tidal conditions.) The flushing rate (or length of time for water to pass through Commencement Bay) was taken from Cannon and Grigsby (1982), who estimated transit times for the bay to be in the range of 2 days. The predicted concentrations of metals in the water column (Table 3) are relatively low, compared with EPA marine chronic water quality criteria or Puget Sound ambient concentrations. It is unlikely that direct atmospheric deposition of metals has a significant effect on the quality of the water column in Commencement Bay. However, the metals concentrations in the sea-surface microlayer could be elevated at times.

The predicted concentration of CPAH in the Commencement Bay water column is 0.003 μg/L, an order of magnitude lower than the EPA criteria value of 0.031 μg/L PAH based on human health criteria for carcinogens, which is, in turn, based on eating fish exposed to CPAHs in the water.

Table 3.
PREDICTED CONCENTRATIONS OF CONTAMINANTS IN COMMENCEMENT BAY WATER COLUMN DUE TO ATMOSPHERIC DEPOSITION[a].

	μg/L			
Contaminant	Estimated RS Flux[b]	Estimated SL Flux[c]	EPA (1986) Chronic Water Quality Criteria[d]	Puget Sound Ambient Concentration[e]
Arsenic	0.0004	0.004	36	1.8
Copper	0.004	0.03	2.9	0.5
Lead	0.004	0.12	5.6	0.15
Zinc	0.007	0.170	86	1.8
CPAH[f]	0.0007	0.003	0.031	0.013

(a) Assumed 10 m depth of mixed water column and a flushing rate of two days.
(b) Predicted from Riverside School deposition samples.
(c) Predicted from Sea-Land deposition samples.
(d) The CPAH criteria is based on human health criteria for carcinogens, 10^{-6} risk factor from fish consumption (assuming the fish have been exposed 0.031μg/L)
(e) Romberg et al. (1984).
(f) Combustion polynuclear aromatic hydrocarbon.

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THE EFFECT OF TEST SEDIMENT STABILIZATION AND DISTURBANCE ON ACUTE TOXICITY TO THE AMPHIPOD *RHEPOXYNIUS ABRONIUS*

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INTRODUCTION

Sediment bioassays based on research done by Swartz et al., (1985) using the Phoxocephalid amphipod, *Rhepoxynius abronius*, have been widely accepted. Sensitivity to contaminants and cost effectiveness have also been demonstrated (Word et al., 1989). Researchers in different laboratories have been able to achieve similar bioassay results (Mearns, 1986) and thus add to existing confidence in standard protocols. The findings in this report may help to further establish protocols for sediment handling, compositing techniques, and equilibration times. Test results also have implications for *in situ* sediment disturbances of both natural and man-made origins. That is, if the toxicity of marine sediments increases with physical disturbance, accurate assessments of environmental conditions must consider factors such as beach transport, turbidity currents, storm and flood caused erosion, and dredging.

A total of five, ten-day static sediment bioassays were conducted (Table 1). Four of these bioassays were run concurrently with four-day positive control bioassays for a portion of each ten-day test. $CdCl_2$ served as a reference toxicant to determine the sensitivity of the test organisms and to compare the sensitivity of *R. abronius* collected on different dates over the extended time period required for testing.

Table 1
OVERVIEW OF THE EXPERIMENTAL TIME PERIOD.

TEST	PERIOD OF TESTING	DAY DISTURBED	EQUILIBRATION PERIOD
1	day 1- day 11	0	overnight
2	day 15- day 25	0	14 days
3	day 26- day 36	0	25 days
4	day 50- day 60	48	2 days
5	day 65- day 75	64	overnight

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Test containers for three bioassays were layered with sediments at the same time and then initiated on three different dates. In these tests it was hypothesized that contaminants would become less available to *R. abronius* as time allowed sorbtion to such materials as sediment particles, glass surfaces, colloidal particles, and organic carbon compounds (Voice and Weber, 1983; Weber et al., 1983). This process would, therefore, remove contaminants from the interstitial and overlying waters. Since this amphipod does not spend appreciable amounts of time in the water overlying test sediments, its contact with the interstitial water probably provides most of its exposure to toxic materials under bioassay conditions (Kemp and Swartz, 1988). Change in the survival of *R. abronius* would be used to demonstrate the change in the toxicity of sediments with different periods of physical stability.

Secondly, it was hypothesized that if sediments were disturbed after being allowed time to equilibrate, toxic materials would be released from the surfaces to which they had sorbed and would become re-introduced into the interstitial and overlying waters. The survival rate of *R. abronius* was used to evaluate the bioavailability of toxic materials. Two additional tests were conducted to address this second hypothesis. The sediments used for these tests were layered and disturbed prior to each test.

MATERIALS AND METHODS

Six sediment samples, including reference and control sediments, were used for this experiment. Four test sediments (MA-1U, MA-1L, SS-4L, and C-4) were selected which were known to cause a high mortality rate in *R. abronius* and for which chemical analysis had previously been conducted. Sediments of differing grain sizes were used for test, reference, and control sediments. A reference sediment (SB) from Sequim Bay, Washington and a control sediment (WB), native to *R. abronius* and from West Beach of Whidbey Island, Washington, were used. Each sediment sample had five replicate test containers. Thus, each of the five, ten-day sediment bioassays consisted of thirty test jars.

In addressing the first hypothesis, Tests One, Two, and Three were designed to test toxicity of sediments which had been allowed to equilibrate over increasing periods of time up to thirty-five days after the initial disturbance. This was accomplished by layering all jars for the first three tests one day after the disturbance of compositing by thorough hand mixing of each core sample. Initiation of each test occurred after different periods of stability on the water table had been allowed. [This first hypothesis had its origins in the work of Word et al. (1987) with equilibration of DDT. Their findings demonstrated a decrease in the interstitial water's DDT concentration over a period of nearly forty days.] Test Three's sediment and overlying water would then be

retrieved and reused after a disturbance was induced to test the second hypothesis. This design was implemented to limit variables other than disturbance from entering into the experiment. Test Five was later designed to test the effects on toxicity of a disturbance of a greater magnitude than that used in Test Four.

All bioassays were conducted according to standard protocols (PSEP, 1986; Swartz et al., 1985), with the exceptions of the deviation from the maximum sediment holding time and the deviation of extended time periods between layering and test initiation in Tests 2 and 3.

RESULTS

Chemical Analysis

Polynuclear aromatic hydrocarbon (PAH) analyses were not performed on the C-4 test sediment. However, of the sediments analyzed, the PAH values of the MA-1U sediment stands out at levels above those found by Plesha et al. (1988) to be toxic to *R. abronius*. Arsenic, Chromium, and Nickel all appear in MA-1U's analyses at toxic levels. When organic carbon level were considered, both the MA-1U and SS-4L test sediments contained significant levels of PAH's. The positive correlation between organic carbon and equilibrium partitioning and the bioavailability of organic materials has been discussed by Staples et al. (1985).

Table 2
SEDIMENT GRAIN SIZE AND SOLIDS.

Sediment Treatment	Total Solids % Dry wt.	% Gravel > 2.00 mm	% Sand 0.063-2.00 mm	% Silt 0.004-0.063mm	% Clay <0.004 mm
MA-1U	47.90	0.09	17.14	27.06	55.71
MA-1L	84.25	0.29	41.12	37.07	21.52
SS-4L	84.25	0.00	88.64	7.66	3.70
C-4	70.1	0.00	73.63	14.02	12.35
SB	nm	0.00	27.84	42.75	29.44
WB	76.30	0.00	98.00	0.36	1.63

The sediments samples used show a range of grain size combinations ranging from the 98.02% sand in the West Beach sample to the 55.71% clay of the MA-1U (Table 2). The high values for Sequim Bay's silt and clay content make it an excellent reference sediment to contrast with other fine grained sediments, while the West Beach control sediment demonstrates the survival rate of *R. abronius* in sediments of a larger size. The significance of this physical feature of the test sediments will be considered carefully in light of the very fine grain

size found in test sediment MA-1L. Further testing of the effects of sediment grain size on *R. abronius* is needed.

Bioassay Results

Results from Test 1-3 indicate a increase in amphipod survival through the time MA-1U, SS-4L, and C-4 test sediments were allowed to remain physically stable under test conditions (Figures 1-3). It appears from the MA-1U and SS-4L data that the sorbtion of toxic materials continued over the 36 day equilibration period, while the C-4 bioassay results suggest chemical stability was achieved during the 36 day period.

Figure 4 shows a low and nearly stable survival rate for the very fine grained MA-1L sediment. In Figures 5 and 6, both SB reference and WB control sediments' survival rates remained high and relatively unchanged in Tests 1-3.

DISCUSSION AND CONCLUSIONS

Tests 1-3

While sorbtion of toxic materials and equilibrium partitioning has been well documented for many hydrophobic organic compounds, some characteristics of this process are not fully agreed upon (Gschwend & Wu, 1985). The possibility of sorbtion and desorption of toxic materials in the test sediments' interstitial waters impacting the survival of *R. abronius* is considered in light of the test results observed in these tests and the results from previous testing (Word et al., 1987).

Sorbtion to solids and organic carbon compounds has been investigated by several researchers (Lambert, 1968; Voice and Weber, 1983; Voice et al., 1983; Weber et al., 1983; Gschwend & Wu, 1985; Staples et al., 1985; and Whitehouse, 1985). The position of this paper is that the sorbtion of compounds in interstitial water is a means of removal of toxicants available to *R. abronius.*

For those researchers using *R. abronius* for sediment bioassay testing, these results shown in figures 1-5 may be of significant interest. For although present protocols allow fourteen days from sediment collection until bioassay initiation, the findings of this paper indicate the time period between sediment layering and test initiation is also of great importance and should be considered for standardization.

While the total silt/clay fraction of the MA-1L sediment was only 58.59% dry wt., a considerable percentage (14.65 % dry wt.) of fine clay particles (< 0.000976 mm) was present. Observations reported during Tests 1-4 of the

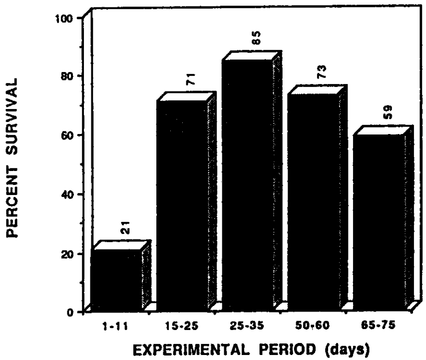

Figure 1.
STABILITY AND DISTURBANCE: MA-1U.

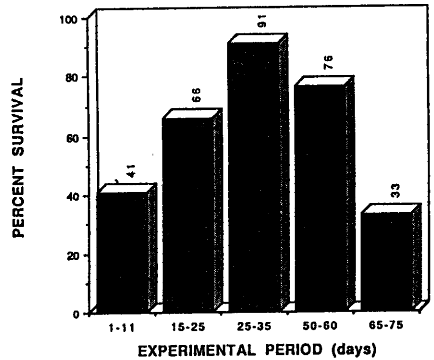

Figure 2.
STABILITY AND DISTURBANCE: SS-4L.

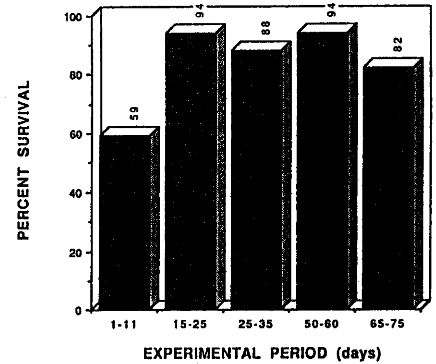

Figure 3.
STABILITY AND DISTURBANCE: C-4.

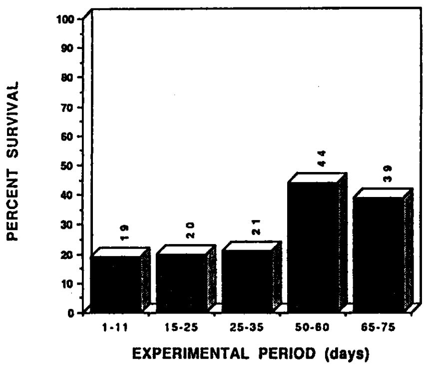

Figure 4.
STABILITY AND DISTURBANCE: MA1-L

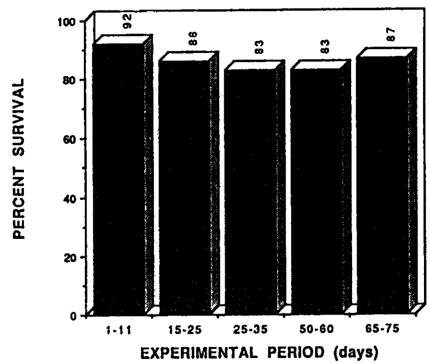

Figure 5.
STABILITY AND DISTURBANCE: SEQUIM BAY SEDIMENT.

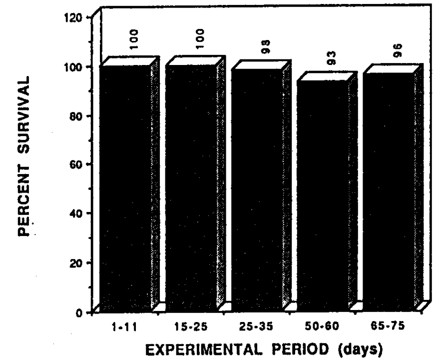

Figure 6.
STABILITY AND DISTURBANCE: WEST BEACH.

unusually persistent turbidity of the MA-1L test sediments also indicate their very small particle size. As shown in Table 1, MA-1L sediments did not contain a high organic carbon content. The high percentage of fine clay particles is suggested as the primary cause of the consistently low amphipod survival results in MA-1L sediment. While grain size is a difficult factor to isolate where some level of chemical contamination may exist, it is felt by many researchers to impact the survival of *R. abronius* (Swartz et al., 1985a; DeWitt et al., 1988; Word et al., 1989).

The sediment disturbances in Tests 4 and 5 were brief interruptions in the process of increasing sediment stabilization which occurred during the 75 day testing period. That a defined sediment disturbance took place is felt to be the significant variable between Tests 1-3 and either Test 4 or Test 5. Yet, since Test 4 sediments were allowed to stabilize on the water table with aeration at 20 °C for 50 days prior to initiation, and Test 5 sediments were allowed to stabilize for 64 days in stainless steel bowls without aeration at 4 °C, these two disturbances must be considered independently.

In Figures 1 - 3, the trend toward increased survival over the time of stabilization is clear in MA-1U, SS-4L, and C-4 sediments, especially when the degree of amphipod sensitivity shown by the positive control is considered. Also, amphipod survival in MA-1U, SS-4L, and C-4 test sediments was negatively impacted by both sediment disturbances, with the greater impact occurring with the greater disturbance. Only the SS-4L test sediment had survival results (Figure 2) which were lower in the Test 5 bioassay than in any other of its bioassay tests. Other test sediments had their lowest survival rates in bioassay Test 1. Factors such as particle size, toxic materials present, concentration of toxic materials, equilibrium partitioning coefficients, organic carbon content, and the magnitude of the sediment disturbance would be involved in the desorbtion process. Thus variation in bioassay results would be expected of differing test sediments, while the trend of lowered survival with increased disturbance of contaminated sediments is maintained. The consistently high survival rate of Sequim Bay reference and West Beach control sediments show independence from the responses of test sediments. The significant increase in the survival of *R. abronius* when MA-1U, SS-4L, and C-4 sediments were allowed to stabilize indicates the importance of the time period between sediment compositing and test initiation. Physical sediment disturbances may also affect bioassay results by increasing the bioavailability of contaminants. The decrease in amphipod survival occurring with increased disturbance suggests the degree of disturbance during compositing and sediment handling should be considered. The low survival in the very fine particle size of the MA-1L sediment sample similarly implies further testing should be done to determine the capability of *R. abronius* to survive in such sediments during 10-day bioassay conditions.

Implications that natural and/or man-made sediment stability opportunities or disturbances could change the toxic level of *in situ* marine sediments suggest a need for further study in this area. The impact of a disturbance of toxic sediment must be accurately evaluated to assure sound decision and policy-making abilities.

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DISTRIBUTION OF NEOGASTROPOD IMPOSEX AS A BIOINDICATOR OF TBT CONTAMINATION IN PUGET SOUND AND ADJACENT WATERS

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ABSTRACT

Neogastropod imposex (imposition of male characters on female snails) is a bioindicator of contamination by the highly toxic organotin compound, tributyltin (TBT), whose use in marine anti-fouling paints has been banned by the EPA and the state of Washington. It occurred in 100% of female snails collected from just outside Elliott Bay and Commencement Bay in July 1989, and on the Port Angeles breakwater. It occurred at lesser levels in snails on west coast rocky shores in the Olympic National Park. In British Columbia, the impact was detected on all female snails within 1 km of all harbours and marinas examined, and at lesser levels throughout the Straits of Georgia. Only two remote sites in the northwest corner of Vancouver Island showed some species without imposex.

The implications of these results for the Puget Sound area are that TBT contamination remained in the marine environment in 1989, possibly at levels continuing to affect mollusc mariculture. TBT regulations may not be effective, due to the use of Puget Sound waterways by foreign and national ships still using TBT-based anti-foulant paints, and from paint-scraping boatyards. TBT testing should be continued to monitor the effectiveness of the existing regulations.

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HYDROCARBON BIODEGRADATION IN THE PRESENCE AND ABSENCE OF WEATHERED ALASKA NORTH SLOPE CRUDE PETROLEUM

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On March 24, 1989, over eleven million gallons of crude oil were spilled into Prince William Sound, Alaska, by the tanker Exxon Valdez. Approximately 20 to 25% of the oil slick had been removed by evaporation or dissolution within the first 20 days after the spill (Rall, 1989). Much of the remaining oil formed a water-in-oil emulsion referred to as mousse. Within ten years the remaining crude oil in the environment is expected to significantly decrease by natural biodegradation, leaving only a small amount of asphalt compounds as evidence of the spill. Weathering, the process of degradation, has been reported to take place in a stepwise fashion, starting with the straight chain aliphatics and then the low molecular weight aromatics, and finally the higher molecular weight and substituted aromatics are slowly degraded (Atlas, 1988). Petroleum products provide a large reservoir of carbon for the growth of microorganisms, but it has been found that mineral nutrients may be limiting factors (Atlas, 1988). Degradation of crude oil in the marine environment has been studied extensively for the past twenty years, and recently the Petroleum Industry Response Organization (PIRO) has targeted bioremediation as an area of needed research (Drew, 1989).

The aim of this study was to compare the degradative capabilities of indigenous microorganisms that are present in seawater and those that are present in weathered crude oil. Inorganic nutrients were added in the form of a commercial bioaccelerating agent, Inipol, which contains nitrogen, phosphorous, and an oleophilic agent.

MATERIALS AND METHODS

Conditions studied

Three glass aquaria were filled with 30 liters of sand-filtered seawater and each tank was aerated.[3] The following amounts of crude oil and Inipol were added to the tanks: 1) 24 ml Inipol, 2) 25 ml of crude oil and 24 ml of Inipol, and 3) 25 ml of crude oil and 48 ml of Inipol. The crude oil was heated to 24°C to enable transfer. The weathered Alaska North Slope crude petroleum was provided by Exxon. It was collected on May 5, 1989, from Skimmer #81

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[3] Each tank contained six herring for the first four days as part of another study (Atrim and Word, 1990).

working west of Disk Island in Lower Passage, near Naked Island, Prince William Sound, Alaska, and shipped to the Battelle Marine Science Laboratory at Sequim, Washington, where it was stored at 5°C. Inipol was also provided by Exxon. Samples of 50 ml were taken from each tank after four weeks. These samples included a portion of the floating Inipol and Inipol/oil mixtures. Aseptic techniques were used for handling the samples after collection.

Mineralization

The samples from the three tanks were diluted in sterile milk dilution bottles. Sixteen bottles were used for each of the three samples; thus a total of 48 bottles were used. The bottles were fitted with Teflon tape wrapped rubber stoppers in order to limit sorption. Each bottle contained 49 ml of sand-filtered, autoclaved seawater, 1 ml of sample, and approximately 1 ml of one of the ^{14}C labelled compounds. Each of the four ^{14}C labelled compounds were added to four replicate bottles. The fourth bottle was poisoned with 500µl of 0.125M $HgCl_2$. Sterile mini (7 ml) scintillation vials, suspended in the headspace above the cultures by Teflon tape, were used for CO_2 traps, and 1 ml of 0.3M KOH was put in each trap. See Figure 1.

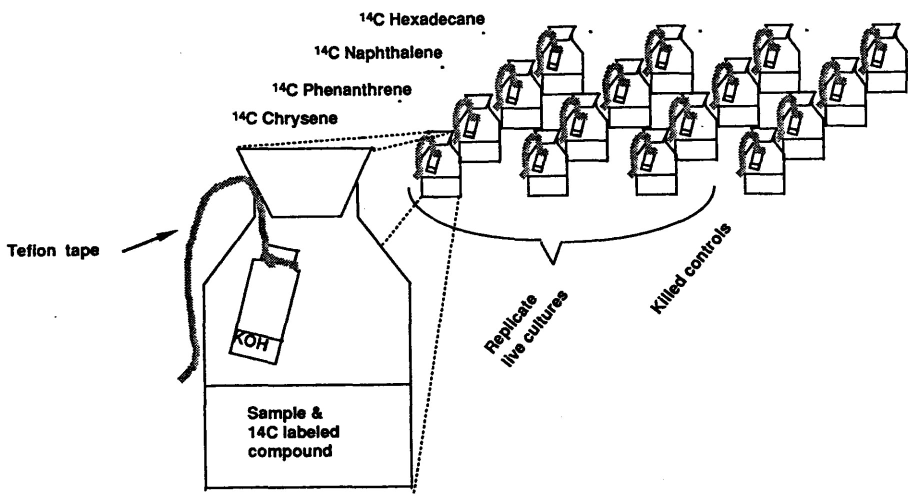
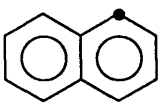


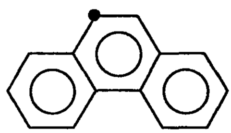
Figure 1.
EXPERIMENTAL DESIGN.

The following compounds were chosen as representative of the components of crude oil and were purchased from Amersham: [1-^{14}C] n-hexadecane, [9-^{14}C] phenanthrene, [1-^{14}C] naphthalene, [4-^{14}C] chrysene. The final concentration of each of the labelled compounds was 2.2X10^5 dpm per bottle.

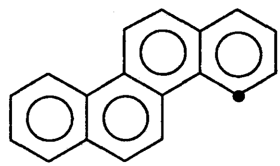
[1-^{14}C] n-Hexadecane



[1-14C] Naphthalene



[9-14C] Phenanthrene



[4-14C] Chrysene

● Indicates position of the ^{14}C labelled carbon.

The cultures were incubated at room temperature in the dark with no shaking. At the end of each time period the scintillation vials were replaced with new vials containing 1 ml of 0.3M KOH and the old vials were filled with cocktail (NEN Aquasol-2) and stored overnight at 4°C to reduce chemilluminesce and then counted on a Packard Bell scintillation counter. The percent of the ^{14}C labelled compound mineralized was calculated by subtracting the poisoned control from the average of the three replicates and assuming that the total amount added, 2.2X10^5 dpm, was available to the organisms in each sample. The actual amount available is probably lower due to volatilization, leakage and sorption.

RESULTS AND DISCUSSION

After 97 days a larger percentage of naphthalene was mineralized in the absence of crude oil (Figure 2), and larger percentages of phenanthrene, chrysene and hexadecane were mineralized when crude oil was present (Figures 3 and 4). Naphthalene was 50% mineralized by the samples with no crude oil present, and about 20% mineralized by the samples containing crude oil. This pattern was reversed for phenanthrene and chrysene; both were only slightly mineralized by samples with no oil present. But phenanthrene was mineralized by about 30% and chrysene was mineralized by about 15% when

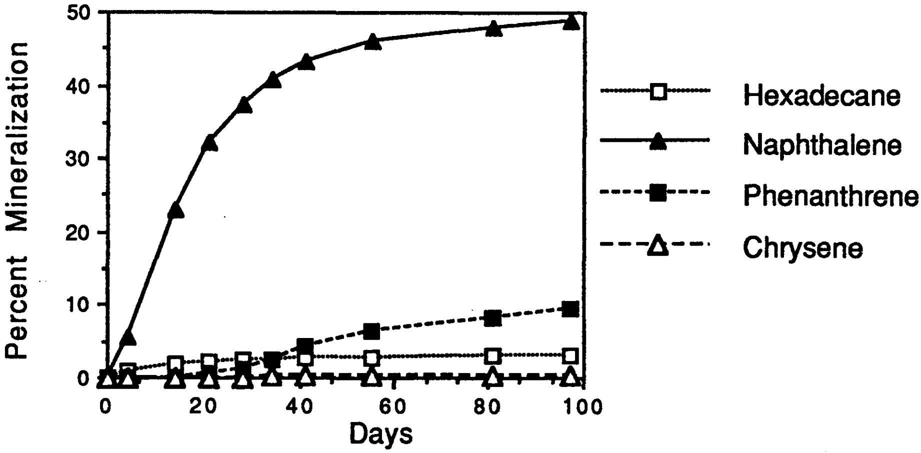


Figure 2.
MINERALIZATION IN THE PRESENCE OF SEAWATER AND INIPOL (NO CRUDE OIL).

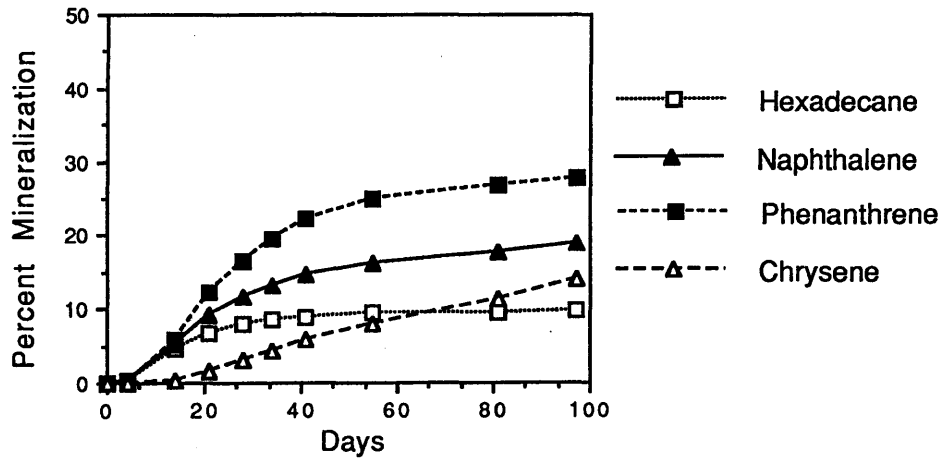


Figure 3.
MINERALIZATION IN THE PRESENCE OF EQUAL CONCENTRATIONS OF CRUDE OIL AND INIPOL.

crude oil was present. Even though hexadecane was mineralized less than 10% under all three conditions there was a slight increase in the amount of mineralization when the crude oil was present.

The fact that all the percentages of mineralization were lower than 50% may be due to the assumption that all of the ^{14}C labelled compounds were available, or the batch cultures may have become limited in inorganic nutrients and/or oxygen.

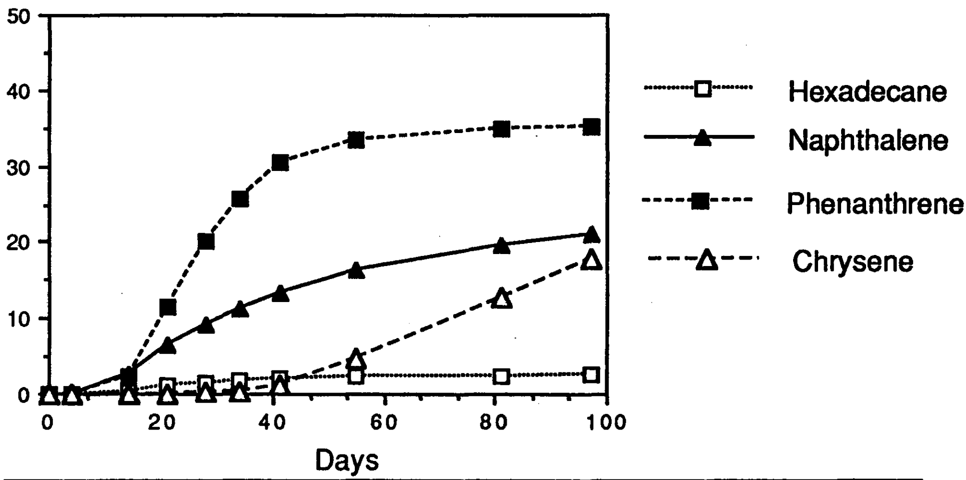


Figure 4.
MINERALIZATION IN THE PRESENCE OF 2 TIMES THE CONCENTRATION OF INIPOL AS CRUDE OIL.

Weathered crude oil collected from Prince William Sound approximately one month after the spill of the Exxon Valdez apparently harbored organisms that were capable of degrading components of crude oil. Organisms present in a relatively pristine environment may not be capable of significantly degrading crude oil within a short time period, even if a bioaccelerating agent is added. This is in contrast to organisms present in one month old crude which were able to degrade three of the sample compounds at a significantly higher rate.

This information could be used to develop an assay to indicate whether an area has been exposed to periods of contamination by crude oil. The ratio of the mineralization of naphthalene and phenanthrene could be monitored in soil or sediment samples.

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A HISTORICAL SURVEY OF OIL POLLUTION IN PUGET SOUND AND SURROUNDING AREAS

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INTRODUCTION

Pursuant to the Federal Water Pollution Control Act (FWPCA) of 1972, the United States Coast Guard (USCG) began enforcing federal regulations pertaining to the discharge of certain pollutants into navigable waters of our coasts, major inland rivers and Great Lakes. The United States Environmental Protection Agency (EPA) was designated as the lead agency for enforcing these same regulations inland. The FWPCA gave authority and responsibility to the President which was delegated in Executive Order 11735. Responsibility for developing a national contingency plan (NCP) for pollution response was delegated to the EPA. Responsibility for administering the revolving pollution fund, utilized during some oil pollution responses, was delegated to the USCG.

The NCP defines terms such as the "On-scene Coordinator" which is the title designating either the EPA or the USCG as the responsible government body for responding to oil discharges or chemical releases within certain geographical areas. All reports of oil discharges are required to be investigated by the predesignated on-scene coordinator (OSC).

A national computer system was needed to compile all reports investigated by the USCG. The development of a system began in 1972. Several alterations, additions and updates to the system led to the development of the Marine Safety Information System (MSIS) used today. MSIS enables the USCG to track pollution trends within specific geographical zones around the United States.

The original intent of the legislators in 1972 was to eliminate all pollution by 1985. Obviously this hasn't been the case. Recent events in and around Puget Sound have demonstrated that the discharge of oil is still an all too common occurrence. Since 1985 several incidences of major oil spills have occurred, including the discharge of over 200,000 gallons of crude oil at Port Angeles in 1985, 67,000 gallons of heavy cycle gas oil at Anacortes in 1988, and 227,000 gallons of bunker C oil near Grays Harbor, along the coast of Washington, in December, 1988. In addition to these large events, there has been growing concern over the cumulative contribution by smaller discharge events to the overall oil contamination problems in marine waters of Washington.

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The objectives of this survey were to summarize USCG data on oil discharge events and to evaluate possible trends by year, season, month, and source. Its purpose was to provide environmental professionals with valuable information concerning incidence of oil discharges in Puget Sound and on the Washington coast. Future surveys and research programs should be conducted to further define biological and ecological implications of the rate and volume of oil discharge in our marine waters.

METHODS

This study reviewed the USCG database for oil discharges contained within the Marine Safety Information System (MSIS) for the period between 1981 and 1989, inclusive. The area of concern extended north from the mouth of the Queets River, and eastward through the Straits of Juan de Fuca and all US waters of Puget Sound (Figure 1). The MSIS records oil discharges based on actual observations by USCG personnel. Initial detection and reporting of an oil discharge may be accomplished by USCG personnel, ship or oil facility operators, and private citizens. Each reported oil discharge includes information on the date, time, location, volume, and source.

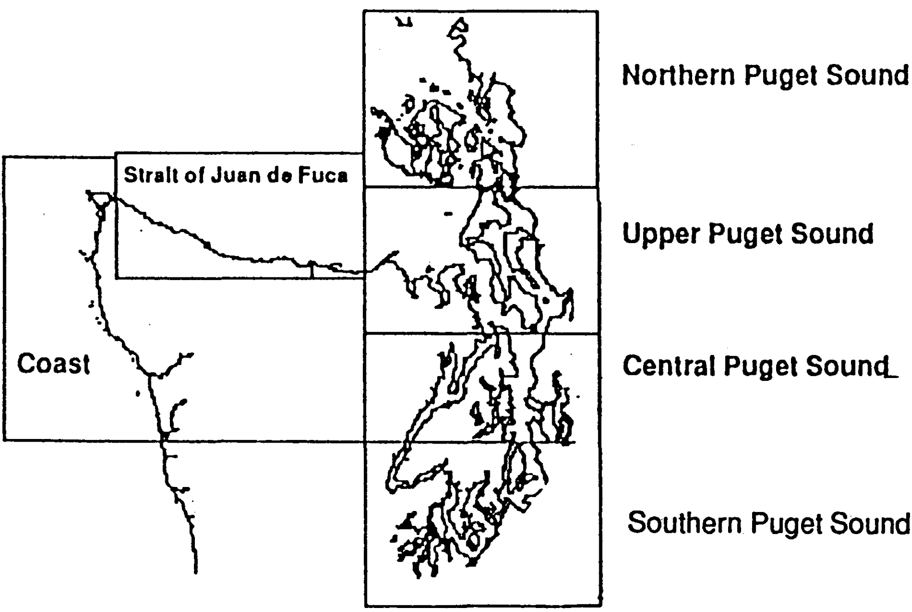

Figure 1.
THE AREA OF CONCERN COVERED BY THE OIL SPILL SURVEY.

RESULTS

The number of reported oil discharges decreased from 1981 to 1986, with 451 discharges reported in 1981 and 188 in 1986 (Figure 2). The incidence of reported discharges has risen steadily since 1986, with 457 discharges reported in 1989, the highest yearly total of discharges reported over the nine years of observation.

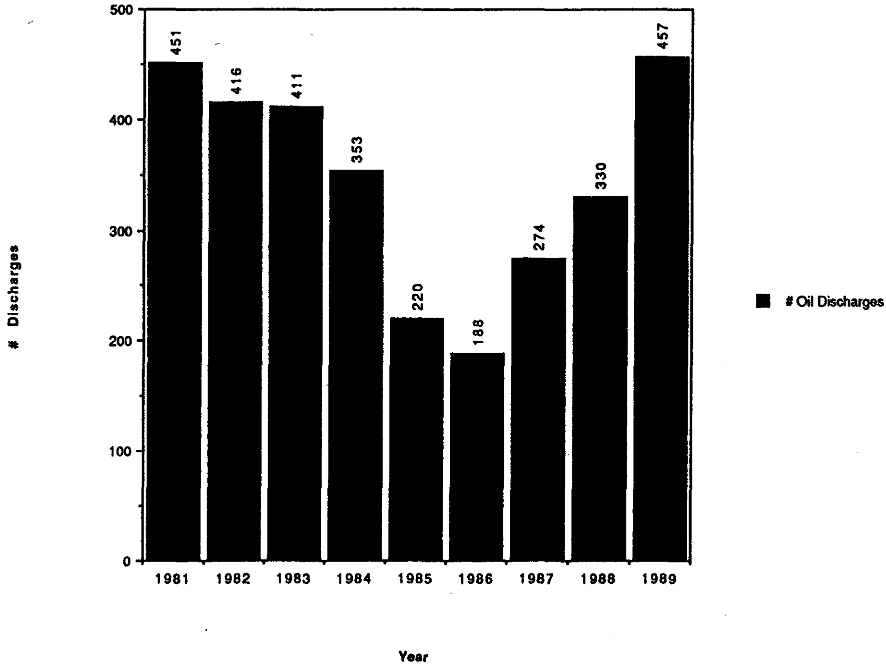

Figure 2.
NUMBER OF REPORTED OIL DISCHARGES, 1981-1989.

From 1981 - 1989, the Central Puget Sound Region (encompassing Elliott Bay west to Bremerton) had the highest frequency of reported oil discharges (Figure 3), ranging from a high of 278 separate incidences in 1981 to a low of 94 in 1986. This region generally had more than three times as many reported discharges as any other region. Between 1981 and 1986, the Southern Puget Sound Region, including Tacoma and Commencement Bay, had the second highest frequency of reported discharges. However, since 1986 the Northern Puget Sound Region, which includes the San Juan Islands and the Anacortes/ Bellingham area, has become the second most significant region for reported discharges. The Coast Region, extending south from Neah Bay to the Queets River, consistently had the fewest reported incidents of oil discharges, with as few as 2 reported incidents in 1986 to a high of 11 in 1981.

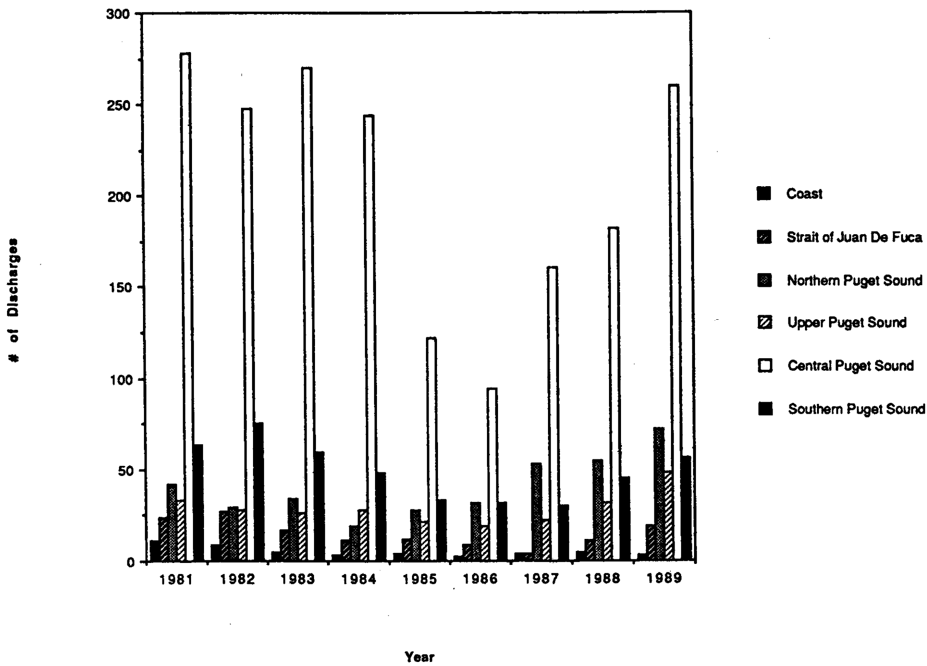

Figure 3.
NUMBER OF REPORTED OIL DISCHARGES BY REGION.

Unknown sources contributed the highest frequency of reported oil discharges, representing 43.6% (1363) of all reported incidences from 1981 through 1989 (Figure 4). However, by volume, unknown sources were only the third largest (6.4%; 33,000 gallons) contributor to oil contamination (Figure 5). Among known sources, those from land contributed the most by number (460; 14.7%) followed by fishing vessels with 9.2 % (287). Tank ships contributed only 4.6 % of the total number of reported discharges but were the largest contributor by volume of any source with 323,742 gallons (62%) discharged. Recreational vessels, which include pleasure craft and small private fishing boats, had the smallest contribution in terms of both frequency (114; 3.6%) and volume (1283 gallons).

The majority of reported discharges from 1981 - 1989 were less than 100 gallons (Figure 6). Conversely, large discharges (1,000 gallons and greater) were relatively infrequent.

Due to time constraints, we were unable to statistically analyze the monthly data for significant differences between months. However, there did not appear to be any consistent monthly trends in discharge when data were

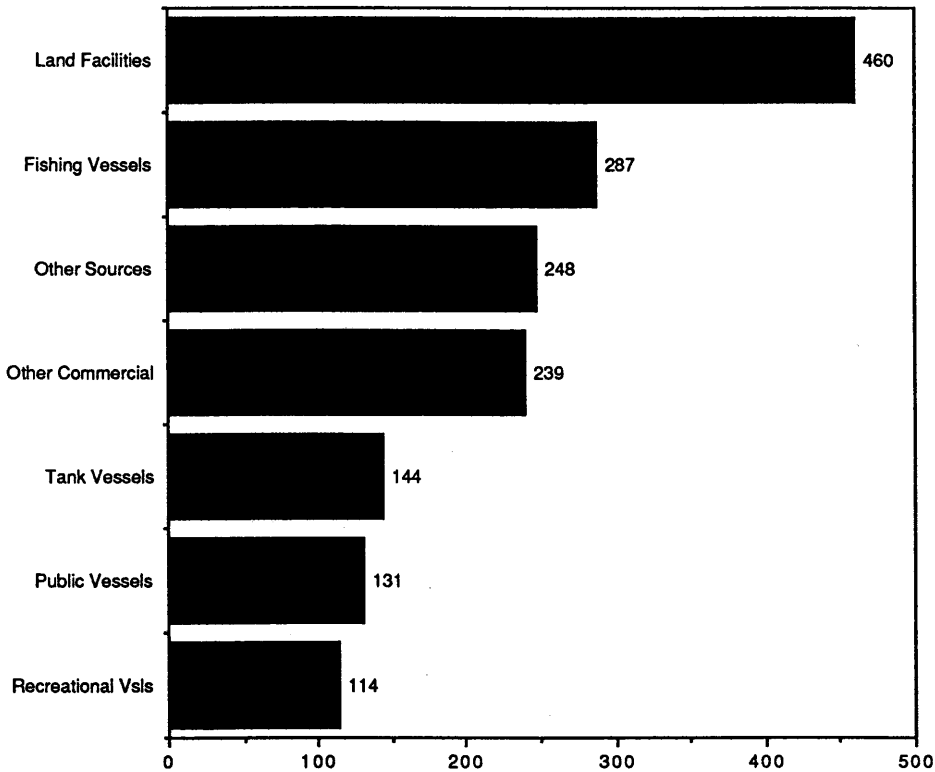

Figure 4.
***NUMBER OF DISCHARGES BY SOURCE (1981-1989).** Of 3119 oil discharges, 1363 (43.6%) were from unknown sources.)*

compared by month for the nine year period (Figure 7). Total reported discharges by month were highly variable.

DISCUSSION

The data show that despite increased awareness of both private and public operators and of regulatory agencies in the past ten years, oil discharges are still a frequent event in Puget Sound. The USCG data base is dependent on human observations, and as a result may be affected by several factors, including changes in funding for harbor patrols, efficacy of the FWPCA in its requirement for polluters to report discharges, and increases in the numbers of people living and recreating around marine waters. For instance, Figure 3 indicates that the Central Puget Sound Region had a higher incidence of reported spills than any other. It is also the most industrialized and populated

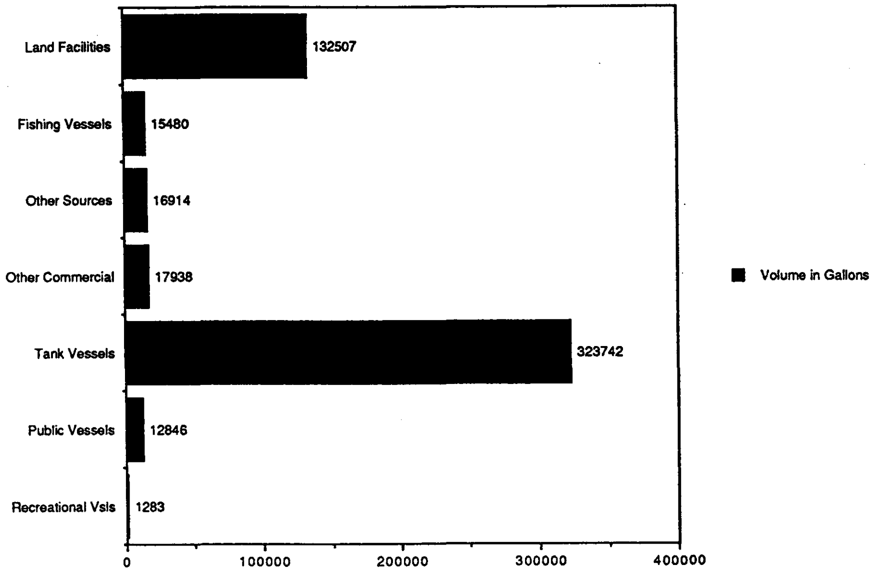

Figure 5.
VOLUME DISCHARGED BY SOURCE (1981-1989) in gallons. Notes: 1) Of 520,000 gallons discharged, 33,000 (6.4%) was from unknown sources. 2) Two incidents contribute over 94.6% (306,357 gal) of the volume spilled by tank vessels.

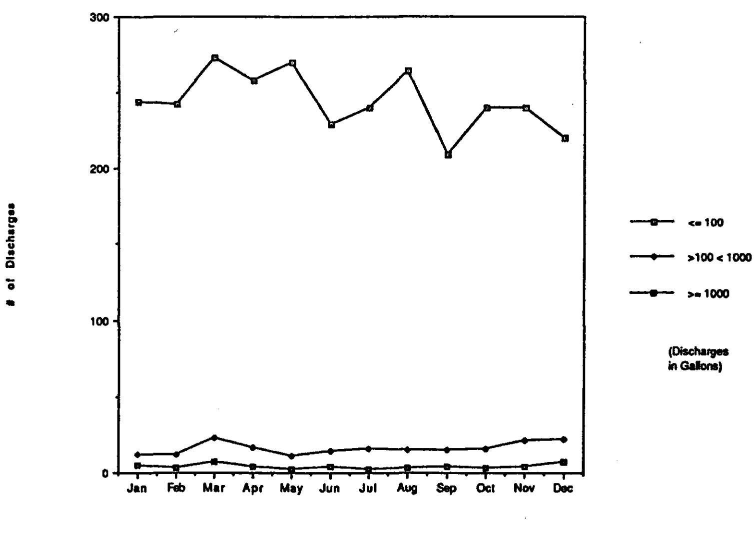

Figure 6.
FREQUENCY OF DISCHARGES BY VOLUME (1981-1989).

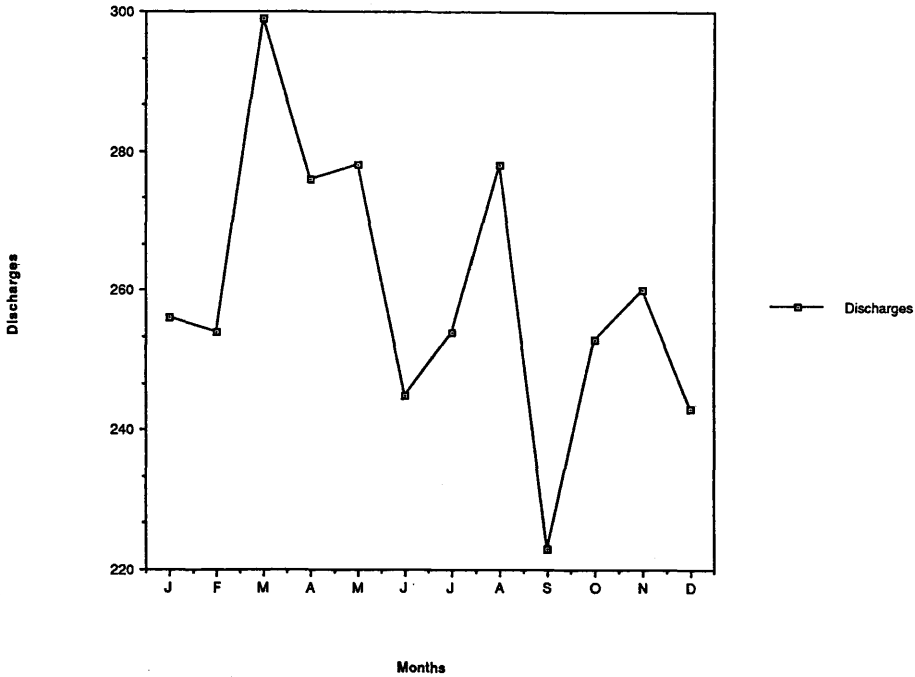

Figure 7.
TOTAL DISCHARGES PER MONTH OVER NINE YEARS (1981-1989).

of all listed regions. One might expect this region to have the highest incidence of oil discharges; therefore, number of reported discharges and total number of actual discharges may be closely correlated for that particular region. In contrast, The Washington Coastal Region is very sparsely populated and has little land based marine industry within the region, making it difficult to determine whether the number of reported discharges is closely correlated to total number of actual spills. Essentially there are so few potential witnesses within the coastal region that it is possible that a large percentage of the total number of actual spills is undetected and/or unreported. More research is necessary to determine how closely correlated the number of reported discharges is to the total number of actual discharges within a given geographical region. If the two are closely correlated, then number of reported discharges for a given region might be useful as an indicator of the degree of oil pollution impacting that region. In addition it should be noted that the authors believe that the data presented here may be representative of only a portion (possibly less than 50%) of the actual number of discharges that occurred over the nine year study period.

There is no clear indication why there was a decrease in the number of reported oil discharges during the mid 1980s. It may be related to the activity of the marine industry, vessel movements and number of oil transfers during the same period. Likewise, it would be interesting to make the same comparisons into the late 1980s, when the number of reported discharges increased each year. One might expect that the renewed environmental awareness so prevalent in this time period contributed to the increase in the number of reported oil discharges. A similar comparison could be made between the Southern and Northern Puget Sound regions to determine the cause of the shift in frequency of reported discharges described above.

Upon comparing the sources of reported discharges to the total volume of oil discharged from those sources (1981 - 1989), it is interesting to note that land-based discharges contributed the greatest amount of oil when two events, the wreck of the Arco Anchorage and the MCN5 Barge, are excluded from the tanker vessel data (Figure 5). Effects of the land-based pathway of contamination may be greater than many other sources because of the high importance of nearshore areas in productivity of marine waters and because many of the organisms found there, such as juvenile fish and benthic invertebrates, are ill equipped to avoid oil contamination. The data also indicate that while fishing boats had the highest frequency of spills from known sources, they spilled much less volumetrically than many other known sources (Figures 4 and 5). This may be due to their relatively high abundance and frequent operation in the region and low fuel capacity.

The biological and ecological implications of the data are difficult to assess because of a lack of information on chronic effects of low levels of oil. Many biological effects of oil contamination have been extensively studied, particularly with respect to acute effects following large spills. Significant recovery after such large spills is often accomplished within five years after the incident in temperate coastal waters (Mann and Clark, 1978; Vandermeulen, 1982). Long term subtle effects may be present for as long as ten years (Sanders et al., 1980). Much of this recovery is assisted by a variety of mechanisms for physical and biological breakdown of oil and the ability of many organisms to recover after a disturbance. Our data suggest, however, that in certain areas of Puget Sound the low level presence of oil may be a common water quality condition rather than an exception. If this is the case, then the ability of populations and communities to recover from such frequent water quality disturbances may be compromised. The result may be a reduction in species diversity, community complexity, and loss of resilience to additional disturbances.

CONCLUSIONS

Oil discharges continue to be a common occurrence in Puget Sound, despite increasing efforts by many citizens and agencies to eliminate such events. Oil

in the environment of Puget Sound may be becoming an increasingly common element in the overall water quality of the area, rather than the infrequent disturbance element it is often perceived to be. It is unclear what the long-term biological and ecological effects of low chronic oil contamination are, but if they follow typical responses to pollution, then we would expect a reduction in complexity, and ultimately in productivity, of the aquatic community. Land-based sources were the single largest contributor to oil contamination and may have the most significant effects, since they directly contaminate highly productive nearshore habitats. A program which identifies and remedies land-based problems while simultaneously improving vessel and ship handling of oil would provide significant benefits in reducing oil in the waters of Puget Sound.

ACKNOWLEDGEMENTS

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PUGET SOUND
RESEARCH '91

PUBLIC ATTITUDES

Session Chair:

Richard Shikiar, Battelle Seattle Research Center

INTRODUCTION

Richard Shikiar[1]

Obviously attitudes, beliefs, values are extremely important in the issues of the environment. They are also related in a very strong way to issues of governance. In a sense our panel session is the twin of the one dealing with public governance. The papers that we have here deal with the really crucial link in instituting reform and change in our society.

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TELL ME IN FATHOMS, FEET DON'T MEAN ANYTHING TO ME: MARITIME FOLKLIFE FROM PUGET SOUND

Phyllis A. Harrison [1]

Participants in **Puget Sound Research '91** have gathered in response to a common concern with environmental and quality-of-life issues that affect all of us here in the Puget Sound region. To date, these issues have been scrutinized primarily from a hard data, scientific point of view which has produced highly significant data for use in planning, prevention and management. We must, however, realize that environmental issues in Puget Sound involve more than watershed basins, sediment depositions, non-point pollution and measurable resources like shellfish harvests and salmon runs. Environmental issues also involve cultural resources: sites, structures, expressions, activities and ways of life developed around the unique environment of Puget Sound. Regional folklife is one such resource that plays a large role in the complex ecology of humans and the Sound.

Folklife is shared knowledge, gleaned from living and working within a community on a daily basis, hearing what is said, watching what is done and seeing how it is done. That intangible knowledge frequently finds expression in specific ways, like fishermen speaking in fathoms rather than feet. When studying folk tradition, folklorists frequently look at discrete forms like arts (fancy knotwork), crafts (boat building), legends (a haunted fish camp), customs (tying a broom to the mast to indicate a good catch) or beliefs (whistling in the wheel house will bring on a storm) which we can document and isolate. But folk expression is more than isolated incidents. Growing out of the shared experiences of community life, folk tradition encapsulates and reflects community beliefs, attitudes, knowledge and values. Local folklife helps to identify a region, as Puget Sound is identified by chainsaw carvers, wooden fishboats and jokes on local subjects ranging from rainfall to slugs to spotted dowels. Further, by giving form to the abstract, local folklife can provide access to those intangible aspects of human habitation, those culturally-based and community-based meanings that make a set of geographic circumstances a region and that create a sense of place, of personality, for its residents.

Puget Sound Indian culture includes a wealth of traditions occasioned by a way of life intimately and integrally tied to the environment. One is the annual ceremony welcoming the return of the salmon each year. Tribes in the region have always depended heavily upon the salmon for survival, and for generations they celebrated and safe-guarded its migration with prayers and ceremonies marking the official opening of the fishing season. A number of Puget

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Sound tribes, including the Tulalip and the Squaxin, have revived the traditional ceremony, and their annual celebrations bring together tribal fishermen, tribal members and non-Indian participants in a festive and ritualized acknowledgement of this vital natural resource. The first salmon, caught specifically for the ceremony, is brought to the longhouse in a ritual procession, carried on a mat decorated with cedar boughs. Following the ritual butchering, cooking and serving, the bones are carried back to the water with equal ceremony. A community feast concludes the celebration. Anthropologist Hilary Stewart's observations apply as aptly to the contemporary ceremonies as to the historic:

> The significance of the prayers and ceremonies cannot be fully understood by those of us who were not a part of the culture, but they nevertheless convey a message as meaningful today as it was a thousand years ago. It is a legacy of wisdom: that to honour and respect the resources of the sea and river is to ensure their continuous abundance for all time (Stewart, 1977).

A traditional narrative, passed along from elders and told to me by Squaxin fisherman David Whitener, explains the ceremony in traditional terms.

> That story about the first salmon was a story about a little boy and he loved salmon. He swam with the salmon and he played with them. Finally the salmon people decided to take him home with them, and he wanted to go. So they took him to the land where the salmon people lived, and he lived there for several months, maybe years, but he got homesick and so the salmon people agreed to bring the boy back to visit with his family. The messages were sent so that the family of the little boy knew they were coming and prepared real carefully, cleaned the streams and cleaned the beaches, prepared for the salmon boy and the salmon people to come. They had the ferns and the moss and the carriage all ready and waiting, and they caught the first salmon, cleaned him carefully, made sure that everything was taken care of real nice, cooked the salmon, but before they ate the salmon they took the skeleton very carefully, very ceremoniously took it back down to the beach and placed it upstream to show the direction for the rest of the salmon people. So the message was pretty clear that the family of the boy was taking very good care of the salmon that were coming back. The idea is that every year they still come back to visit and it's important for us to make sure that they're welcome, that they're taken care of and that everything is waiting for them (Whitener, 1990).

The salmon becomes both symbol and sustenance for Puget Sound Indians, and its significance is expressed and maintained through folk traditions of narrative and ceremony. Such traditions are as significant a resource as is the natural resource that inspires them.

Suquamish basketmaker Edward Carriere learned basketry from his great-grandmother, Julia Jacobs. Each year, she spent the spring and early fall gathering materials like cedar bark, cedar root, cattail, cherry bark and various grasses, and then spent late fall and winter weaving baskets to sell or trade to tribal members, to Indians from neighboring tribes and to non-Indian customers in Seattle. Clam baskets were her particular expertise, and young Carriere spent hours helping her gather materials. "I soon learned which kinds to bring home, as the bum ones were promptly thrown out. Even as a small child, I sat for hours watching her make these baskets" (Carriere, 1988). At fifteen, he began making baskets. "The first two were weak and crooked, but the third one was a real masterpiece. Even Grandma commented on it." Though he wove few baskets during his working years, he has resumed his weaving since retirement and, though his clam baskets are no longer used for harvesting clams, he is known throughout the Northwest as a master basketmaker and teacher. Carriere's clam baskets reflect more than an indigenous craft passed along for hundreds of years and hundreds of generations. They reflect a profound respect for and an intimate knowledge of the environment that provides the resource and reasons for their creation. Besides knowing how to weave a basket, the native basketmaker knows where to find these materials, when to harvest them so they will be pliable for weaving, and how to harvest them to avoid damaging or depleting the resource for future basketmakers. The process of weaving a basket becomes a collaborative one for the native basketmaker who feels a genuine responsibility for the resources used in basketry.

Native traditions are not the only cultural resource from the region. Gig Harbor, located across the Narrows Straits from Tacoma, is a good example of how traditional culture continues to shape the identity of a once-isolated community. Before European exploration, the area that is now Gig Harbor served as seasonal camping grounds for Puyallup, Nisqually and Steilacoom Indians. The first Europeans to visit the area were scouts from the Wilkes expedition (Para, 1990). 1867 saw the arrival of the first Yugoslavian settlers who selected Gig Harbor as a fine site for a fishing village, and from then on a steady influx of settlers, particularly Yugoslavian and Scandinavian, arrived to occupy themselves with fishing, boatbuilding, logging, farming and related businesses and industries. In 1990, Gig Harbor faces the same issues of most communities around the Sound: a decline in those traditional occupations accompanied by steady growth in development, commuter communities and various support services housed in shopping centers and office parks. Yet its maritime heritage is still a vital part of Gig Harbor's identity, if not of its economy.

Restaurants and storefronts capitalize on maritime themes with names like The Tides Tavern, The Shoreline, The Harbor Inn, Look and Sea Antiques and Neptune's Court, while street names like Dorotich, Novak, Skansie, Harbor-

view, Soundview and the newer forms like Snug Cove Lane memorialize early families and the maritime landscape. Yard and lot decor also reflects a clear maritime influence, with anchors, blocks and pulleys, piles and heavy line, "webbing" (fish net), and the ubiquitous seagull appearing as regular themes.

Land use, both historic and contemporary, revolves around the needs of maritime occupations. Though pleasure boat marinas and rented moorage are becoming more common, family-owned docks still dot the waterfront, serving as moorage for the family fishing vessels and as a place to repair both boats and gear during the off season. A few yards inland, many of the older homes sit on large lots, built by fishing families and designed to provide room for vegetable gardens, as well as space to repair, maintain, dry and store their large fishing nets.

Marco Malich lives in such a house. Born in 1913, Malich has fished since 1928, when he first went out with his father. "We'd fish from June through November, then I'd work in the shipyard. But I always went back to fish" (Malich, 1988). In September of 1988, when I first interviewed him, Malich was still going back to fish. He is well known to his Gig Harbor neighbors as an expert fisherman and as a real expert in the craft of mending gill nets. Malich has "sewn web" (built and repaired fish net) since he was twelve. After school and on weekends, he would join his father in the net shed to load the needles with twine and eventually to mend net. His schools were the fishboat and the net shed; his teachers were family and the community of older, more experienced fishermen with whom he worked.

About a quarter of a mile down the road from the Malich house is another set of cultural markers—a cluster of net sheds, barn-like work areas built on pilings over the shoreline with a dock on the waterside for mooring a fishing boat. Built by first and second generation Yugoslav fishermen, the sheds are another visible sign of an active fishing culture.

Fourth generation fisherman Donald Gilich owns and uses the shed his father built in 1934. "Nothing's square. They didn't use any plans" (Gilich, 1989). Gilich mended his first net at age seven, and he took his first cut from a fishing trip at age sixteen, in 1936. For most of his life, he fished the San Juans and the Sound during the summer and fall. During the winter, he worked in the woods, either logging or picking evergreens, and during the spring, he worked on gear in preparation for the fishing season. Though technology and politics have impacted his work significantly, Gilich still works a seasonal round much like his father and grandfather before him. He still fishes the Victory, a wooden seine boat inherited from his father, and still spends much of his off-season time in the net shed working on gear. The shed combines work space and social space. During the off season, when Gilich works alone in the shed, other fishermen stop in to share local news. Come late spring, when Gilich and his

crew are busy with repair and maintenance to boat and gear, hanging lead, hanging cork line, and checking the net for holes, the shed becomes work space, training ground and cultural archive as newer crew members learn techniques and skills from more experienced fishermen, and as all participate in the informal, oral processes of cultural education—recollections of past seasons, expectations of the upcoming season, jokes, and anecdotes concerning the lot of the fisherman.

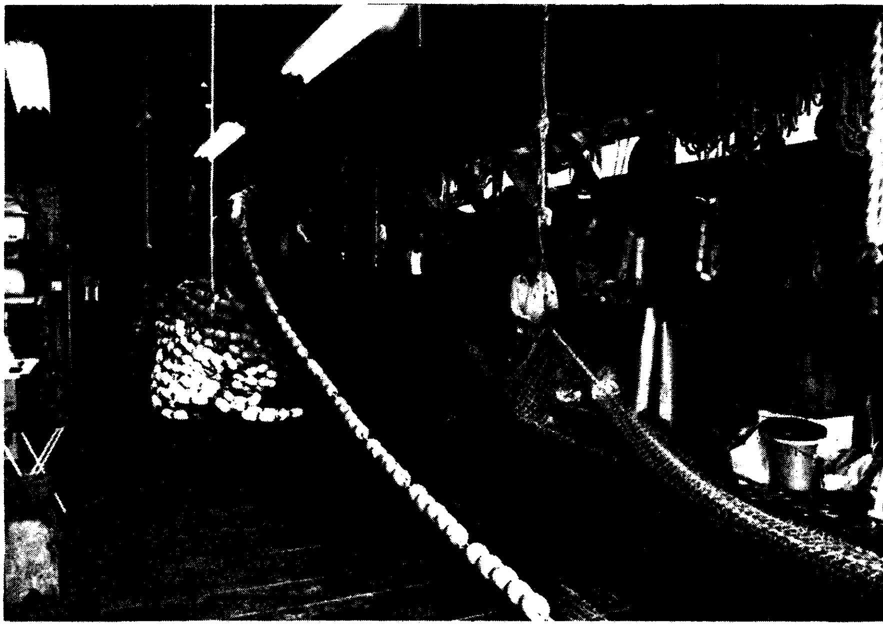

Figure 1.
THE GILICH NET SHED, GIG HARBOR, WA. *(L to R, Donald Gilich, crew members Matt Dyer, Mike Vlahovich, Rich Vlahovich, and Quentin Clark.) Photo by Phyllis Harrison.*

Gilich and Malich are living cultural resources, carrying in their minds generations of knowledge about fishing, navigating, weather lore, local plant, animal and marine life, not to mention the qualities that make a good fisherman or a poor one. In addition, they share history and experience, intangible factors that give heightened meaning to the tangible artifacts like a net shed, a seine boat, or a house with an empty lot beside. As one of Malich's fisherman/ apprentices says, his knowledge is the kind "You can't find in a book. . . One thing that's odd. Guys like this have little formal education. But they have tremendous knowledge, tremendous skill. He's an artist" (Harrington, 1988).

Further examples of maritime folklife abound in the Puget Sound region: from the south Sound, oyster farmers who, despite severe economic setbacks, strive

to maintain traditional diked oyster beds for farming Olympia oysters; from the Skagit River, boat builder Frances Hildebrand whose river scows are designed for negotiating the lower Skagit, and Russell Orrell whose carved decoys reflect an insider's intimate and expert knowledge of an area and its waterfowl; from further north, the practice of reef net fishing in the San Juans and by the Lummi Indians; and from around the Sound, techniques and recipes handed down within a family or community for preserving or preparing regional seafoods. Many show changes in response to a changing world: third-generation fisherman and shipwright Michael Vlahovich spends his time repairing, not building, wooden seiners, and Guy Hoppen builds his father's wooden skiff, but of fiberglass, not wood; Quileute canoe carver Ribbs Penn has adapted his traditional dugouts to support an out-board motor; Martinac Shipbuilding Corporation still christens its seiners with champagne, though contemporary masts eliminate the space that used to house the silver dollar included for good luck; most skippers use radios and barometers to predict the weather, though many still watch the natural signs like mackerel skies and seagulls flying inland.

My purpose here is not to provide a laundry list of folk traditions, but rather to suggest that the cultural resources of Puget Sound are vast and varied, and to suggest that an integrated understanding of the Sound as a habitat must include its human occupants, particularly those whose lifeways depend upon its natural resources. If we are to devise realistic, workable and democratic answers to the difficult issues of environmental conservation and planning, we need a sensitivity to all the factors, tangible and intangible, natural and cultural. We need a bridge between the scientific and the humanistic. We need to speak in both fathoms and feet.

ACKNOWLEDGEMENTS

Research and programs conducted by the Institute of the NorthAmerican West on maritime folklife from Puget Sound have been supported in part by grants and contributions from the National Endowment for the Arts, the Washington Commission for the Humanities, Battelle Memorial Institute, Brown & Haley Candy Co., The King County Arts Commission, Foss Maritime, The Forest Foundation, The Nesholm Family Foundation, The Norman Archibald Charitable Foundation and the membership of the Institute of the NorthAmerican West. This paper owes a large conceptual debt to the American Folklife Center's study of cultural conservation in the New Jersey Pinelands, *One Space, Many Places* (Hufford, 1986).

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PUBLIC OPINION ON AQUATIC LANDS ISSUES AND POLICIES

Gene Patterson[1] *and Lisa Randlette*[2]

INTRODUCTION

Who is "the Public"? And why is it important for the Aquatic Lands Division of the state Department of Natural Resources to understand "Public Attitudes"?

The Aquatic Lands Division manages two million acres of state-owned aquatic lands—an area equal in size to King County—for the benefit of all Washingtonians. Public benefits include encouraging direct public use of and access to aquatic lands, fostering water-dependent uses, ensuring environmental protection, utilizing renewable resources, and generating revenue in a manner consistent with these stewardship responsibilities. Half the revenue is currently dedicated to providing new public access to rivers, marine waters, and navigable lakes.

The Division has a distinct "public," and it is important to understand the characteristics of this public. It is also important to understand fully the public's attitudes and needs so that the public may be well served. In many cases, attitudes and needs of different residents may be in conflict and require aquatic land management policies to balance the public interest.

As part of developing a long-term management plan, the Division wished to tap different sources of information so as to fully consider public attitudes on aquatic issues. A public opinion survey was recognized as one way to gather input and feedback about public priorities. Unlike committees and hearings, surveys may accurately depict the range of public attitude. The Division sought answers to questions on the following topics:

- Uses of waterfront and bodies of water
- Attitudes toward development issues
- Attitudes toward environmental issues
- Priorities for waterfront recreational uses
- Preferences for aquatic land management strategies
- Preferences for expenditures of state funds

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[2] Division of Aquatic Lands, Department of Natural Resources, MS QW-21, Olympia, WA 98504

SURVEY

A questionnaire was designed and pretested by Elway Research, Inc. of Seattle. Interviews were conducted by telephone from a central facility in Seattle. Interviews were completed with adults from 403 households across Washington, in proportion to state population distribution. Households were contacted through a random-digit dialing method which allows for the inclusion of unlisted numbers. Interviewing occurred from January 23 through February 4, 1990.

The maximum margin of error for a sample of this size is ± 5% at the 95% confidence interval. In theory, in 95 out of 100 similarly drawn samples, these results would be within 5% of the results obtained from interviewing all state residents 18 years or older.

RECREATIONAL VISITS TO STATE WATERFRONT

Washingtonians interviewed for this survey were frequent visitors to the state's shorelines. In fact, 41% stated that their residences were within one-half mile of a body of water. When asked how often in the last year they had visited fresh water lakes, Puget Sound and the coast, 84% reported at least four visits. Twenty-six percent visited at least two different types of water at least seven times total; only 23% had visited shorelines fewer than three times in the last year.

Twenty percent had visited Puget Sound once a month or more, including 25% of Western Washington residents, and 17% of those who lived more than 1/2 mile away from water. Almost half (45%) of Eastern Washington residents reported visiting Puget Sound at least once in the last year for recreational purposes.

ISSUES FACING BODIES OF WATER

Nine respondents in ten (91%) volunteered at least one "serious problem facing shorelines and bodies of water in Washington." The single most cited problem was "trash or litter." The top problems named in this unaided question were:

Trash or Litter	46%
Oil Pollution	31%
Industrial Pollution	16%
Sewage	11%
Chemical Pollution	11%
Keeping Areas Natural	10%
Overcrowding	10%

By three to one, respondents favored reserving "remaining urban waterfront" as "open space for public use" (68%) over "a mix of commercial uses" including marine and non-marine uses (23%).

If more money is needed to manage and protect submerged lands, respondents favored getting it from "those who lease the lands for their own use" (68%) rather than from "the state general taxes" (20%).

MANAGEMENT PRIORITIES

Protecting the environment should be the top priority for state government shoreline managers, according to these state residents. When asked to rate six management functions on a scale of "very high priority" (7) to "very low priority" (1), the results (by overall mean rating) were:

Priority Ranking	Management Function
6.5	Maintaining and protecting the environment associated with shorelines and bodies of water
5.7	Resolving conflicts over how shorelines and bodies of water are used
5.5	Promoting existing and new renewable resource industries, such as raising clams, fish, or seaweed
5.4	Providing public recreational opportunities on shorelines and bodies of water
4.6	Collecting fees for private use of public shorelines
4.2	Creating new jobs through economic development of shorelines

Average scores for these functions were remarkably similar across geographic and demographic categories of respondent.

ENVIRONMENTAL POLICY GUIDELINES

Each presented policy for protecting the marine environment got high priority ratings: the lowest mean score was 4.9 on a 7-point scale. The rankings echo the earlier mention of "trash and litter" as the number one problem in the marine environment; the top three priorities involve keeping foreign material out of the water:

Priority Ranking	Environmental Policy Priorities
6.6	Limiting sewage disposal into bodies of water
6.6	Limiting the potential for oil spill damages
6.5	Controlling marine plastics and debris pollution
6.4	Protecting wetlands and wildlife areas
6.1	Cleaning up contaminated sediments from the bottom of bodies of water
6.0	Protecting marine mammals, such as seals, sea lions, and whales
5.9	Controlling negative impacts of shoreline development
5.8	Controlling storm water runoff pollution
5.8	Protecting recreational and commercial navigation channels and routes
5.4	Resolving conflicts between shoreline residents and commercial industrial uses
4.9	Preventing activities on the water from interfering with or disrupting views from the shore

One gets a sense of what respondents include in "environmental protection" from examining correlation data. "Protecting the shoreline environment" correlated with:

Protecting wetlands (r=.49);
Resolving conflicts (r=.48); and
Limiting oil spills (r=.45).

"Protecting wetlands," in turn, was related to:

Cleaning up contaminated sediments (r=.50);
Protecting marine mammals (r=.45);
Limiting oil spills (r=.43);
Limiting sewage disposal (r=.42).

By three to one, respondents preferred spending to prevent clean sites from becoming polluted rather than cleaning up polluted sites.

Given a choice between the state or business paying for cleaning polluted submerged lands for which the responsible party could not be identified, seven in ten respondents chose to tax industry.

RECREATIONAL USES OF AQUATIC LANDS

When asked to choose between types of water bodies for "providing recreational opportunities," respondents were split. One third (33%) said lakes; 27% said Puget Sound; 19%, the coast; and 13%, rivers. Overall, those who had used waterfront *least* in the previous year were most likely to name lakes as the highest priority for recreational opportunities (41%).

The most frequent waterfront users were more likely to name Puget Sound (34%). Even those who visited the coast most often chose Puget Sound (35%) over the coast (30%).

When forced to choose between development priorities for recreation, most respondents chose small-scale, neighborhood waterfront parks over large regional ones (61%), and pedestrian trails over docks (67%).

PRIORITIES FOR STATE GOVERNMENT

Educating the public about submerged lands and buying wetlands in order to protect and manage them should be the top priorities of state government, according to ratings given by respondents.

Respondents were asked to rate six activities of state government.

Priority Ranking	State Government Actions
5.5	Public education about submerged lands
5.4	Buying wetlands in order to protect and manage them
5.3	Hiring more staff to help ensure that state-owned waterfront and submerged lands are not abused
5.2	Developing new aquaculture industries, such as salmon net pens, seaweed harvesting, and oyster beds
3.9	Encouraging development of new ports and shipment facilities
3.7	Encouraging shoreline tourism, through the construction of marinas, hotels, restaurants

Public education was rated highest—and tourism was rated lowest—in *every region* of the state and by low frequency users and high frequency users alike. Port development was rated next to last in *every region* of the state.

COMPARISONS TO 1982 STUDY

In the autumn of 1982, the Department of Natural Resources commissioned a similar study of public priorities for submerged lands. "Litter and trash" were named most often in 1982 as things "disliked" about the respondents' favorite shoreline or body of water.

Washingtonians today seem less concerned about collecting rent for lessees of submerged land than they were eight years ago. In 1982, 57% said "shipping facilities" should pay "maximum rent;" 36% said houseboats should pay "maximum rent;" 29% said marinas should pay "maximum rent." In the present study, only 23% said houseboats should pay "maximum rent," and only 24% said water dependent industries should pay "maximum rent."

The 1982 study asked respondents to rank the priorities for different uses of waterfront land. While the wording was not always identical, some of the questions correspond to priorities from the present study. Average ratings for the two surveys were standardized to a 100-point scale for comparison.

Study Year	Waterfront Use	Priority Ranking
1982	Habitat protection	91/100
1990	Protecting wetlands and wildlife areas	91/100
1982	Commercial food production	67/100
1990	Promoting existing and new renewable resource industries, such as raising clams, fish and seaweed	79/100
1982	Public recreation access	73/100
1990	Public recreational opportunities	77/100

As the standardized scores show, priority rankings did not shift appreciably for these items between 1982 and 1990.

CONCLUSIONS

Overall, these findings reveal a consistent orientation to the issues covered. They are internally consistent, in that protection of the environment was invariably given the highest priority for action. They were also consistent with the findings of eight years ago: many of the same problems were named and similar objectives were given highest priority.

It is apparent in these results that Washingtonians value their marine environ-

ment—that comes as a surprise to no one—and that they want state government to act on their behalf to protect that environment. They want users to pay, but they are users, too. They seem willing to contribute their fair share for managing and protecting these areas.

Public education is both desired and needed. At one point in the survey, "educating the public" was named as the most useful thing state government could do. The need for public education is not only pointed to by these respondents, but is reflected in the overall results. Respondents assigned priorities to management activities because the questionnaire forced them to. One gets the sense that most people would endorse anything they thought would do some good. As state resource managers indicate the relative benefits of each activity, latent public support for "protecting the environment" can be translated into support for effective public policies.

Many of the Division's current policy and program directions were reinforced by the survey findings. Controlling trash or litter was the single most cited problem. In the past year and a half the Division has initiated a Marine Plastics Debris Program to coordinate statewide cleanup and prevention. The Division has increased its efforts to protect aquatic habitats through the Puget Sound nearshore habitat inventory and the open-water sediment disposal program, discussed elsewhere in these proceedings.

The findings on recreational priorities were the most immediately useful. Preferred geographic areas and types of recreational facilities will be considered when funding future public access sites.

The Division of Aquatic Lands has used the results of this survey to help frame the critical issues for the strategic planning effort. Public education was rated as a high priority for state government action. Strategies are currently being developed by the Division on how best to present aquatic lands information to the public, how to identify desired outcomes of public education programs, and how to monitor the effectiveness of efforts and make adjustments.

Copies of the report and public opinion survey are available from the Department of Natural Resources at the following address:

Division of Aquatic Lands
Department of Natural Resources
Mail Stop QW-21
Olympia, WA 98504
(206) 753-5324

ANGLER PREFERENCE FOR BOTTOMFISH MANAGEMENT IN PUGET SOUND

Cyreis Schmitt, Han-Lin Lai, and Gregory Bargmann [1]

INTRODUCTION

Puget Sound has long been known as a productive and popular fishing area. Although its salmon fishing is renown, bottomfish also provide enjoyable recreational experiences to sport fishers and a livelihood to commercial fishers. As interest in harvest of bottomfish has increased, the Washington Department of Fisheries (WDF) has sought to develop management approaches that incorporate angler preferences while conserving the resource. This process has intensified since 1989 when Governor Gardner declared his intent to make Washington State the "Sport Fishing Capital of the Nation".

Sport fisheries for bottomfish in Puget Sound can contribute substantially toward achieving the Governor's goal. Of the 1.5 million fishing trips taken by Puget Sound boaters in 1987, about 20% were targeted on bottomfish. Anglers fishing for salmon also frequently catch bottomfish. Anglers fishing from boats harvested 750,000 bottomfish in 1987. More than 20 species of bottomfish commonly appear in anglers' catches. Sport fishers currently harvest more rockfish, walleye pollock and lingcod than commercial fishers. Sport harvests of Pacific cod, greenling, flatfish, and surfperch are also significant, and halibut sport fishing has soared in popularity in the past five years.

For Washington to become the sport fishing capital of the nation, WDF must not only practice wise stewardship of fish resources but also provide high quality fishing experiences to anglers. To help identify what sport fishers view as high quality fishing, WDF conducted a random opinion survey of angler preferences for bottomfish management in Puget Sound. This information, together with public input WDF receives in many other ways such as through public hearings, from organized fishing groups and from departmental advisory councils, is used to formulate management plans to meet the needs of the resources and public.

METHODS

The target audience for this study included sport anglers and divers who fish for bottomfish in Puget Sound. Although WDF does not have lists of names or phone numbers for these fishers, it does maintain a list of names and ad-

[1] Washington State Department of Fisheries, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115

dresses of anglers (residents and non-residents) who purchased a Washington salmon catch record card in 1989. Most anglers who fish for bottomfish are included on this list because over 90% of all sport fishers purchase a salmon catch record card. Consequently, this list was considered an adequate sampling frame for this study, and a random sample was selected for a telephone survey. The Social and Economic Sciences Research Center (SESRC) at Washington State University was contracted to conduct a telephone survey and assist in preparation of the survey questionnaire. SESRC obtained telephone numbers for anglers in the sample from current U.S. West directory information. SESRC trained all interviewers in the correct manner to ask and provide interpretation to the questions. The interview consisted of 65 questions and took about 15 minutes to complete.

Several pretests of the questionnaire were conducted to resolve any wording problems. Pretest data were not included in the results. The survey was conducted between July 16 and July 31, 1990. Up to five attempts were made to contact each angler. In total, SESRC attempted to contact 1,347 anglers, and 408 completed the interview. The number of interviews was constrained by funding limitations.

Many questions required the respondents to rate the importance of a particular item among one of five categories: extremely, very, moderately, slightly, or not at all important. Similarly, many other questions asked the respondents to rate the priority they would give a particular item among one of five categories: very high, high, medium, low, or not a priority. For both types of questions, the qualitative responses were transformed into quantitative scores by assigning values from 0 to 4 so that the highest categories of importance and priority received the highest value. The percentage of total responses in each category was multiplied by the corresponding value, and the results were summed to yield a single score, on a scale of 0 to 400, for anglers' responses to each question.

RESULTS

The focus of this paper concerns anglers' opinions on general topics related to sport fishing for bottomfish in Puget Sound. During our survey, a number of questions related to specific fishing regulations were asked but are not addressed here. A full report addressing all questions and data is being prepared for publication as a WDF Technical Report.

Who Responded?

The majority of the respondents were Washington residents (99%), male (85%), Caucasian (96%), and had completed high school (94%). Nearly 62% reported they had completed at least some college training and 11% reported

they had attended vocational school. Nearly 12% were aged 65 or over and 22% were aged 50 to 64 years. Younger anglers were more numerous, with 36% aged 35 to 49 years and 30% between ages 18 and 34.

Anglers' Fishing Activities

For the 264 anglers who reported fishing for bottomfish in Puget Sound during the preceding 12 months, most (70%) went fishing less than ten times, although six anglers (2%) reported fishing more than fifty times. The 144 anglers who did not fish for bottomfish during the previous year reported doing so within the last five years. Forty percent of all anglers reported that their fishing participation during the past five years has remained the same, while 30% reported it has decreased and 30% reported it has increased. Most anglers (85%) fished from a private boat, whereas 8% fished from the shore or a pier and 7% fished from a charter boat. Over half (56%) planned their vacation around the fishing season.

Most anglers (71%) said they did not put most of their effort into fishing for one particular kind of bottomfish in Puget Sound. However, for those who did, lingcod was targeted by 34% of the anglers, rockfish was targeted by 20%, and halibut was targeted by 16%.

Anglers' Impressions of Present Fishing Quality

Fishing quality is a very subjective measure and based on many factors, such as catch, weather, scenery, etc. We allowed anglers to use their own definition. When asked to rate the present quality of sport fishing for bottomfish in Puget Sound, 44% rated it as fair and 29% rated it as good. Over 3% rated it as excellent, but 23% rated it as poor. However, when anglers in our study compared it to quality five years ago, 39% rated present quality as worse and another 16% rated it as much worse. Nearly 30% rated the quality the same as five years ago and 4% rated it as better or much better.

A factor affecting the quality of sport fishing for bottomfish in Puget Sound is anglers' perceived health risk from eating their catch. When asked to what extent they felt that eating bottomfish from Puget Sound is a risk to their health, 36% indicated it was not at all risky whereas 27% said it was somewhat risky, and 26% said it was moderately risky. Over 9% reported it was highly or extremely risky and 2% did not know.

What Is Important to Anglers?

Anglers were asked to indicate which of four general arenas was most important to improve sport fishing for bottomfish in Puget Sound. Habitat protection and fisheries management were most important to equal numbers (38%) of anglers whereas fishing access was most important to 18% and the remaining 6% considered public education and information most important.

In a series of questions, anglers were then asked to rank the importance of several specific ways within the four general arenas to improve sport fishing. Although individual responses varied widely, quantitative scores, given in parentheses, are used for comparisons among questions.

Anglers were asked to indicate the degree of priority they would place on each of three possible actions to improve public education and information about sport fisheries for bottomfish in Puget Sound. Although all three actions were important, increasing public education through fishing guides, pamphlets, etc. received greatest priority (236), increasing law enforcement by WDF was somewhat lower priority (226), and establishing a phone hotline for bottomfishing regulations and conditions was lowest overall priority (213).

Similarly, anglers indicated the degree of priority they would give to each of three possible actions to improve access to bottomfish resources. Increasing the number of public boat ramps scored highest (206), increasing the amount of shoreline open to the public for bottomfishing was lower priority (196) and building more public fishing piers received the lowest priority (179).

Of six possible management actions to improve sport fishing for bottomfish in Puget Sound, anglers were asked to rate the priority of each. Creating more reefs for fish habitat was considered highest priority:

Create more reefs for fish habitat	269
Maintain opportunity to fish every day of the year	238
Culture bottomfish	233
Establish more restrictive regulations to increase the abundance of bottomfish	223
Establish preserves for fish protection and underwater sightseeing	216
Establish a trophy fishery	166

In a similar question, anglers were asked how important they felt each of the following six considerations were for management. Again, the opportunity to fish every day and enhancement ranked high:

Enhancement of marine fish through hatcheries or cultures	285
Year-round fishing opportunity	269
Maintain current management practices	242
More restrictive fishing regulations	184
Catch and release fishery	168
Trophy fishery	140

SUMMARY

Several general themes were evident from anglers' responses. Nearly half of the anglers consider the quality of sport fishing for bottomfish in Puget Sound as only fair, and over half consider the quality worse than five years ago. The degree of concern about potential health risks from consuming bottomfish from Puget Sound appears to vary widely, perhaps as a result of little or confusing information. Over one third consider eating bottomfish moderately to extremely risky to their health, yet an equal number do not consider it at all risky. The remainder consider it somewhat risky.

Overall, the results reflect anglers' concerns for protecting fish resources and especially their habitats. More anglers considered habitat protection and fisheries management more important to their fishing satisfaction than access and public information. To improve the quality of sport fishing for bottomfish, anglers give high priority to enhancement through culture and artificial reefs and to year-round fishing opportunity. Non-traditional fisheries, such as catch and release and trophy fisheries, were relatively unimportant to most anglers.

The information from this survey, together with public input WDF receives in other ways, is used to formulate management plans to meet the needs of the resources and public. Achieving the Governor's goal of making Washington State the sport fishing capital of the nation depends on successfully incorporating anglers' needs while conserving the resources for future fishers.

ACKNOWLEDGMENTS

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THE QUALITY OF WASHINGTON'S WATER AND OTHER NATURAL RESOURCES – A 1990 SURVEY OF CITIZEN OPINIONS

Arno W. Bergstrom, Don Hanley, and Robert Howell[1]

ABSTRACT

A formal and systematic process was needed to identify current, emerging and strategic natural resource issues in Washington that are of wide concern to Washington citizens. The project objective was to seek citizen input in planning future educational programs conducted by Washington State University.

In March of 1990, a mail survey of 1300 randomly selected households throughout Washington State was conducted to gather opinions on environmental and natural resources issues. Survey respondents rated the quality of water and other natural resources. People expressed their opinions on the impacts of human activity on the environment and specifically identified water quality issues and related problems.

Natural resource issues considered very serious in the State of Washington by at least 70% of the survey respondents included:

- Lack of solid waste disposal sites
- Loss of land due to urban growth
- Water and soil contamination from hazardous waste
- Exporting of logs from public forests
- Loss of wildlife habitat in woodlands and wetlands
- Clear-cutting of public forests
- Over dependence on non-renewable energy
- Water pollution from fertilizers and pesticides

Fifty-six percent of the respondents believed the quality of the state's natural resources has gotten worse compared to 10 years ago. People were most concerned about air and water quality and population growth and development as contributors to this decline. Additional concerns raised included all types of pollution, clear cutting of timber, and the intensity of logging activities. Fifty-eight percent of the respondents expected the quality of the state's natural resources to get worse by the year 2000.

Cooperative Extension and the Department of Natural Resource Sciences are using the survey results to develop relevant educational programs that will serve a larger segment of Washington's citizens.

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PANEL DISCUSSION

Richard Shikiar (Battelle Seattle Research Center, and the moderator), and the speakers, Phyllis Harrison (The Institute of the NorthAmerican West), Gene Patterson (Elway Research, Inc.), Cyreis Schmitt (Washington State Department of Fisheries), and Arno Bergstrom (WSU Cooperative Extension), were joined by Robert Bish (University of Victoria, School of Public Administration) and Daniel Jack Chasan Vashon Island Groundwater Management Advisory Committee). Chair Shikiar began with an observation:

Richard Shikiar: Since this panel discussion has to do with public attitudes, it always has struck me that the public is very slow to react, or very unsure to react, to slowly evolving public events. Issues such as global warming [and other] slowly developing changes in environment don't cause the sort of public outcry that crises do—the Valdez oil spill, gas shortages, other types of societal crises. So I would ask the panel if they have any thoughts about how we can get the public mobilized (or is the public currently mobilized?) to take action regarding environmental change and to demand legislation for protecting the environment, when environmental degradation is such a slowly moving phenomenon?

Daniel Jack Chasan: I think there are two parts of a response to that. One is that I think people are, to some extent, if not mobilized then ready to be mobilized now. They feel, at least vaguely, that these things are important, but I don't think that it is very easy for people to focus [on], to pick things out of, the multiplicity of situations that they are told about virtually daily. The fact that they care in the abstract doesn't mean necessarily that they are going to be willing to take any very strenuous action or to spend any particularly large sums of money in the future.

The sad part, I think, [is that] while clearly people do tend to respond more when you have something like a Valdez oil spill, you are going to some extent "create" an event if both the main news magazines suddenly discover the topic the same week, which is something they tend to do. And then people are pontificating about it for the following week or two on television and in the other print media—you're going to have a Valdez oil spill. You have created at least the perception of something that's [suddenly] happened, rather than some kind of slow situation.

Robert Bish: While the crises come and go it, is terribly critical to have an infrastructure of scientists, of interest groups, of agencies who are plugging away, so that when you do have a crisis there is some source of information or ability to make a response. The dilemma is how to keep the infrastructure going, and many of you keep it going because you work for governments. But the science end can often be difficult, as Marsha [Landolt] discussed yesterday

morning. [There you have people] turn[ing] to big projects that are routine, rather than having a lot of independent scientists who are funded at a modest scale to be poking away at the frontiers of problems which, for all you know, may be the next emerging problem [or crisis]. And the infrastructure is just as important as the visibility that comes from time to time. I think in *this* region the infrastructure is exceptionally good. The question then is when do you get the crises when things happen. The Shorelines Management Act is a pretty good piece of legislation for its time, but it took some crises, coming out of Guemes Island and some previous disputes, to then get it through. But if there hadn't been a lot of work and knowledge *first,* we would likely have ended up with a big lemon, and you wouldn't be [any] better off.

Gene Patterson: When you said "how to get the public mobilized," that's a good way to put it. In all the surveys we have done, including the Seattle Times survey, the public is quite interested and is looking for answers. In the DNR survey it looks like they are just trying to find people to give them solutions, and as soon as they can find something that makes sense, a solution that makes sense to solve the problem that they perceive, then they'll jump on it as soon as they can. They may not be mobilized, but I would like to reiterate that the surveys seem to show that they are quite concerned and ready to do what's needed.

Cyreis Schmitt: I can only speak with regard to bottomfish in Puget Sound and working with the Department of Fisheries, but oftentimes it seems that the squeaky wheels get the grease. One of the objectives we had was to see if the squeaky wheels are representative of the majority of people that may want to enjoy these fishing experiences, and to try and get some idea of what they wanted, as opposed to what they didn't want. I think that is equally important. Trying to decipher what *will* make them happy from what they say they *don't* like is sometimes not so fruitful. So, hopefully we are trying to be better in that.

Phyllis Harrison: As an educator I always come back to education as the primary answer. Obviously educational programs working through our schools and also institutions like museums and aquariums—all of those entities that reach the public at large—don't have the same kind of dramatic impact as a huge oil spill in Prince William Sound. But I do think in the long run that is the way to get people to a point of view and a state of mind where maybe they'll respond *before* the disaster comes. Maybe we even reach a point where we can do something to prevent some of those disasters from happening. But I always think that education is the key.

Q. *Alyn Duxbury*: For Dan Chasan: I think we all know that the public's perceptions, attitudes, opinions, are pretty much formed by the only access to data that they have, which comes through the media. I would like Dan to comment on how responsible he feels the media has been in this area

with correctly presenting what the actual problems are in an objective manner, by factual reporting, versus presenting them as editorialized material.

Daniel Jack Chasan: I think that the media in general does a very poor job of reporting scientific subjects unless they can be dramatized somehow, and this is no exception. That doesn't mean that the reporting has all necessarily been inaccurate, but I also don't think that it has been any better on this than it has been on other subjects with a large degree of scientific content.

Arno Bergstrom: That is one of the challenges that we faced in terms of our discussions in preparing for the survey. There is a tendency, as scientists and educators, to discount the opinions of citizens, given their primary source of information, be it the facts or not. The point of view that I am taking, and that I like to think Washington State University is taking, is that we still have to recognize and work with the fact that citizens do have some ideas, some opinions, regardless of how accurate or misguided they may be.

Q. *Adelle McCallum (Island County)*: On the angler survey, what are your feelings on the question of [a] squeaky wheel being reflective of public opinion?

Cyreis Schmitt: [People tend to see the] Department of Fisheries as generally salmon-oriented. We did have a remarks [section] as part of the questionnaire, and what I gleaned from the [respondents'] remarks is that there is a great deal of confusion about what the management responsibilities were for the Department of Fisheries, as opposed to the Department of Wildlife. Many of the remarks were oriented towards steelhead, or trout fishing, or other topics than bottomfishing in Puget Sound, for example. There were individuals, though, that said they were glad to finally see that the Department was paying attention to bottomfish. One of the efforts that the Department has tried to undertake in the past few years is to give more attention to shellfish and bottomfishing issues, recognizing their importance as well, and not taking away, hopefully, from any of the salmon work that is going on. But [it wants to] start to do as good a job with those resources as has been done with salmon.

I think in general there hasn't been a large amount of "squeaking" over bottomfish, in comparison to salmon, so that the legislature and policy makers haven't paid as much attention to this subject as they have to others.

Q. *Bill Hashim*: Most of the questions I have heard or have seen in polls always ask about humans *and* nature. They presuppose this world view that creates a separation. How about asking questions like "Humans *in* nature," or "humans as part of nature"? Something that transcends the dualism.

Gene Patterson: Unfortunately, for something as structured as a telephone or

mail survey, you usually have to make it as easy as possible for people to fill it out, or you won't get 15% return, or anyone doing it on the phone. Unfortunately, since at this time, as you pointed out, the paradigm is people here and then nature somewhere out there, we have to phrase things usually the way people can do them. However, in smaller, more qualitative ways, like in focus groups and such, it is really interesting to find out that there are people out there who are thinking just that way. It is just more difficult to do that in a structured survey, where you are trying to get high response.

Arno Bergstrom: Our survey did [ask those kinds of questions], and I would encourage you to talk to me later, because there was a question or two that dealt with that. I wasn't even going to attempt to disclose that. Besides, the question has a bit of ownership with Dr. Riley Dunlap in the Department of Rural Sociology at WSU. He is going to use the analysis of that question for some papers he is going to be co-authoring. You might want to talk to me about it, and I can get you together with Dr. Dunlap.

Q. *Catherine Verill.* I have a couple of speculative analyses that I would like some comments on, if you can. First, I was struck with a dichotomy—that some of your surveys stressed preferences more than attitudes. They were requesting user groups to express their preferences to a management regime, I think in hopes of influencing it. That was [the case] both [for] the DNR shoreline user and the Department of Fisheries' bottom fisherman [surveys], and I would speculate that there is a difference between preferences (gear, or seasons and uses) versus the kind of attitude thing that I heard the morning panel talk about, which is more about values, senses of community, joint risk assessments, impacts, timeframes for those sorts of managements. I think if we get the two confused we will really end up spending a lot of Centennial Clean Water cigarette money sending out brochures, and pamphlets, and hotlines about preferences, and not really get to the attitudes I think Dr. Bish and Mr. Chasan talked about.

The second thing was finding that the "public information" in your survey included everything from telephone hotlines to enforcement. I think that is a real dangerous precedent, because if we spend all this time dealing with attitudes being the same as hotlines, and public information being the same as brochures, we will *miss* the point which I think that all of your surveys talked about, which was a strong attitude [sic] for experiential [sic] experience—small regional parks, "I'd rather be on the water all of the time, whether I catch any fish or not," and the kind of one-on-one basis that I think will instill the attitudes we need to really protect.........[tape out]

Phyllis Harrison: I would comment, at least, that you are absolutely correct. I think we certainly need to look at attitudes [as opposed to preferences], but then those become interpretive sorts of questions, and they often require very

different kinds of research tools. They are much harder to quantify, and it is much harder to make a pie chart, or a bar chart, that kind of graphic that we can put up on a screen and say, "Hey, look at this! This is [it in] black and white!" I can't do that with Ed Carriere's feelings about cedar trees, or Don Gilich's feelings about his net shed. That's the dilemma. And so we get back again to it being a slow process when we start looking at some of those things, even slower than some of the other things you have been dealing with. It is not easy.

Cyreis Schmitt: Also, the focus of our survey was really looking at things we can do, and in terms of attitudes, I agree that it is useful to know [them], but then we have to decide how do we do things in order to match those attitudes, and what specifics do people have in mind when they have a certain attitude. So we focussed more on preferences and giving them a bit more specificity in choices. Your comment about the public education, and incorporating enforcement and hotline, and so forth—that was a very simplified [way of] look[ing] at things, mainly for the purpose of this talk. We asked those things not even in the same set of questions, and much more specific wording was given on each of those [questions], so that they weren't ever really, during the course of the survey, lumped as public education. There was a whole series of questions on public involvement in education and fisheries management, and so forth. I lumped them—obviously not a very good idea—for simplicity here and in order to meet the timeframe.

Robert Bish: Your question is an extremely good one, but I think we expect people in the Department of Fisheries to worry about preferences for, say, bottomfish, and we expect Arno [Bergstrom] to be a little broader, because he is looking at a range of things that [WSU Cooperative] Extension can get involved in. And then we get to the more abstract level of attitudes like I was discussing this morning. I think those are best explored by academicians in a university setting who are curious about the techniques of survey research and curious about the relationship to political institutions and how they function. We may not have as much of that going on here as I would like. We don't have that ongoing survey that, say, UCLA runs in the L.A. basin, or that Michigan runs. Boy, it would be valuable to have a quarterly survey here, over time. [That kind of survey] can be self-sustaining, economically, because you sell some questions to people who want to know about products, and so on, but you can have other parts of the survey to find what you want to find out about. That would really be useful to answer some of the questions that I think are important. But I wouldn't expect any operating state agency or local government agency to be doing that.

Q. *Doug Dobbins*. I have a question for Bob Bish. This morning you used the word 'bargaining', and you said 'bargaining and negotiation'. I see there is a distinction there, and I wonder if you could comment on the fact that we don't have very good bargaining skills in general, and that maybe by developing

these skills we would develop the attitudes that you were proposing.

Robert Bish: I was using the terms in a more general way. But if people have a lot of confidence in themselves and that their agency is doing a good job, they then are much more comfortable moving into bargaining with others or negotiating in a way to find mutually beneficial solutions, or solving common problems where they both do seek the same objective. (Sometimes it is exchange, sometimes its common objective.) I think there is a pretty high level here, compared to other jurisdictions I've worked in closely. So if you are a specialist in the area you see the deficiencies, but believe me, there are places where agencies are weaker, staff are weaker personally—they are defensive, they hoard information. Those kind of systems work much less well than here. I tend to see the glass as half full. If you are on the ground, you probably see it as half empty,

Q. [No name given]: How do we deal more effectively with misleading environmentalism, such as was exemplified in the Alar scare, with Meryl Streep's involvement? Or with some of the illegal activities, such as we have had with the tree spikers and some of the Greenpeace organizations?

Daniel Jack Chasan: Those are a couple of different questions, and obviously one's approach to them depends, in part, on one's perception. There are clearly people who didn't think that the Alar thing was misleading, at least, if nothing else, as an expression of people's concern about even small amounts of carcinogens. I think the general answer has to be general education. To some extent that is begging the question, though. How do you educate people? And how do you get people to agree on, or acknowledge levels of certainty, or levels of safety, or levels of hazard? I am not sure I have a very good answer for that.

Earlier in this panel session Al Duxbury asked about media coverage of Puget Sound pollution issues, and I said that I thought that the media in general did a lousy job of covering things with a large amount of scientific content. I think that is part of the problem. I think until you get better coverage, more detailed coverage, more analytical coverage in the mass media—which is something that may never happen—you're not even going to get people talking about the same things.

Richard Shikiar: I think another issue is how we manage risk in our society, and we don't do a very good job. We overrespond to some risks and underrespond to others. There is a running controversy now, in *Science* magazine, about the risk of asbestos. Our society has spent lots of money and we have created an industry of asbestos removal, and now there is some controversy as to whether it is more harmful to remove the asbestos in a public building, as opposed to just leaving it there. One article I read, for example, showed that there has never been any illness associated with stable asbestos

in a public building, and yet we have created this whole controversy, and we haven't addressed other issues. So, there is quite a bit of controversy about how we assess and then manage risk in our society. In the absence of some coherent policy or approach to that, we tend to take up whatever seems to be in the headline that day.

Phyllis Harrison: Also I think this question is leading into a talk that is going to be given in the afternoon session by Andrea Copping, dealing with the scientist's role in dealing with that question. I do not want to scoop her presentation, but she may offer some insight into that—more to come.

Q. *Genevive Thissorski (Muckleshoot Tribe)*: I would like to direct this at Professor Bish, and anyone else who would care to comment. That is, to throw out for discussion a phenomenon that I think those of us who work in environmental public policy tend to encounter, which may be yet another dimension of attitudes. That is the "hidden agenda." Maybe in your vocabulary, Professor Bish, it would be a "shadow attitude." For example, the problem of the environmental impacts of high density development tend to be characterized and discussed in terms of needing to balance jobs and housing, say, against fisheries resources. People may actually go so far as to invoke property rights as well. But, in fact what may be going on is the belief of part of the population in the right to cash in on, or profit to the maximum from, property holdings, versus the economic interests of the fishermen or people's desire to hang on to a semi-rural lifestyle and be able to continue to afford a semi-rural lifestyle.

Briefly, another example would be, let us say, a county council fails to uphold an interim, low-density zoning ordinance, invoking the adequacy of existing laws, when in fact they are in a power play with the county staff. The other examples, I think, are too numerous to mention.

Robert Bish: Political organizations work best if the boundaries are such that they encompass the citizens that are most affected by their actions. Then we can at least hope for some countervailing pressures and some balance. In some of the situations where the most severe problems exist—say a small local government wants to do something but the effects occur outside of it—well, we know we are going to have a problem unless we have a larger agency to deal with that.

The kind of example I would use of the "hidden agenda" would be people who want to go in and zone one acre lots in the suburbs to keep out low income people, but say they are preserving the environment. That's as good an example as I can think of. Housing prices are pretty important, and the kind of development policies we are following in suburbs are exacerbating the problem, rather than alleviating them, often in the name of clean environ-

ment. There are places where we can clearly diagnose the problem more easily than the solution, because the problem is basically that all of the people who are affected are not accounted for in the decision-making in that political unit. We can never get it perfect, in the sense of the big developer versus a diffuse citizens group. But remember, the developers might be few, but the only reason they can make money is because they satisfy somebody's preferences who wants to buy their development. They in fact represent non-voters and want us to keep those in mind. By in large, though, over all you'll find different things happening in different areas, and I simply expect people basically to look out for their own self interest in one sense, but in another sense self interest rightly understood, where there is a little broader community there. When you have tree spikers, the political system has lost legitimacy from their perspective, and when a political system looses legitimacy from the perspective of very many people it *really* won't work. We are thankful there are so few of them, rather than more.

Those are just some of the kinds of problems—they are partly structural. The others are just the interplay of interests. They get outcomes that we don't like, but somebody else does. I hope that answers it. It is an awkward question. It is not very well phrased in one sense, but that is not because you can't phrase it. It is because the issue is not very clear, [nor is] how we want to get at it.

Q. *Maxine Keesling.* I was very interested in what Professor Bish said this morning about considering how your actions affect others—put yourself in their places. We have owned, since WWII, a large amount of acreage on Whidbey Island, and since the early 1960s a large amount of acreage in Woodinville, where we live. We have never developed that property. A huge chasm has opened in King County between the regulators and the regulated. We who have saved our properties from development all these years are suddenly being tapped to preserve our properties forever, without even notification, let alone consideration and respect. We are being told that we have to fence our animals out of their pastures; even we and our kids can't use major portions of our property.

Typical treatment is Governor Gardner's October 18th Executive Order implementing Washington Environmental 2010 Action Agenda which, like all other government advisory committees does not include property owners as members of any advisory committee. If we didn't love the environment we would not have saved our land from development. Under today's regulations we would not be able to clear our 10 acres of pasture on Hollywood Hill in Woodinville. My question is, why don't the regulators and media publicize all sides of environmental issues, just as an EIS does on a development project? Otherwise the readers and the public at large hear only the environmental side of these issues and don't have any other way of knowing what's happening.

Robert Bish: My views are published on this, in a sense. If you have had a tradition of a right to do something, and you want to downzone it to a lower density use, or preserve it, the public—the government—should buy that right from the owner. That's the only way in which we can see if the value of that is really worth it to the other people who are going to benefit. Put up you tax money, buy those development rights from people, don't steal them. My views are very strong on that.

The problem, to some extent, is the benchmark, however. I happen to live in an area of open range. We have to fence wandering horses out. We don't have the right to make them keep their horses home. The rights are well known, however; we build fences, we keep the horses out. In areas where there are change, those boundaries change, in terms of what rights you have. But when you have had a long history of planning, zoning, and control, my argument is if you want to make a change in the rules of the game that deprives somebody of what they *reasonably* expected as under the rules of the game, you should compensate them. That's expensive, politicians don't like it, you are in a minority, so we can understand why it doesn't happen. But in any ethical sense, it should.

Q. *Pat Wennekens*: I think one of the issues that should run through the education process is how the public can defend itself from arbitrary decision by a governmental body. If you go and look at the records, you are going to find that the agencies are usually very reluctant to act in favor of what we call the public interest. They look to the vested interest first, before they look to the public interest. But I think it would be very worth while to look at how public interest agencies have brought some changes in attitude and thinking in the government system we have. Similarly, NRDC has gone to court in many instances, and if you see change in the environmental quality laws here it is because we have brought changes by fighting in the courts about it. This is very expensive, for the public to defend itself.

Somebody mentioned Greenpeace. Well, people can see them as becoming extremist. But to make a point you probably have to get an extreme attitude to get the attention that produces some changes. I think this is a factor that in your education program and in your discussion on changing public attitude or public perception should be brought into the equation.

Robert Bish: I would like to make a comment on the first part. There are two things in British Columbia that I have become very impressed with that deal with your question. One is the Ombudsman, which deals with both individual issues and systematic reviews of agency behavior. It has made some major changes in the behavior of places like the Department of Highways and others who were not doing what they really should. The other I am less familiar with in Washington State, but there is something called the Judicial Procedures

Review Act which allows you to challenge a government's decisions in a very quick, inexpensive court proceedings, which still can be appealed. But [this act] has made available to very small, poor interest groups the ability to call an agency to account very quickly, before you get three months, six months down the road. You can get them in within two weeks, essentially, not over six weeks at the outside, for a very inexpensive court review process by a judge. I am impressed by those two things, and how they help correct the behavior of administrators who are otherwise quite impervious to external control, and in a parliamentary system of government where you only vote every five years for a party and where many of the politicians seem to feel very impervious to control. Those devices to lower the cost of making a complaint are extremely valuable.

Q. *George Barnt.* This a comment on the education issue. If we accept the premise that elected officials generally reflect the population that they represent, and I mean educationally now, the issue of scientific perspective and the ability of some of those elected officials to actually assimilate the information and understand it and have a large view of the world is really a tough one. For example, traditionally and historically, people who are elected to port commissions are people probably in their late 50s, 60s and 70s who have succeeded in business—people don't understand ports very well, as voters—now becoming port commissioners who have tremendous influence on what happens in and around bodies of water. So scientific groups and citizens organizations have to visit with those port commissions long hours, they have to educate them in order to create effective decision makers who can understand the issues that they are going to be making decisions about.

Until yesterday, when I came to this meeting and heard about TBT, I had no idea that that stuff was still being used or that the Navy had exemptions and could use it however they wanted. And there are lots of issues on which I consider myself currently informed, but I want you to know that I would venture to guess that most of the other officials in the small jurisdictions—largely ports, and other counties as well because they haven't urbanized yet—need education at a small group level. Politicians tend to be insecure. They have a great facade of assurance, but they are very insecure people in general, I think, and they are easily threatened. And so you've got to work with them, educate them so that they become part of the decision, rather than being beaten over the head and resisting because they think that somebody is trying to get something out of them that they do not deserve.

Richard Shikiar. I would like to take the first crack at that, not that I am an elected official. Of course we do have an educational program for elected officials—its called lobbying. Also, it depends on the level of government that you are talking about. But as you move to the state legislature and, certainly, Congress, although the elected officials there may not have the scientific

background, certainly much of the legwork is done by their staffs, which do have quite a bit of scientific expertise. Certainly in Congress the staff is doing all of the legwork for the Congressman/Congresswoman who will then usually take their staff's direction on a vote. So I think, certainly at the higher level of governance, they are getting decent scientific input.

Phyllis Harrison: I'll go out on a limb, too, and offer a general comment to the whole education issue, since it has come up several times, and I was one who was a major proponent of education as a problem solver. I am an optimist too. I tend to see the glass as half full, rather than half empty. And I believe that people can be educated, although it is a long and time-consuming process. But one of the things we all need to think about here [is language], since we are all concerned with environmental problems and we are all concerned with how we communicate between government and scientists and fishermen and net menders, and all of these diverse groups.

I'll make my point by a personal anecdote. When I first received my brochure and looked through it to look at what the other papers would be about, I couldn't pronounce three-quarters of the words in many of the titles, and gosh, I have a Ph.D! One of the things we need to think about, in terms of language—and it goes back to my title, "Tell Me in Fathoms,"—we need to look at the kind of language we are using and how we are talking to people when we communicate, because it is a hard process, but I think we can educate one another. But we need to understand where we are all coming from, and we need to speak each other's language to do that.

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PUGET SOUND
RESEARCH '91

HABITAT: THE BASIS OF PRODUCTION

Session Chair:

Duane E. Phinney, Washington Department of Fisheries

INTRODUCTION

Duane Phinney[1]

From my perspective, and I'm sure most would agree with me, one of the most important aspects of Puget Sound is its role and importance in supporting a variety of fish and shellfish resources. These resources certainly are one of the primary attributes and one of the primary reasons for the increasing emphasis on protection and rehabilitation of the Sound. These resources are of course totally dependent upon the Sound to provide their vital needs—their habitat. The Sound and that habitat truly is the basis for production of these and the other living resources that reside in, upon, and around its waters.

There are many and varied efforts underway to protect, create, enhance, rehabilitate, and mitigate impacts to fish and shellfish habitat in Puget Sound. The papers presented in this session give a sampling of some of those efforts.

The first five papers focus on Puget Sound proper. The final paper takes us out of the Sound and looks at efforts to protect part of our aquatic environment that is important in itself as fish and wildlife habitat and that also has a significant role in determining the quality of Puget Sound—the rivers and streams that discharge into the Sound.

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SHOULD ARTIFICIAL REEFS BE USED AS MITIGATION?

Kathleen R. Matthews [1]

ABSTRACT

Seasonal habitat use of young-of-the-year, subadult, and adult rockfishes (*Sebastes caurinus, S. maliger,* and *S. auriculatus*) were compared for four habitat types: high relief rocky reefs, low relief rocky reefs, high relief artificial reefs, and sand/eelgrass. Diving surveys conducted December 1986 through October 1988 on two representative sites of each habitat type revealed significant seasonal changes in rockfish densities and habitat use. Young-of-the-year (YOY) recruitment varied between the two survey years: YOY were observed on all habitat types in the summer and fall of 1987, whereas they were observed at only one site (artificial reef) in a similar time period of 1988.

High-relief rocky reefs had the most consistent densities of the three rockfish species, mostly fish >200 mm TL. Adult and YOY copper, quillback, and brown rockfishes were observed on the low relief rocky reefs primarily in the summer months coincident with the summer algal growth; when the kelp died back in the fall, most rockfishes left these reefs. The highest densities of rockfishes, primarily 80-200 mm quillback rockfish (up to 420/90-m^3 transect) and large copper rockfish (up to 56.3/transect), were observed on the artificial reefs. Here, also, density fluctuations were dramatic; copper rockfish densities peaked in fall and winter and declined (to 0/transect) during the summer, and quillback rockfish densities also fluctuated seasonally. Sand/eelgrass areas were the least-utilized habitat type; only during July and August were YOY and low densities of adult copper and brown rockfishes observed on one sand/eelgrass site.

Although all four habitats were used, natural reefs may represent source habitats that are used by and maintain rockfishes on less productive sink (artificial reef) habitats. Thus, the recent use of artificial reefs in Puget Sound as mitigation for the loss of natural reefs could have negative impacts on rockfish populations.

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SITING AND LOADING CRITERIA FOR SMALL VOLUNTEER SALMON NET PENS

Richard G. Kolb[1]

INTRODUCTION

Puget Sound has long been the most popular winter salmon sport fishing area in Washington. It is normally protected from high swells and waves, and historically, the salmon were plentiful. Over the years the abundance of salmon living in Puget Sound has declined. Through its Volunteer Fisheries Resource Program, the Department of Fisheries (with monies from the Department of Natural Resources' Aquatic Lands Enhancement Account) is working to help restore this resource.

The water quality of Puget Sound has also declined, and people are concerned with it's protection. Fishermen are often active in both areas of concern: improving the water quality and increasing the salmon population. They know water quality has a direct effect on salmon survival and abundance. The question today is, can volunteers raise additional salmon in net pens throughout Puget Sound and not have an adverse affect on its water quality?

The Department of Fisheries thinks the answer to this question is yes. With correct management of these small, short term net pens, salmon can be raised around Puget Sound with no negative annual impact on the environment.

METHODS

The Department contracted with Parametrix, Inc. of Bellevue to develop siting and loading criteria. Much of this presentation originated from their report. These criteria would result in no annual measurable accumulation of organic material below the net pen sites. Factors used to formulate the criteria were based on a combination of depth, current, and length of operation for differing numbers of fish.

Parametrix developed a model to simulate the amounts of un-eaten feed and fecal material that would settle below a net pen over a period of time in relation to depth and current. The model allowed for deposition with organic decay over part of the year and decay without deposition for the period when the pens were not in operation. The result provides levels below which accumulation could not be reasonably detected.

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RESULTS

The model is the basis for the generation of graphs for the two rearing schedules, 120 and 180 days, as presented in Figures 1 and 2. To determine the number of fish to rear in a net pen measure the mean water depth and tidal velocity for the site. Locate these values on the appropriate axes on Figures 1 or 2 (depending on rearing time) and plot their intersection. The number of fish can be determined by multiplying the value derived from the graph by the size of the pen in square meters.

An example is shown in Figure 3. A tidal velocity of 10cm/sec and a mean depth of 20 feet gives a value of 1300 fish/m² from Figure 1. If the pen is 16ft x 16ft (5m x 5m), the total number of fish to rear is 32,500.

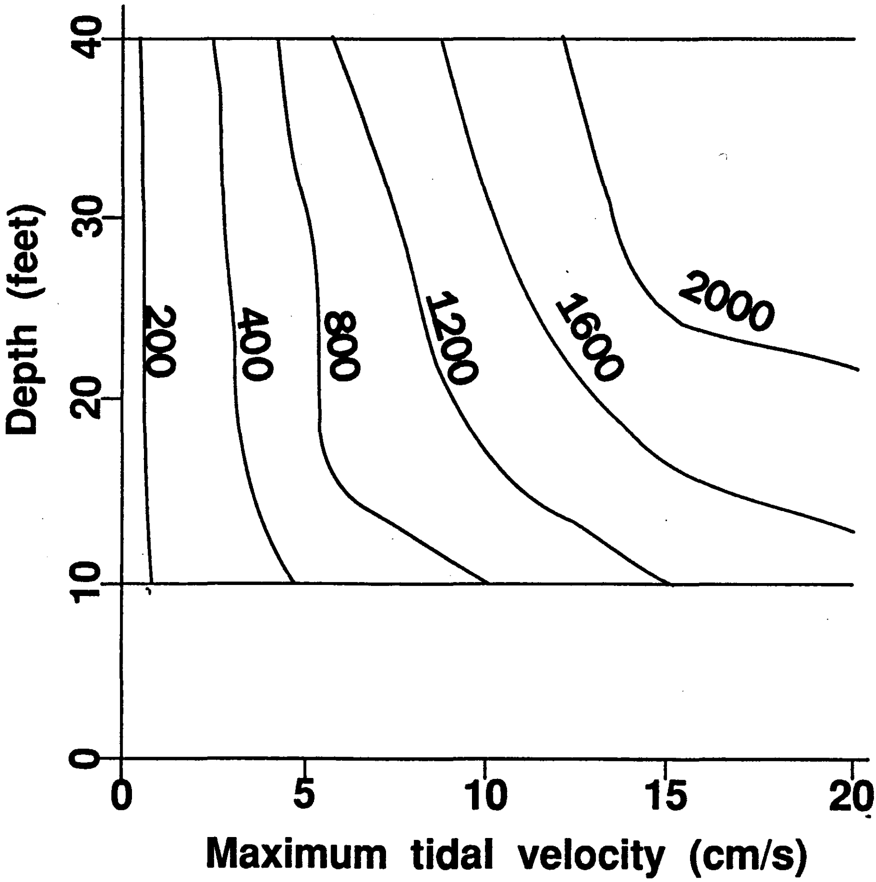

Figure 1.
MAXIMUM ALLOWABLE FISH DENSITY IN NET PENS WITH 120 DAY OPERATION PERIOD. *Contour vales are in fish/square meter.*

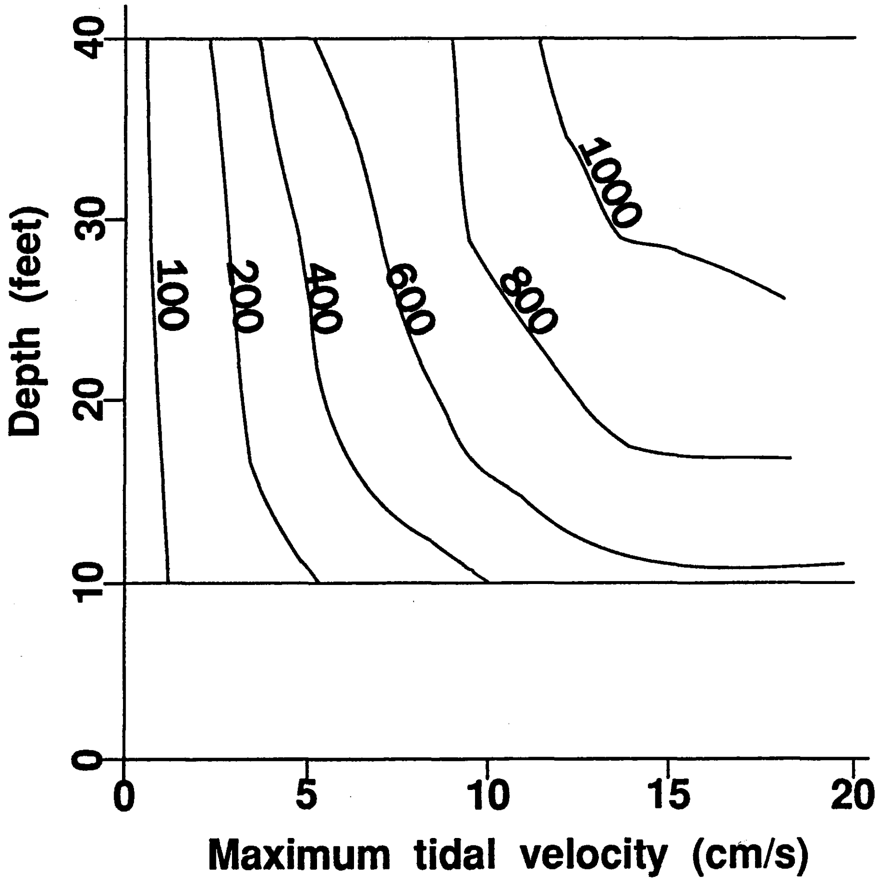

Figure 2.
MAXIMUM ALLOWABLE FISH DENSITY IN NET PENS WITH 180 DAY OPERATION PERIOD. *Contour vales are in fish/square meter.*

DISCUSSION

These figures are conservative and provide maximum protection for the environment. The Department is monitoring six volunteer net pens around the state to verify the model and will adjust the guidelines if the monitoring shows any inaccuracies. This approach should allow interested people to participate in salmon rearing on a small scale and offer the safety necessary to protect the environment.

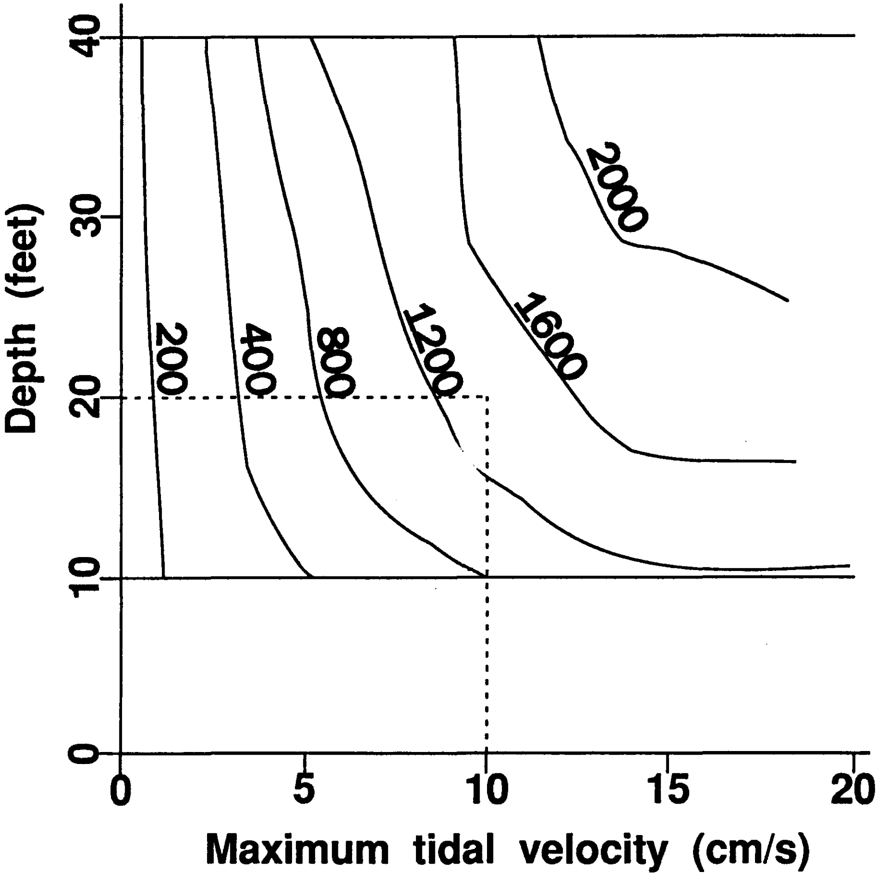

Figure 3.
ILLUSTRATION OF METHOD FOR DETERMINING MAXIMUM FISH DENSITY IN A NET PEN FOR A GIVEN VELOCITY AND DEPTH.

CONTAMINATED BOTTOM SEDIMENT CAPPING DEMONSTRATION IN ELLIOTT BAY

Alex Sumeri[1] *and Pat Romberg*[2]

A contaminated bottom sediment capping project was conducted offshore of the Denny Way combined sewer overflow (CSO) as an experimental demonstration project to evaluate the benefits of capping as a way of improving sediment quality in Elliott Bay. This 1990 project was a cooperative effort between the Seattle District of the U.S. Army Corps of Engineers (COE) and the Municipality of Metropolitan Seattle (METRO) both of which support using clean dredge material for beneficial uses. The COE dredged clean sand for capping during routine maintenance in the upper Duwamish River (Figure 1). A total of 13 barge loads of sand were delivered and slowly spread over a rectangular capping site with an area of about three acres (200 ft. x 600 ft.). A modified COE survey system was used to monitor the location, speed, and application rate as sand was "sprinkled" from a partially open, split-hull barge being moved sideways. Several thinner applications were used to construct a capping layer about 3 feet thick that should isolate marine biota from contaminants in underlying bottom sediment. METRO is conducting a five-year postcapping monitoring program and during 1990 obtained baseline information from diver surveys and sediment samples analyzed for priority pollutant chemicals.

BACKGROUND

In 1895 Seattle constructed a sewer pipeline to discharge untreated sewage and storm water into Elliott Bay at the foot of Denny Way. In 1969 this continuous discharge was diverted into an interceptor line that METRO constructed along the Seattle waterfront for transporting wastewater to their new West Point treatment plant. The Denny Way regulator station has since served as a CSO when the interceptor capacity is exceeded during rainstorm events. In the late 1970s and early 1980s several studies investigated contaminated sediments and led to the identification of about thirty "toxic hot spots" in Elliott Bay and the Duwamish Waterway. The Elliott Bay Action Program studied these sites further and continued to identify a potential problem area at the Denny Way site. A task force was convened in 1986 by the Regional Environmental Affairs Committee of the Puget Sound Council of Governments to consider the feasibility of capping "toxic hot spots". A capping demonstration project was recommended for Elliott Bay with the recognition that source control had to be addressed first.

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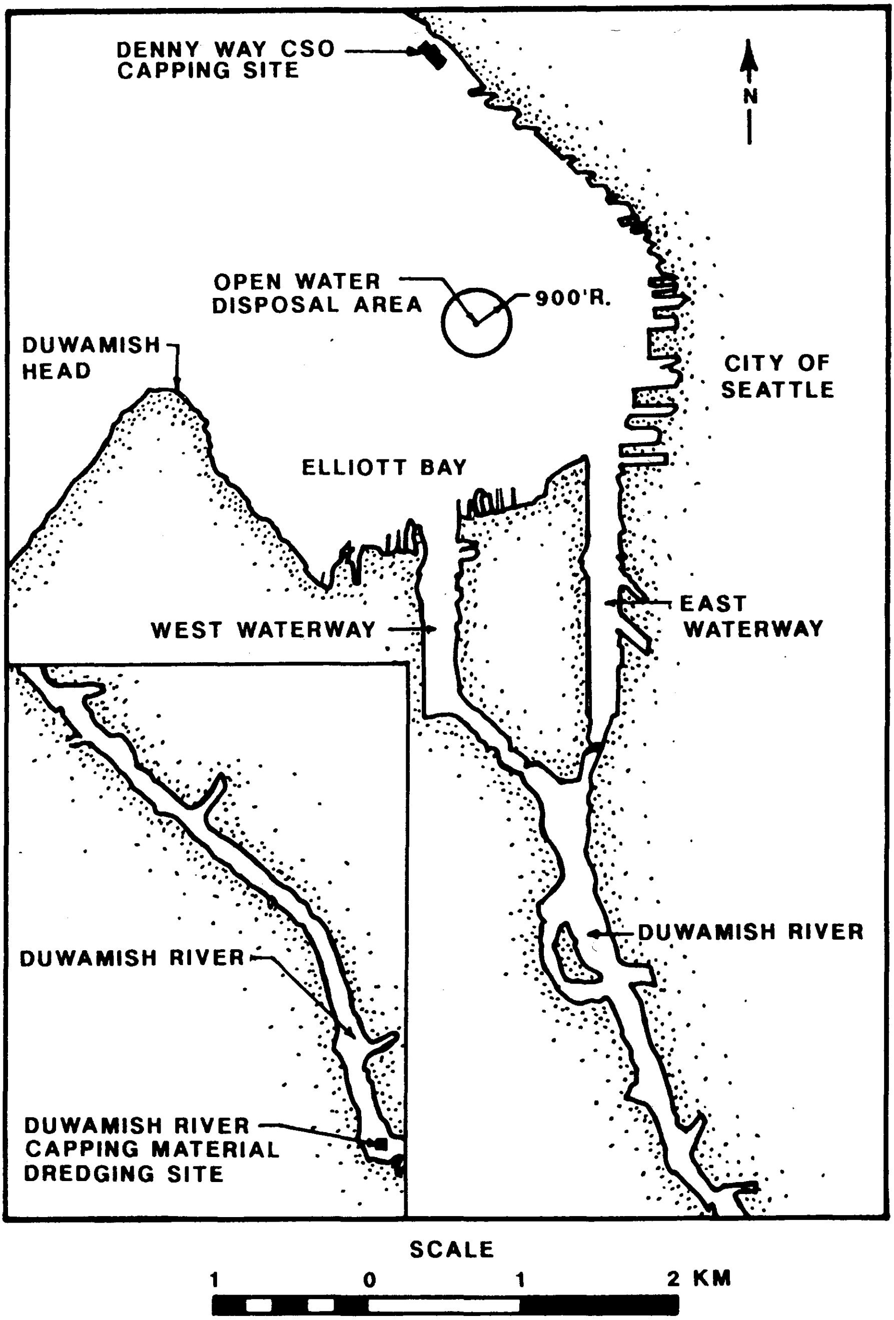

Figure 1.
VICINITY PLAN.

A METRO toxicant reduction study for the Denny Way CSO recommended source control and capping. METRO and Seattle District began informal staff-level discussions of a potential capping project at Denny Way in 1988. METRO and others implemented a multi-faceted program that reduced toxicant loading prior to scheduled reductions in overflow volumes. This program includes the following: removal of toxic sediment from a mile-long sewer tunnel; the City of Seattle cleaning sewer lines immediately below industrial laundries; improved maintenance of catch basins by the City of Seattle to reduce input of street dust into sewer lines; METRO operating an active pretreatment program that maintains contact with permit holders and other businesses that are potential toxicant sources to the sewer system; a regional educational program on proper disposal of toxic material; and initiation of a year round facility for collecting household hazardous waste. Storm water separation projects will reduce overflows to one tenth the present amount by 1999.

With COE technical assistance, METRO obtained the necessary permits addressing issues raised by the Washington Environmental Council, Muckleshoot Indian Tribe, Washington Department of Natural Resources (DNR), and others. Seattle District planned the placement system and designed the dredging/disposal contract. The Corps' research lab, the Waterways Experiment Station (WES), furnished Seattle District funds for the survey software modifications and has research interest in this project as part of the COE Dredging Research Program. As the COE policy is to dispose of dredged material by the least costly, environmentally acceptable method (i.e., at the Elliott Bay PSDDA Open Water Site), METRO agreed to conduct sediment tests on the Duwamish Waterway material to be maintenance dredged in return for COE placement of the cap and performing hydrographic surveys. METRO, acting like a project sponsor, signed an agreement to "hold and save the Corps of Engineers harmless" from issues that arise after cap placement. METRO negotiated a five-year monitoring plan with regulatory agencies to obtain the information needed to document how the cap is functioning.

CAPPING DEVELOPMENT

The capping method of "sprinkling" sand from a split-hull barge was developed and used by Seattle District in 1984 for confined aquatic disposal (CAD) of contaminated dredged material in the lower Duwamish Waterway. This is the oldest CAD or capping project in Washington. The Duwamish CAD project has five years of successful monitoring experience with no evidence of compromise of the cap. Two other successfully completed Puget Sound CAD and capping projects, at the One Tree Island Marina and at Simpson Tacoma Kraft Company, respectively, are also being monitored and show no signs of compromise. New capping projects are being proposed in Lake Union in Seattle and at superfund remediation sites in Eagle Harbor and in Commencement Bay at Tacoma, Washington.

DENNY WAY CSO CAP

The capping area off METRO's Denny Way CSO (Figure 2) measures 200 by 600 feet and lies in water depths between -20 to -60 feet (mean lower low datum). Sediment contaminants include lead, mercury, zinc, low and high Polynuclear Aromatic Hydrocarbons, and PCBs.

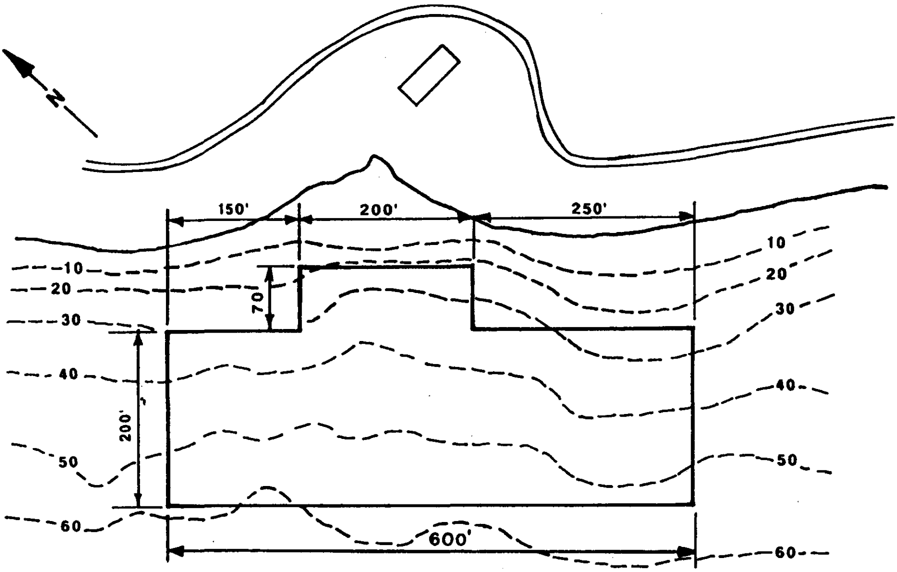

Figure 2.
DENNY WAY CSO CAPPING AREA.

Between 16 and 30 March, 1990, Seattle District capped the three-acre contaminated bottom area with a uniform blanket of clean sand approximately two to three feet thick. The cap consisted of thirteen barge loads, about 20,000 cubic yards, of uniformly-graded sand (mean diameter = 0.4 mm) dredged from the upper Duwamish Waterway, a Federal navigation project. Only the cleanest dredged material from the upstream end of the navigation project was used for capping. Previous experience has shown this sand to be chemically clean and suitable as capping material. The expected volume of shoaled sand in the navigation channel limited the size of the capping area to about three acres. The rectangular shape of the cap allowed maximum coverage of bottom sediments with the highest chemical concentrations. Care was taken in siting the capping area to avoid impacting a kelp bed located on both sides of the rectangular area that extends shoreward.

CAPPING METHOD

Placing a uniform blanket of dredged material over contaminated bottom sediment is not a big technological challenge. However, placing the uniform sand blanket without displacing the contaminated bottom mud, and doing so with available equipment at a cost close to that of routine open water disposal, required some ingenuity in the design process, due to the COE's least cost disposal policy.

The engineering considerations at the capping site included water currents due to tides, storm wave erosion currents, bottom sediment characteristics, contaminants, bathymetry, future site use, ground water, recontamination potential, the types of local burrowing organisms that could compromise the cap, and the desired cap thickness. Other design considerations included volume and physical and chemical properties of the dredged material; availability and cost of dredging and disposal equipment; survey equipment available to the Seattle District and how that equipment had to be modified to accomplish the required positioning by the least costly method.

Seattle District's barge "sprinkling" technique was thought to provide the least costly capping method. However, contractors were allowed to bid any other cost effective method they proposed, as long as their proposals were fully documented. Figure 3 shows a schematic of the split-hull barge sand spreader system employed. A 180 foot long by 50 foot wide Zeidell split-hull, hydraulically opening barge was used to haul 1300 to 1900 cubic yards of heaped sand. The barge was opened 6-8 degrees (Figure 4) and pushed sideways (Figure 5) spreading a slowly released 128-foot-wide blanket of sand (Figure 6). Two 800-horsepower tugs controlled location and speed of the barge. One tug was positioned at the middle of the barge, perpendicular to it, pushing/pulling the barge sideways; the other tug was positioned at the end of the barge away from shore and used to steer by pushing/pulling.

Two pressure transducers from Hazen radio-transmitting tide gauges owned by Seattle District were positioned in steel standpipes centered at each end of the barge (Figure 7). These were used to measure the changes in barge draft. The averaged change in barge draft combined with the rate of change in horizontal barge position was used to calculate the theoretical rate of deposition of sand along the barge track. The tide gauges were sped up to send radio signals every 2 to 2.5 seconds; normally, tide readings are transmitted every five to twenty minutes. Government radio frequencies were used so as not to disrupt communications.

Note: two different frequencies are required to prevent interference between the two gauges. The signals were entered into Seattle District's hydrographic survey Hewlett-Packard 300 microprocessor via two radio receivers and two

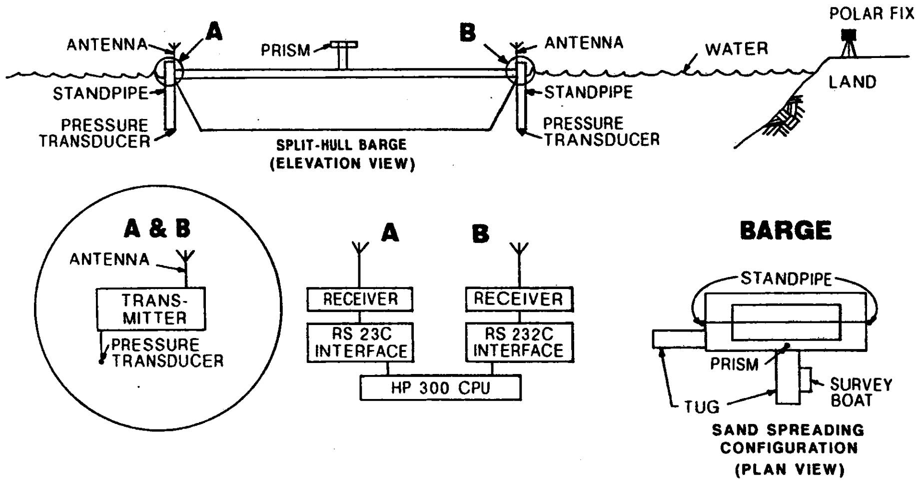

Figure 3.
SPLIT-HULL BARGE SAND SPREADER SYSTEM.

RS-232C ports. The hydrographic survey program was modified to read the tide gauge data in lieu of the depthsounder data, and provided graphic barge position, graphic theoretical rate of sand deposition, speed, time, draft, station, range, and other information as illustrated in Figure 8. The software program was also required to have the ability to replay a capping run; both a graphic and a numerical replay showing data for each fix were provided. Gehagan & Bryant of Tampa, Florida, authored the original hydrographic survey program and provided the new software modifications which were mostly funded by the Corps' Waterways Experiment Station. Positioning during capping was accomplished by the District's range azimuth laser positioning system following a prism mounted on the side of the barge. The District's survey boat was tied alongside the tug moving the barge and provided the tug operator a hard-wired computer monitor showing the same screen information mentioned above to control tug steerage, speed, and rate of sand deposition.

MONITORING

COE conducted hydrographic surveys before, during, and after cap placement. Due to the complexity of the slopes and the wide range in depths, the surveys did not accurately quantify the cap thickness. A heavy reliance was placed on the settling plates and corings to monitor cap thickness. Cap thicknesses measured from settling plates by a diver are shown in Figure 9. METRO conducted monitoring that supported the capping operation and will

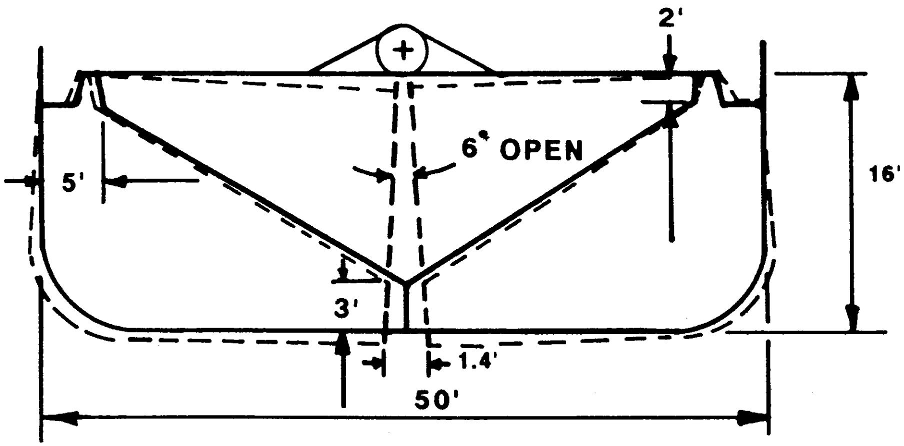

Figure 4.
CROSS-SECTION OF THE BARGE.

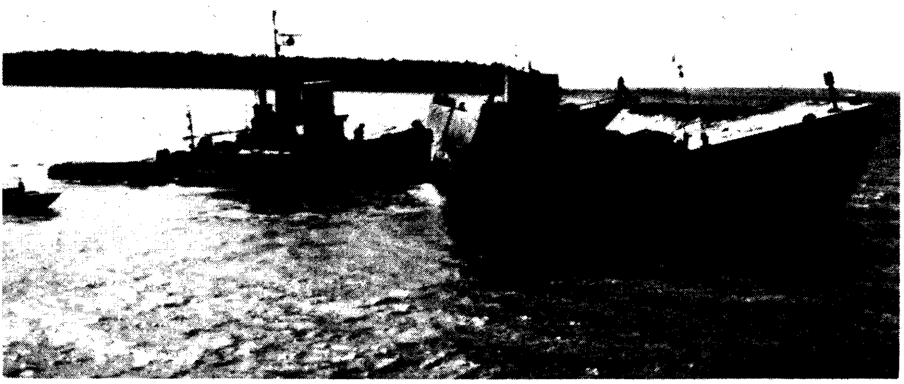

Figure 5.
SAND-SPREADING BARGE BEING MOVED SIDEWAYS.

conduct a 5-year post-capping monitoring program. The METRO monitoring for cap placement included pre-dredge testing of capping sediments, dissolved oxygen testing during cap placement, and measuring at six diver-installed rods and plates to determine foundation settlement and cap thickness. Post-capping monitoring includes surface grab sediment sampling to measure cap chemistry for recontamination, and benthic taxonomy to evaluate recolonization; a video camera survey to view overall bottom condition; REMOTES provides a photo of a vertical slice pushed into the bottom

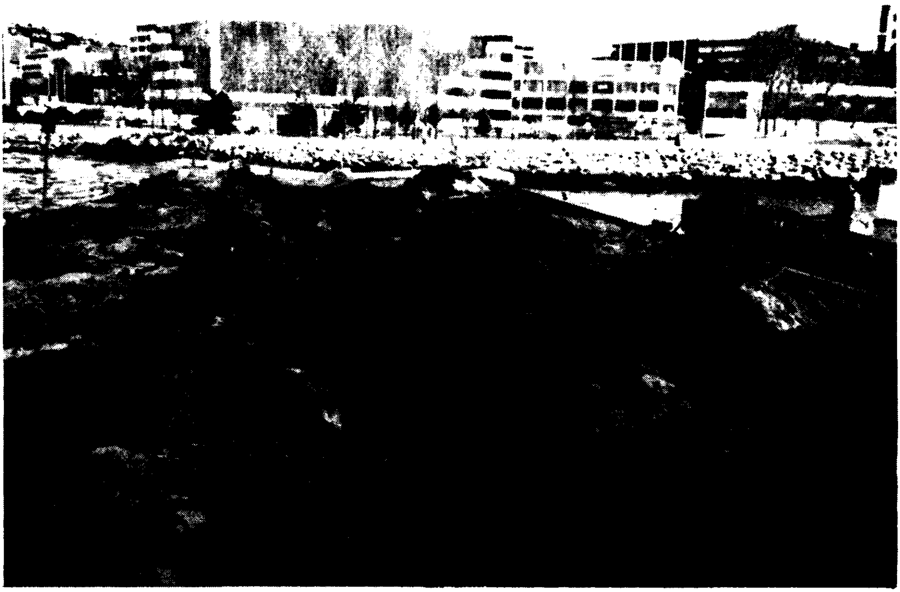

Figure 6.
SAND BEING SLOWLY DISCHARGED FROM A BARGE.

sediment to evaluate cap recolonization; coring through the cap with sediment chemical testing at six-inch intervals to determine cap effectiveness in isolating chemicals; and preparing periodic reports during the five year monitoring period.

DIVER INSPECTION OF CAP

Metro contract divers inspected the cap 5 days after placement, and EPA divers performed another survey 45 days after cap placement. These inspections were primarily over the northern half of the capping site and involved transact lines perpendicular to shore across bottom stakes A to B and C to D, plus a transact parallel to shore across markers A to C (Figure 9). The cap surface appeared fairly smooth or gently rolling, with only a small amount of elevation change. A thin layer (less than one inch thick) of lighter density sediment resides at the very top of the cap, probably because it settled slower than the coarser sand or came from other sources. This layer could be swept away by the diver waving his hand over the bottom and was observed on both surveys. In some places the cap surface is dotted with small pieces of partially rotted wood debris that originated from twigs and branches in the dredged river sand used for capping. Also present on the surface are an occasional basket ball-sized clump of either solid clay or matted leaves.

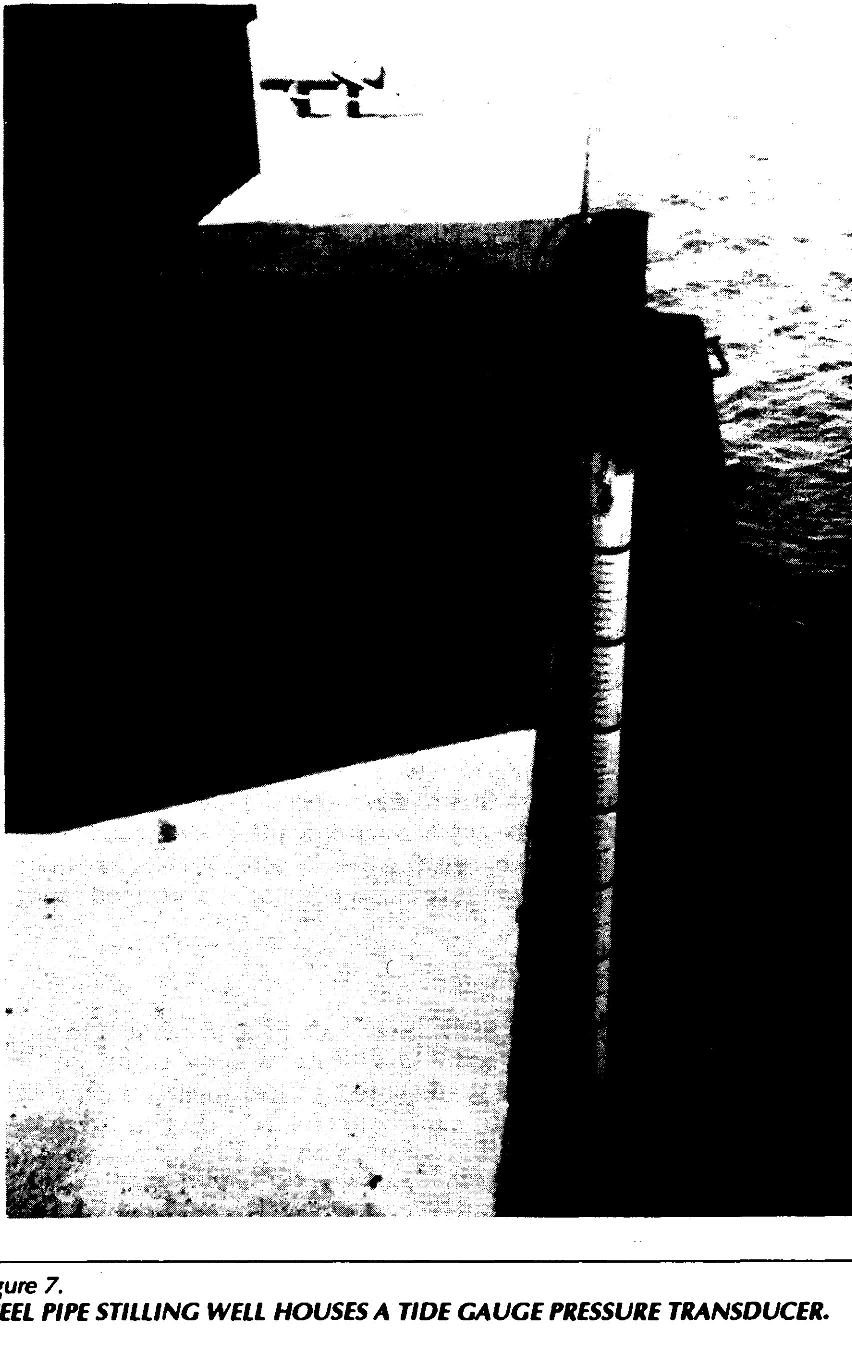

Figure 7.
STEEL PIPE STILLING WELL HOUSES A TIDE GAUGE PRESSURE TRANSDUCER.

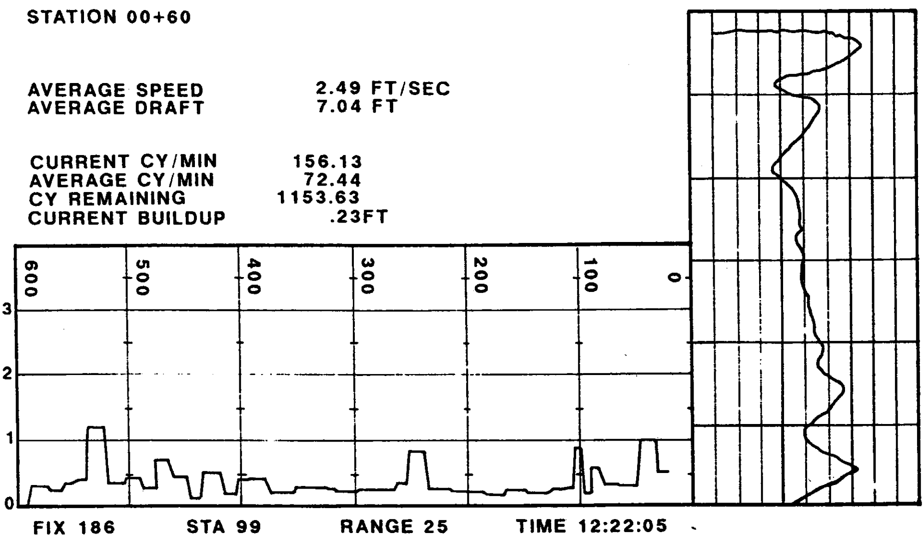

Figure 8.
MONITOR SCREEN VIEW OF THE CONTROL SOFTWARE.

A few bottom animals had moved onto the cap within 5 days, but the number and type of animals had increased greatly by 45 days. One crab and a few flatfish were observed on the site after only 5 days, but many more of these animals were observed on the site after 45 days. Two different species of starfish were present on the site after 45 days, and EPA divers also saw a small octopus on the outer edge of the cap at a water depth of about 50 feet. A few small burrowing animals were occupying the site after 45 days as evidenced by small holes in the cap surface and a small amount of excavated sand.

SEDIMENT CORE DATA

Three cores were collected the second month after cap placement to provide baseline data on the distribution of chemicals within the cap. A diver-operated hydraulic hammer was used to drive a 4 inch diameter, thin-walled aluminum coring tube through the cap at stations "N", "O", and "P" shown in Figure 9. Each of these three core samples was cut into five 6-inch long sections and analyzed for both metal and organic priority pollutants. One section was from below the cap while the other 4 sections were all from within the lower two feet of the cap. A one-inch thick section of sediment at the bottom of the cap was omitted to insure good distinction between the cap and underlying sediments.

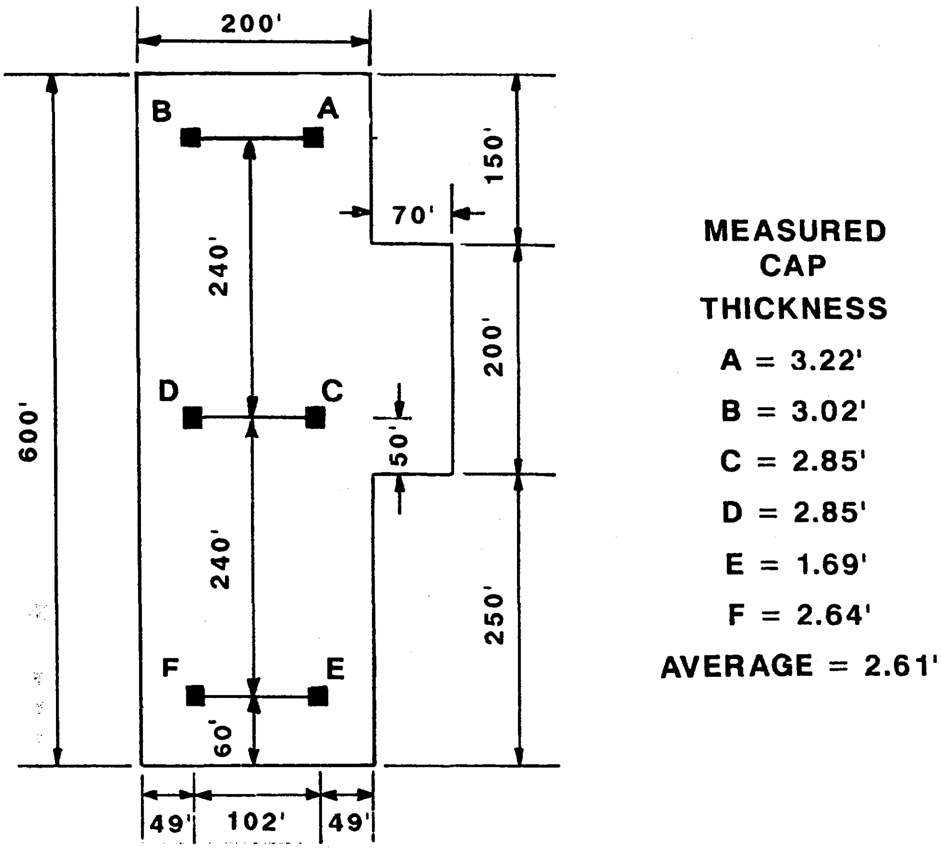

Figure 9.
CAP THICKNESS MEASURED FROM SETTLING PLATES BY A DIVER.

Vertical profiles of the sediment chemical data show a sharp break between the low chemical concentrations in the cap and the substantially higher concentrations in the sediments underlying the cap. Figure 10 shows a good example of how metal concentrations at stations "O" and "N" were nearly uniform throughout the cap and at the surface. Metal values were generally low and frequently below detection limits for silver and cadmium. Few organic chemicals were found in the capping material. Typically, less than 6 compounds were above detection limits and these were uniformly low throughout the cap. The most frequently detected organics, phenanthrene, fluoranthene, and pyrene, were found only slightly above the detection limit in three out of four of the cap sections as shown in Figure 11. Sediment samples from below the cap all contained about 20 organic compounds at substantially higher concentrations.

The core at station "P" was different because it contained a 4 inch thick layer of clay about mid-depth in the cap. The section containing clay had elevated levels of both metals and organics as indicated by the example for mercury shown in Figure 12. The physical characteristic of this clay was much different than the underlying sediment and appears to be a patch of bog type material that was dredged up with the clean sand. It is important to recognize these anomalies so they can be taken into account when interpreting future coring results relative to chemical migration within the cap.

CONCLUSIONS

The capping method appears to have potential for economical remediation of some superfund areas and lesser contaminated bottom areas if the right conditions exist and proper engineering is applied. Costs of remediating contaminated bottom sediments by capping can be 1% to 20% of dredging the contaminated material for upland disposal, provided that an adequate upland site can be found. In-place remediation by capping also reduces possible

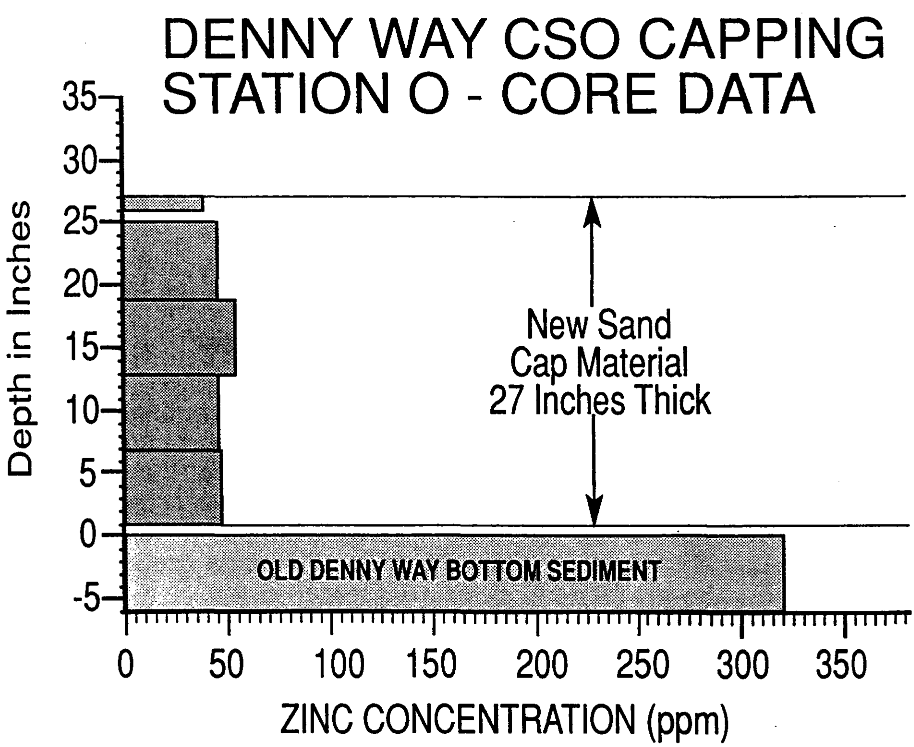

Figure 10.
ZINC SEDIMENT CONCENTRATIONS AT STATION O.

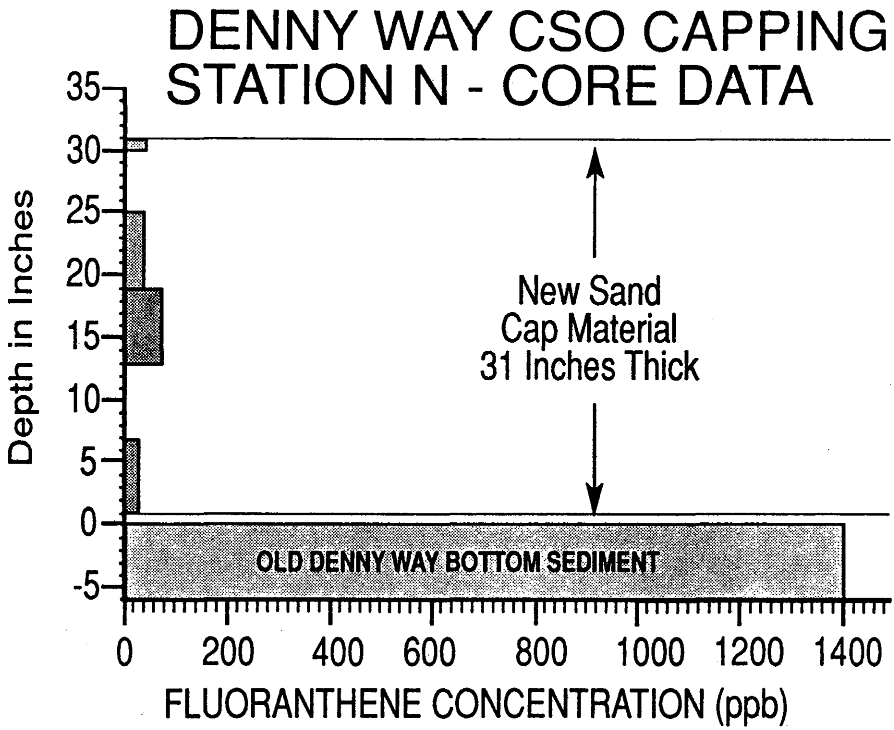

Figure 11.
FLUORANTHENE SEDIMENT CONCENTRATIONS AT STATION N.

spread of contaminants to the surrounding area and the water column. Also avoided is the possible need of a run-off water collection system to control salt and chemical leaching that can occur at an upland disposal site. Oxidation of contaminated sediments in an upland environment may also release contaminants which may have been bound to submerged sediments. Conventional dredging and disposal equipment can be used in capping contaminated bottom sediments. However, to avoid disappointments, these types of projects should be engineered, as many parameters must be evaluated. Also, a word of caution during cap placement: this stage must be carefully monitored to prevent rushed placement by the contractor or the contract administrator. We experienced some displacements of bottom material by too-rapid releases of sand which required additional placement of cap material.

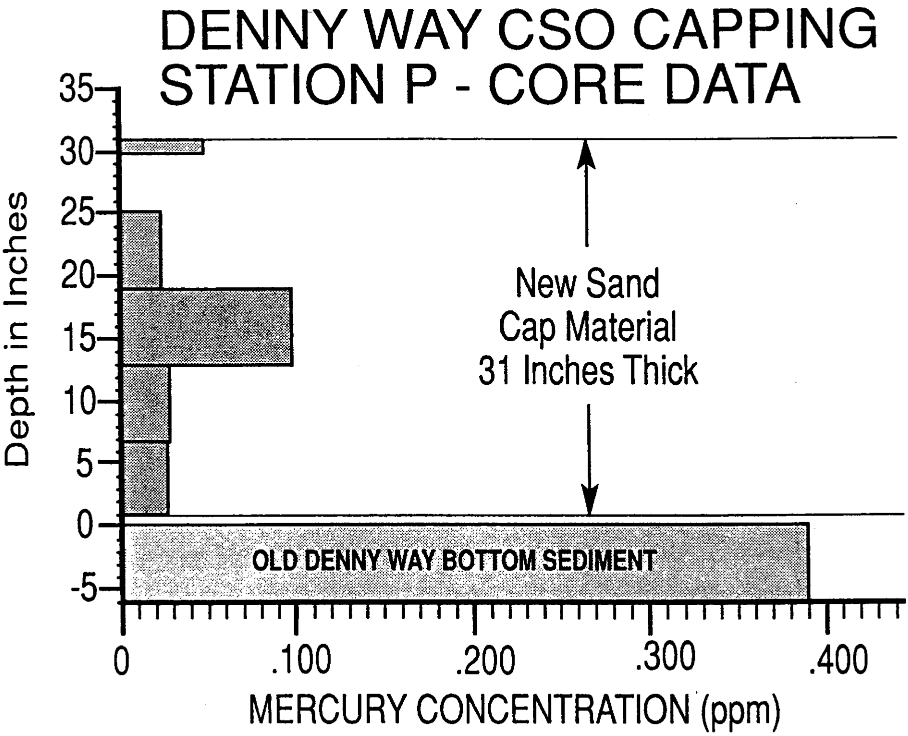

Figure 12.
MERCURY SEDIMENT CONCENTRATIONS AT STATION P.

ENHANCEMENT OF HARDSHELL CLAM HABITAT BY BEACH GRAVELING

Doug Thompson and Walt Cooke [1]

INTRODUCTION

Throughout the past decade, there has been a steady increase in fishing effort on hardshell clams by tribal and recreational diggers (Schloz, 1990). Non-point source pollution of public shellfish beds has served to concentrate this fishing effort at fewer sites. New clam habitat needs to be developed to increase the resource base for the growing fisheries and to replace the beach area and production that has been eliminated by pollution. Through this enhancement effort the Washington Department of Fisheries (WDF) hopes to meet increasing harvest demand and to protect shellfish stocks.

One method of hardshell clam population enhancement is to develop new clam habitat through a process known as beach graveling (Belding, 1930; Turner, 1960; Castagna and Kraeuter, 1977; Kraeuter and Castagna, 1977; Manzel et al., 1976; Flagg and Malouf, 1988). Beach graveling is the placement of gravel or a mixture of gravel and crushed oyster shell on a mud or combination mud, sand beach that does not naturally produce a significant population of clams. The graveling process adds predator protection and creates interstitial space and substrate stability for newly settled juvenile clams. Crushed oyster shell keeps plots from compacting and provides calcium carbonate which buffers pH values and may improve natural recruitment.

Washington State Department of Fisheries (WDF) has constructed several gravel plots for the enhancement of hardshell clams. The sites were selected for their potential as recreational and tribal use beaches, with the target species being the native littleneck clam (*Protothaca stamina*), the butter clam (*Saxidomous gigantea*) and the Manila clam (*Tapes philippinarum*). This paper compares the success and failures of initial gravel plots established between 1974 and 1983, and discusses the results of a recent gravel site. Guidelines for future site selection are presented that are based on observations and results of the initial plots. Studies in progress to measure the impacts of graveling on the infauna and epifauna are briefly discussed.

[1] Washington Department of Fisheries, Point Whitney Shellfish Laboratory, 100 Point Whitney Road, Brinnon, Washington 98320

METHODS

Between 1974 and 1983, the WDF constructed gravel test plots at Bywater Bay on Hood Canal, Frye Cove in South Puget Sound, Long Island in Willapa Bay, Oak Bay in Admiralty Inlet, Port Townsend Bay and Semiahmoo Spit near the city of Blaine, WA (Table 1). Oak Bay and Port Townsend Bay were graveled by the U S Army Corps of Engineers during maintenance dredging of the Port Townsend Ship Canal. Dredge spoils, approximately 7.5 cm minus, were pumped by pipe to each site and spread using a deflection nozzle. At the other sites gravel was brought in by barge and spread over the plot by a dump barge or a crane-operated bucket. At all sites except Long Island the gravel was further spread and leveled using a bulldozer on the beach at low water. At Long Island the plot was leveled using a small drag line-operated scoop, and by hand with shovels and rakes. The plots were sampled in 1985 and 1988 to estimate hardshell clam abundance. Replicate 0.1 m^2 quadrants (n=30) were selected at random within each plot. The area of each quadrant was dug and clams were separated from the substrate by hand sifting the soil.

In February 1989, a 0.8 ha area was graveled in Oakland Bay near Shelton, WA to test gravel composition and layer depth on recruitment and survival of Manila clams. The plot was divided into four study plots to test different treatments of gravel, including 100% gravel (6-19 mm) and a 50/50 mixture of gravel and crushed oyster shell, each at layer depths of 2.5 and 10.0 cm. The gravel and crushed oyster shell were barged to Oakland Bay and spread at high tide over the study plots at tidal levels between 0.6 to 1.3 m MLLW using a crane-operated bucket. To estimate abundance and survival of the 1989 year class of Manila clams, 10 x 10 cm core samples (n=30) were collected randomly from each plot in September 1989 and August 1990. These samples were sieved through wire mesh screens ranging in size from 10.0 to 1.0 mm to separate clam seed from substrate.

RESULTS

In 1985 clam production on the initial gravel plots varied from 18 kg/ha at the south Semiahmoo Spit to 11,500 kg/hectare at Willapa Bay (Table 1). In 1988 production ranged from 367 kg/ha at Oak Bay to 13,500 kg/ha at Willapa Bay. Winter storms between 1986 and 1988 caused sever plot erosion and excessive sedimentation at the Port Townsend Bay, Frye Cove (1983) and S. Semiahmoo gravel plots. This resulted in 100% clam mortalities at these sites and as a result these plots were not sampled in 1988. The clam production at Oak Bay dropped from 1,345 kg/ha in 1985 to 367 kg/ha in 1988 and this decrease was due to storm damage.

At Oakland Bay all treatments had nearly the same level of natural recruitment in 1989. Clam population estimates ranged from 1497 clams/m^2 on the 2.5 cm

Table 1.
***BEACH GRAVELING SITES ESTABLISHED BETWEEN 1974 AND 1983** showing the year graveled, area graveled, gravel depth, tide height, gravel composition, target species and production in 1985 and 1988.*

Area	Year Graveled	Area Graveled (ha)	Gravel Depth(cm)	Tide Height(m)	Gravel Composition (cm)	Target Species	1985 Prod. (kg/ha)	1988 Prod. (kg/ha)
Oak Bay	4/74	1.40	45-60	-0.6 to 0.0	Ship Canal	N&B*	1,345	367
Port Townsend Bay	4/74	0.24	45-60	-0.6 to 0.0	Ship Canal	N&B	2,946	—
Frye Cove	5/79	0.3 6	15-25	0	2.5 to 7.5	N*	424	992
Bywater Bay	6/79	0.56	17.0	0	Course Screened	N	184	845
Willapa Bay	4/79	0.16	15.0	+0.9	7.5 screened	M*	11,500	13,500
Frye Cove	5/83	0.48	13.25	+0.6	0.6 to 1.9	M		84 —
Bywater Bay	5/83	0.40	18.0	+0.6	screened	M	262	4,362
Semiahmoo Spit S.Plot	9/83	1.08	21.25	0.0 to +0.3	0.6 to 2.5 crushed	N&B	18	—
Semiahmoo Spit, N.Plot	9/83	1.36	19.25	0.0 to +0.3	0.6 to 2.5 crushed	N&B	33	1,675

* N = Native Littleneck clam, B = Butter clam, M = Manila clam

thick gravel plot to 1836 clams/m^2 on the 10.0 cm gravel plot (Table 2). Differences in juvenile clam survival showed up in the 1990 survey where clam population estimates ranged from a low of 197 clams/m^2 on the 2.5 cm thick gravel/shell plot to a high of 886 clams/m^2 on the 10.0 cm thick gravel plot. Seed survival was best on the 10.0 and 2.5 cm thick gravel plots, with values of 48.2 and 45.6 percent, respectively. The 10.0 and 2.5 cm gravel/shell plots had seed survival rates of 28.7 and 11.1 percent respectively.

Table 2.
MANILA CLAM SEED POPULATION ESTIMATES AND PERCENT SURVIVAL FOR THE 1989 YEAR CLASS ON OAKLAND BAY GRAVEL TEST PLOTS.
Plots were sampled in September 1989 and August 1990.

Test Plot	1989 (no./m^2)	1990 (no./m^2)	Percent Survival
Gravel - 10.0 cm	1836	886	48.2
Gravel - 2.5 cm	1497	684	45.6
Gravel/Shell - 10.0 cm	1640	483	28.7
Gravel/Shell - 2.5 cm	1775	197	11.1

DISCUSSION

Based on the results of initial gravel plots, a number of factors have been identified which have contributed to their success or failure. These include natural recruitment, gravel size and shape, layer depth, exposure, sedimentation and predation.

Willapa Bay has significant hardshell clam production primarily due to successful spawnings of large populations of Manila clams present in the Bay. Gravel that was 0.6 to 1.9 cm diameter provided a suitable amount of interstitial space necessary for the collection of fine sediments. Crushed angular rock used at Semiahmoo was found to compact too easily, eliminating any interstitial space. Large, cobble size, gravel used at Bywater Bay provided too much interstitial space, and was too porous to collect fine sediments.

Gravel layer thickness was found to be one of the major factors affecting clam production on the gravel plots. Thick layers smothered many infaunal organisms and macroalgae, causing them to die, decay, and produce hydrogen sulfide gas which is toxic to juvenile clams. Thick layers also take longer to trap fine sediments necessary for clams to survive. Sites such as Oak Bay and Port Townsend Bay with gravel layers 45 to 60 cm thick took eight to ten years to produce clams.

Thin layers of gravel from 10 to 20 cm thick resulted in the fastest rate of clam production. With an average layer depth of 15 cm, the gravel plot in Willapa

Bay had significant recruitment of approximately 1400 clams/m^2 within the first year and annual production of 11,250 kg/ha within four years after graveling. By spreading only a thin layer of gravel at a time, the impact to benthic organisms is lessened. With limited die-off of infaunal and epifaunal organisms, the substrate and interstitial water stayed fresh and clean for optimal clam recruitment and survival.

At the more exposed sites wave action and longshore currents moved the gravel. At Oak Bay wave action piled the gravel into a berm which is now too high tidally to support good clam growth. At Port Townsend Bay the plot has been washed out. At Frye Cove the higher plot was eroded and then covered by silt from seasonal streams or upland drainage.

At Bywater Bay predation by moon snails, crab, and fish has limited production on gravel plots established below +0.6 m MLLW. The gravel plot established at +0.6 m MLLW had an estimated hardshell clam production of 4362 kg/ha in 1988, compared to the estimated production of 845 kg/ha of the lower plot established at 0.0 m MLLW. This lower production was due to a higher intensity of predation at the lower tidal level.

The high production at the Willapa Bay site demonstrates how effective graveling can be when several of these factors such as natural recruitment, gravel size and layer depth can be optimized. Considering these factors, a number of different guidelines have been developed (Newman and Cooke, 1988) which are now used by WDF to assist in the selection of sites for graveling. By following these guidelines WDF can ensure a site's potential success and prevent or minimize environmental impacts. They are:

1) **Substrate base and beach slope.** Sites need to have a suitable substrate base and beach slope. Gravel will bond best to soft mud, and this substrate is selected over hard-pan or seasonally shifting sandy substrate. Gradually sloping beaches will hold gravel better than steep beaches. Beaches with slope gradients less than 1-2% are preferable for graveling.
2) **Natural recruitment.** Selecting beaches within the optimal tidal range for each species and close to naturally occurring clam beds increases the chances for survival for natural clam sets.
3) **Exposure.** Selection of sheltered sites that have a low to moderate exposure to wave action and little longshore current minimizes the potential for gravel displacement or burial from sedimentation. If uncertain of a particular site, a geological consultant with experience in coastal processes is hired to examine the site. Based upon the consultant's recommendations the site is then approved or removed from consideration for graveling.
4) **Eelgrass.** Because eelgrass is a critical habitat for several species of juvenile marine fish and salmon, only those sites with a low abundance of eelgrass are selected for graveling. Where the potential for impact exists, a buffer

area will be established between the gravel and existing eelgrass patches.

5) **Review impacts to species, habitat and archeological sites.** With WDF acting as lead agency, each graveling project is taken through the State Environmental Protection Act (SEPA) process and applications are made for the required permits. This process ensures that impacts to all species and habitat are reviewed and discussed.

These guidelines have been used to develop the Oakland Bay gravel site and they have contributed to the success there. All study plots at Oakland Bay showed recruitment rates and survival of clams equivalent to prime commercial clam ground. The best survival appears to be on the pure gravel plots, both the 10.0 and 2.5 cm thick layers (Table 2). The gravel/shell plots were expected to show the best survival because of the beneficial effects of shell on recruitment and its pH value buffering capacity. The 10.0 cm thick plots were also expected to be slower in becoming productive due to the greater potential infaunal die off and fouling of the substrate. It may be that in Oakland Bay 15.0 cm or even 20.0 cm thick layers can be used before infaunal die off occurs. Possible reasons for the poorer survival on the crushed shell/gravel plots may be:

1) The shell/gravel mixture did not insulate clams against winter freezing as well as pure gravel.
2) The gravel provided better protection than the shell/gravel mixture from predators such as crabs and diving ducks.
3) The shell may have actually attracted crab predators seeking cover in the shell to the plot.

Future gravel sites will be evaluated using replicate plots (500 m^2). In addition to clam population studies these plots will be used to monitor impacts to key polychaete and amphipod species which are important prey for juvenile marine fish. Studies on primary production and nutrient concentrations will also be completed on each replicate plot.

A study is now in progress to determine impacts of beach graveling on epibenthic populations of harpacticoid copepods and gammarid amphipods which are important prey for juvenile salmon. Preliminary results have shown an increase in species diversity and abundance on gravel plots with layers less than 15 cm thick.

Careful site selection and development will ensure increased clam production and minimize any adverse environmental impacts. In fact, the very creation of new hardshell clam habitat, and its subsequent need of protection from pollution, indirectly serves to protect water quality for all Puget Sound dwellers and users.

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ANALYSIS OF MARSH TRANSPLANT EXPERIMENTS AT JETTY ISLAND, EVERETT, WASHINGTON

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INTRODUCTION

In late fall and winter of 1989, the Corps of Engineers (COE) and the Port of Everett implemented a plan to beneficially use clean material dredged from the lower Snohomish River navigation channel. Some 250,000 cubic yards of clean sands and silts were used to form a 1800 foot long by 50-75 foot wide berm across a gently sloping sandy beach on the west side of Jetty Island. This island, formed from decades of confined placement of dredged material, lies adjacent to the navigation channel west of the Port's industrial area. The intent was to create a depositional environment that would provide improved habitat conditions for juvenile salmon. The protected embayment included 19.4 acres inside the berm between elevations of +5 and +10 ft Mean Lower Low Water (MLLW) (Figure 1).

Two of the expected benefits of the project were the establishment of a saltmarsh habitat in the embayment and the expansion of dune grass habitat on the island. Factors affecting the success of saltmarsh establishment were poorly understood. The purpose of the transplanting experiments was to evaluate how successfully several species would survive in different elevations and exposures within the embayment. These data will allow more efficient planting in 1991 and accelerate the establishment of marsh vegetation. Dune grass was also planted on the top of the berm to stabilize the newly placed sands.

METHODS AND MATERIALS

In April and May 1990, one-third of the western portion of the berm (about 3.0 acres) was planted by hand with dune grass, *Elymus mollis*. Plants were obtained from existing dune grass stands on the island and from the Wave Beach Grass Nursery in Florence, Oregon.

Within the embayment, 18 transplant plots were established along five transects spanning an elevation range of +6.6 to +11.0 ft MLLW (Figure 1). At the upper elevations of each transect where beach slope was the most extreme, plots were 5 m x 40 m long (200 m^2). Plot 4-3 was in a less steeply sloped area,

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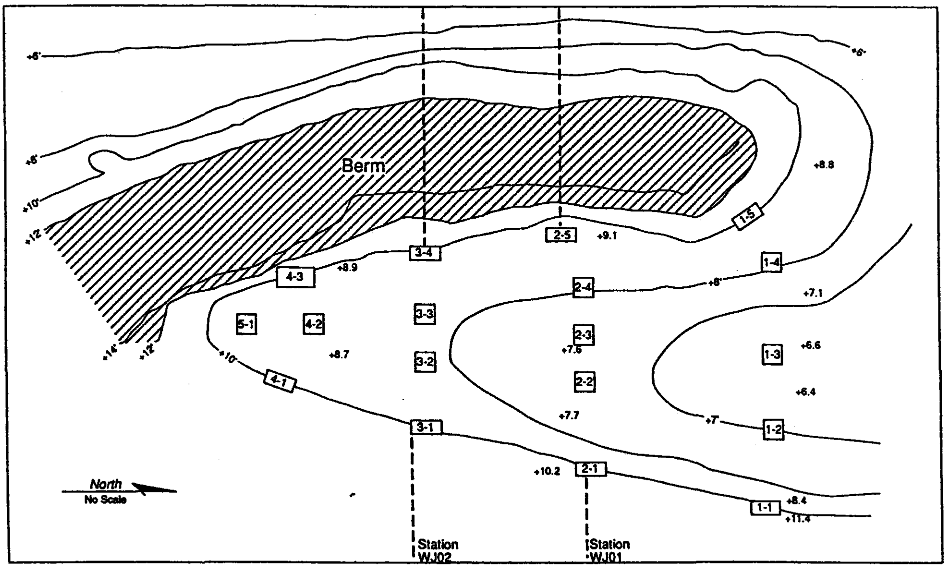

Figure 1.
TRANSPLANT PLOT LOCATIONS ON THE BERM AND IN THE EMBAYMENT.

and was a rectangular plot 10 m x 40 m long (400 m^2). All other plots were 20 m x 20 m long (400 m^2).

Each plot was divided into 25 subplots. For the 400 m^2 plots, subplots were 16 m^2 (either 4 m x 4 m or 2 m x 8 m); for 200 m^2 plots, the subplots were 8 m^2 (1 m x 8 m) in area. Within each plot, four subplots were randomly designated for each of the six target species. The remaining subplot was not planted and acted as a control for natural colonization. Larger subplots received 16 equally spaced planting units and smaller subplots received eight. A total of 432 subplots were planted with 5568 planting units (928 planting units per species).

Lyngby's sedge (*Carex lyngbyei*), tufted hairgrass (*Deschampsia caespitosa*), saltgrass (*Distichlis spicata*), pickleweed, *Salicornia virginica*), hardstem bulrush (*Scirpus acutus*), and seaside arrowgrass (*Triglochin maritimum*) were planted. All of the plants, with the exception of *Distichlis*, were provided by the Wave Beach Grass Nursery in Florence, Oregon. *Distichlis* was collected from a marsh on the northeast side of Jetty Island. Planting units of *Distichlis* were 100 cm^2 x 15 cm deep soil plugs. *Carex* and *Scirpus* were planted as sediment-free individual culms with two to three culms per hole. The remaining species were planted as sediment-free mats of material containing several shoots. The mats were 3 to 5 cm wide at the base of the shoots. *Deschampsia, Triglochin*, and *Salicornia* were also planted in single vertical rows spanning

elevations between +7.0 and about +14.0 ft MLLW. Planting was performed in April 1990 with the help of volunteers. Most planting material was planted within 24 to 48 hours of removal from donor sites.

In June, two additional trial plots with *Deschampsia, Carex, Scirpus maritimus* and *Salicornia* were established and planted on the upper eastern and western shores of the embayment. The plots had different-sized transplants, ranging from 1 gallon (*Deschampsia*) to three to four bare root culms (*Carex* and *Scirpus*), planted on 1-ft centers at elevations between about +9.0 and +12.0 ft MLLW. *Salicornia* was planted as sediment free mats of material containing several shoots. A slow-release nitrogen fertilizer was applied to these plots and raked into the surface.

Approximately every week between April and September 1990 the study site was visited to record and photograph major disturbances and natural colonization of plant species, and to assess plant condition and growth.

In March, April, and July, water temperature and salinity were measured during low tide along two transects (WJ01 and WJ02) in the embayment and on the seaward side of the berm (Figure 1).

The transplants were quantitatively sampled on September 5, 1990. Data taken within each subplot included: number of planting units visible, plant patch diameter, and maximum shoot length and shoot density (*Carex* and *Scirpus* only). Patch diameter was defined as the distance between the two most distant shoots within a unit. The four subplots devoted to each species served as replicate values within each plot.

RESULTS

Qualitative Observations

The seaward side of the berm currently consists of coarser sands and was subject to movement by wave and wind action throughout summer and fall 1990. Evidence suggested that erosion was occurring. Portions of the seaward edge of the berm fluctuated from a nearly vertical slope to a gentle slope. A small sand spit formed at the end of the berm, probably due to erosional processes on the outside of the berm. However, by October 1990, erosion had not yet damaged transplanted dune grass on the western edge. Logs deposited along the seaward side of the berm are expected to reduce erosion rates.

Temperatures and salinities in shallow surface water were consistently higher on the inside of the berm. There was always at least a 5 degree difference in temperature across the berm. Salinity averaged about 15 parts per thousand (ppt) on the inside and 11 ppt on the outside.

Several physical processes reduced plant survival in some plots. The eastern shore of the embayment was subjected to more severe physical processes than the western side. In early summer, erosion along portions of the eastern shore was apparent. Plugs of *Distichlis* were sticking up 4 to 5 cm above the sediment surface. However, later in the summer a severe wind storm deposited a considerable amount of sand on the eastern shore of the embayment, burying plants and changing elevations by 0.5 to 2.0 ft. Over the summer, sand and wind erosion deposited lesser amounts of sand on the western shore. By the end of August, at least half of plot 1-5 was covered by at least 90 cm of sand. Additional sedimentation was noted at plot 5-1 (0.6 ft), the western edge of plot 4-3 (about 1.5 ft), and plot 3-3 (2.5 ft).

The sediments in most of the embayment were very soft during the transplanting in April, and became firmer by September. This was probably due to the natural dewatering that typically follows the placement of dredged material. In late July and August, green algae (*Enteromorpha intestinalis*) formed mats, with extensive, deep (ca. 20 cm) mats covering plots 2-1 and 3-1 completely, and shallower mats partially covering plots 4-1 and 2-5. This coverage probably affected the survival of transplants. Finally, piles of wood chips brought in with the dredged material covered portions of plots 2-2, 3-1, and 5-1. By late summer, wood chips covered up to three-fourths of these plots and may have limited survival of transplants.

A natural drainage channel developed along the north-south axis of the embayment. Features of the channel (e.g., deeper and faster flowing water at low tide) became more prominent throughout the summer. This channel may enhance the biological functions and long-term success of the saltmarsh.

In the embayment, the rich infauna is dominated by ghost shrimp, polychaete worms, and bivalves. These animals include species that survived the project construction and species that became established through natural colonization after the berm was created.

Canada geese (*Branta canadensis*) nested on the island and severely grazed the *Carex* and *Triglochin*, cropping plants to the sediment surface or pulling them up completely. Many of the plots were replanted if additional plants were available. To prevent further predation, Mylar bird scare tape was tied around each plot at about 0.8 m above the sediment. This ribbon appeared to effectively keep geese out and by mid-June the geese activity in the area had dropped off.

An encouraging amount of natural plant colonization has occurred on the top of the berm. Seedlings of several salt tolerant species, such as *Cotula coronopifolia*, *Atriplex patula*, and *Plantago* sp., have taken root. Dune grass is colonizing naturally along the high tide swash line on the west side of the embayment, where roots and seeds have been deposited by water transport

from other parts of the island. Transplanted seeds produced by dune grass in June may have contributed to dune grass shoots observed on other areas of the berm. A few willows, *Salix* sp., were growing along the east side of the embayment.

Japanese eelgrass (*Zostera japonica*), colonized much of the embayment area, particularly along the east side. By late-August, dense stands of Zostera were observed between +6.0 and +8.0 feet MLLW, with cover ranging from 1 to 5 percent.

Incidental transplanting (i.e., those not in plots) and natural colonization of *Distichlis spicata* occurred at several points along the eastern side of the berm at elevations of approximately +12.0 ft MLLW. Although the surface sand material in this area was dry, sediments at approximately 5 to 10 cm deep were moist. This suggests that *Distichlis* would succeed at elevations above +11.0 ft MLLW, if the soil is moist enough to minimize root and rhizome desiccation.

Survival of the extra row of planted *Deschampsia* and *Triglochin* between +11.0 and +14.0 ft MLLW was high (95 percent), while survival of Salicornia was lower (approximately 60 percent). All plants appeared robust. Greater exposure to water movement, sedimentation, and debris (i.e, logs) may have reduced survival of these species below +11.0 ft MLLW.

On the western shore of the embayment, the high-density, fertilized plot had very good survival rates (> 85%) for all species. On the eastern shore, transplants in the plot had lower survival (approximately 50 to 60%) due to physical disturbances. *Deschampsia* flowered and produced seed in July. New above ground growth of *Carex* and *Scirpus* was not observed, but growing root systems were observed in August. *Salicornia* also showed spreading. The size of the *Deschampsia* transplants and the density of plants in the plot appeared to provide adequate protection from sedimentation (e.g., sand transported by the wind) and from being covered with algae. These factors and the plot elevations appeared to contribute to the overall high survival.

OBSERVATIONS ON TRANSPLANT SUCCESS

By the eighth week of monitoring, it was apparent that almost all transplants in plots between +6.0 and +8.0 ft MLLW were not going to survive. In early spring and summer, weekly observations of these plots indicated significant reductions in above ground growth, as evidenced by browning of leaves and eventual death. By September, a few *Salicornia* plugs were the only surviving transplants in plots in the lower elevations of the embayment.

Transplants at higher elevations (+8.0 to +10.0 ft MLLW) had variable success, with *Salicornia*, *Distichlis*, and *Deschampsia* the most successful. Over the summer, Salicornia had horizontal growth of above ground material. By mid summer, *Distichlis* showed a spread of shoots and *Deschampsia* began to produce new roots and seeds. After significant grazing by waterfowl in April, *Triglochin* also showed new root growth and shoots. *Scirpus* had low overall survival. Many stems were broken by wave action or grazing birds and eventually turned brown. Almost all *Scirpus* transplants appeared to be dead within a few weeks of transplanting. By July, there were new shoots in some plots in higher elevations along the west side of the embayment, but most appeared dead by mid-summer.

QUANTITATIVE TRANSPLANT SAMPLING

Transplant survival was generally low for the entire experiment. Mean transplant survival for the entire embayment was 12.8% (sd = 26.7; n = 432). *Salicornia* had the greatest survival, followed by *Distichlis* and *Deschampsia* (Table 1). *Salicornia* and *Distichlis* showed the highest mean patch diameters. In some cases, *Distichlis* had a substantial spread of shoots from the original unit due to lateral growth. *Salicornia* also had substantial spread due to horizontal growth of above ground material. Because the distance between shoots emerging from the sediment was measured as an indicator of patch diameter, the measure of patch diameter is low compared to the actual ground area covered by *Salicornia*. *Carex* had low survival throughout the system. The greatest mean survival for this species was at plot 4-1 (28.5%). *Triglochin* survived best at plot 3-1 (43.5%) and 4-1 (34.5%), but had very low survival at the other plots. Greatest unit survivals for *Scirpus* were at plots 4-1 (37.7%) and 5-1 (20.5%). This species had very low survival in other plots.

Table 1.
TRANSPLANT UNIT SURVIVAL AND PATCH DIAMETER FOR THE TARGET SPECIES.

Species	N	Mean Unit Surv.(%)	SD	Maximum Surv.(%)	Mean Patch Diam(cm)[1]	SD	Maximum Diam(cm)
Carex	72	1.7	8.3	63	0.2	0.9	5
Deschampsia	72	9.6	23.1	88	0.8	1.8	6.5
Distichlis	72	12	27.3	100	3	6.8	30.9
Salicornia	72	37.8	39.1	100	4	4.1	18.2
Scripus	72	7.1	16.4	88	1	2.2	10
Triglochin	72	8.4	18.9	100	1.4	3	15.1

[1] *The mean patch diameter for surviving patches within each subplot was used in the calculation of patch diameter for the 72 subplots for each species.*

Survival varied with elevation and exposure. Exposure generally increased from the closed (southern) end to the open (northern) end of the embayment. Plants survived better in plots along transects 3, 4, and 5 compared with transects 1 and 2. In addition, elevations above approximately +9.0 ft MLLW had higher planting unit survival and larger patch diameters.

The data indicate that future full transplanting efforts should focus on *Deschampsia*, *Distichlis* and *Salicornia*. *Deschampsia* and *Distichlis* survived only at elevations above +9.0 ft MLLW, and *Deschampsia* showed increased survival even above +11 ft MLLW. The data on patch diameter for *Distichlis*, in particular, verified the suitability of the elevations. *Salicornia* had relatively good survival at elevations between +7.7 and +10.0 ft MLLW. The low survival at some elevations in this range was due to physical disturbances. The greatest mean survival of Salicornia for all elevations was about 80%, and survival was generally below 50% for these three species.

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STATUS AND TRENDS OF INSTREAM HABITAT IN FORESTED LANDS OF WASHINGTON: THE TIMBER-FISH-WILDLIFE AMBIENT MONITORING PROJECT

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INTRODUCTION

In the action plan for the Draft 1991 Puget Sound Water Quality Management Plan, special consideration is given to the importance of monitoring to assess the condition of Puget Sound's environmental conditions and natural resources and the effects of human activities on them. Among the many elements included in this monitoring program is instream habitat for both resident and anadromous salmon and trout.

Throughout the Pacific Northwest, concern is growing about both the short and long-term ecological effects of broad scale timber harvesting and related land-use impacts on rivers and streams. In Washington State one focus of this concern is on industrial scale timber harvesting within river basins which occurs on 42 percent (28,125 sq.miles) of the total land area of the state (Yates and Yates, 1987). Patterns of state, private, tribal and federal land ownership resembling a patchwork quilt complicate the issues of land management history, priorities and practices.

Streams and associated riparian systems encompassed within forested watersheds continue to provide economically and culturally important public and treaty tribal resources, including high quality water supplies, wildlife, and a diverse and valuable fisheries resource. Forest harvesting practices within watersheds containing steep slopes, unstable soils and abundant rainfall can trigger slope failures and other erosive processes that deliver large amounts of sediment to the stream channel, altering the condition of fish habitat (Lisle, 1989; Platts et al., 1989). Successive harvesting of forested riparian corridors over the past century has virtually eliminated the input of large woody debris into the channel proper. This woody debris is important in providing both stability and complexity to the instream habitat (Grette, 1985; Hickes et al., 1989).

Environmental groups, state resource agencies and Indian tribes holding treaty fisheries harvesting rights want assurance that stream fish habitats are not adversely affected by forest land management activities (eg., harvesting, road construction and maintenance, fertilization). Timber land managers

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want to know that the regulations required of them are both necessary and effective in providing the desired level of protection to other resources. Yet reliable information on the status or trend of public natural resources subject to land-use impacts is critically lacking. Land managers and policy makers need such information to manage timber harvesting while protecting these public resources. Specific information is needed about the efficacy of best management practices in protecting public resources, about the response and recovery of these resources to cumulative impacts associated with timber management activities, and about management strategies to reduce these impacts.

To this end, the Timber-Fish-Wildlife (TFW) settlement agreement was initiated in 1986 among Washington's timber industry, state natural resource management agencies, environmental organizations and treaty Indian tribes. Along with the provision for improved forest management practices, the agreement provides for a process of research and monitoring to yield new information on fish, wildlife, and water quality in forested streams and their relationship to timber harvesting across large areas of the landscape.

Monitoring is the most practical way to develop current condition, baseline, and long-term trend information on riparian resources within Washington's forested watersheds.

In the following sections we discuss the features of the TFW Ambient Monitoring Project which has been designed to provide this information for the physical instream and riparian habitat that supports salmon and trout.

MONITORING FOR CURRENT CONDITION AND CHANGE

For this monitoring effort, the instream resources of concern are anadromous and resident salmonid fishes. In order to complete their life cycle successfully, salmon and trout depend on instream habitat provided by forested streams for essential spawning and rearing areas. To a large extent, providing suitable habitat conditions for these species is thought to provide both protection for water quality and riparian protection. The quantity and quality of physical instream habitat supporting anadromous salmon and resident trout are particularly sensitive to disturbance events, especially when their occurrence over time (frequency) and space allow little time for such habitats to recover.

DESIGN AND STATISTICAL CONSIDERATIONS IN MONITORING

Study design and statistical analysis of data on ecological response to large scale impacts is a critical step in both basic understanding of the processes at work and applying that knowledge to forest land management and resource

protection strategies. Monitoring is often required as a condition to permit a wide range of land-use activities, or to document the net response of a resource to the effects of land development or other disturbances. Yet little attention has been paid to the design, acquisition, and analysis of field monitoring data as applied at a highly variable forested landscape scale. Without careful consideration of these aspects, monitoring projects may yield inconclusive or misleading direction and thus fail in their intended purpose to provide the information needed.

DEALING WITH DIVERSITY

Attempting to implement a stream monitoring project across a large land mass is complicated by diverse combinations of climate, geology, vegetation, and land form. For the TFW Ambient Monitoring Project, a system of landscape classification is used to organize streams into meaningful groups to simplify sampling procedures and management options. A classification-based monitoring program can provide essential information for basin analysis of potential hazards when coupled with historical information about land use, disturbance events, (eg., fires, landslides, etc), and other key basin features (eg., slope, geology, precipitation).

At the geographic scale and rate at which timber harvesting is occurring, there is virtually no control over "treatments" applied to watersheds or streams. Regional reference sites (Hughes, 1986) that would allow a basis of comparison to "steady state" conditions are in short supply due to historical and current harvesting patterns statewide. Since an upstream-downstream or before-and-after-impact approach is unlikely, we need to find streams with similar watershed features to those sites subjected to forest harvesting. Because there is so much unquantified variability across the landscape, it is difficult to distinguish between natural, inherent variability, that associated with past natural or man-caused disturbance events (eg. fires, hydrologic storm events, or climatic changes), or the consequences of current forest practices intended to protect public resources.

PROJECT OBJECTIVES

The TFW Ambient Monitoring Project is designed to assess the status and trends over time and space of instream salmon and trout habitat within forested streams. The first component of the project includes identifying a mix of measurable characteristics of the physical habitat (ie. variables), and developing a set of standardized methods to take the measurements. The second component of the project involves stratifying the areas of the state by a system of hierarchical landscape classification based on combinations of features at differing levels of resolution (i.e., at the ecoregion level these

include landform features, geology, existing and potential vegetation and disturbance history; Figure 1). The physical habitat and channel characteristics of streams will be related to the geomorphic setting that shapes the stream and the frequency and magnitude of natural and man-induced disturbance events (eg., fire, hillslope failures, changes in hydrologic regime) that have occurred within the watershed.

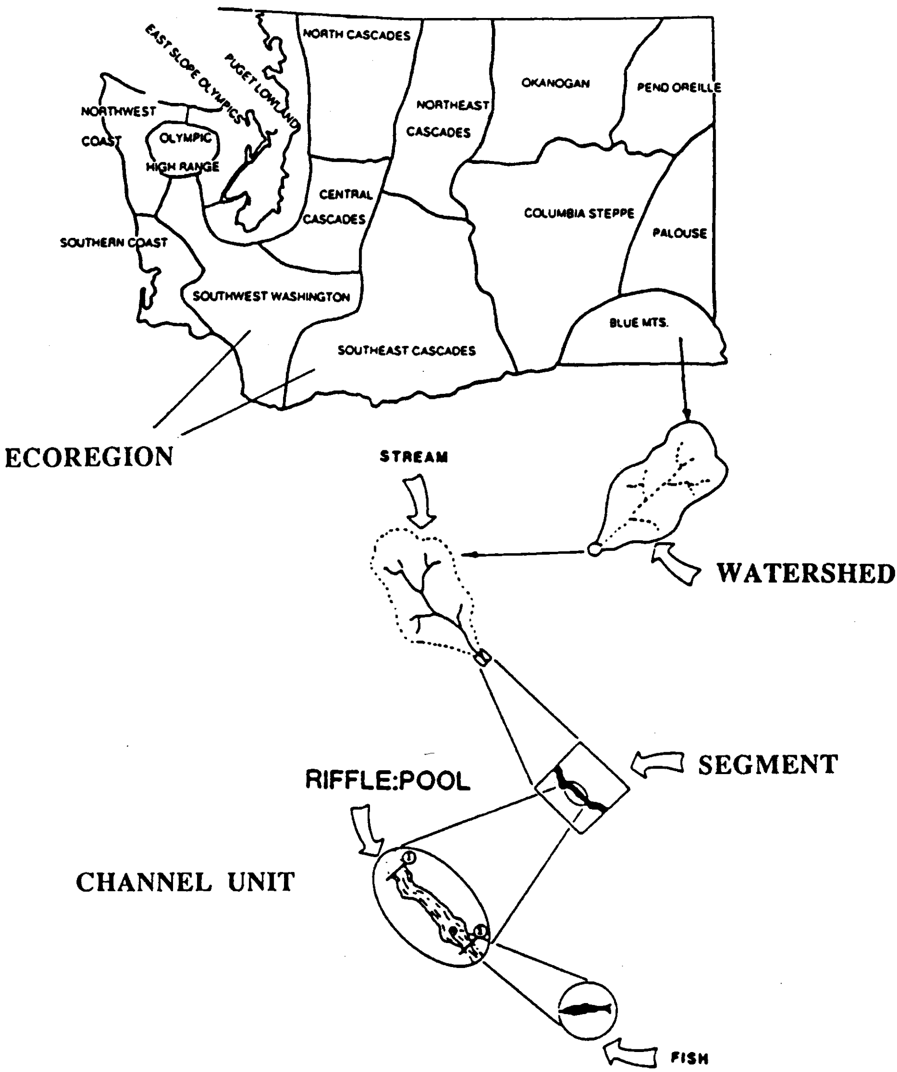

Figure 1.
***HIERARCHICAL ARRANGEMENT OF WASHINGTON STATE** by ecoregion, watershed, stream basin, valley segment, habitat unit, and biota.*

MONITORING IN A LANDSCAPE CONTEXT: STREAM SEGMENT/VALLEY LANDFORM CLASSIFICATION

In the TFW monitoring project to define the initial sampling unit we stratify streams by a segment classification scheme based on five key landform features, termed "valley segments" (Cupp, 1989; Figure 2). Valley segments are distinguished by six diagnostic criteria based on valley and sideslope geomorphic characteristics, including: (1) stream order; (2) valley sideslope gradient; (3) channel gradient; (4) ratio of valley bottom width to active channel width; (5) geology; and (6) channel pattern. Stream channel segments in Washington are placed in one of five broad categories of valley segments (Table 1).

A suite of channel and habitat response variables has been chosen that reflects the changes associated with inputs of sediment and hydrologic discharge. Streams are broken into their component valley segments, and the distribution and physical dimensions of habitat units (Bisson et al, 1981), channel geometry, channel substrate, riparian vegetation and inchannel woody debris are inventoried. Data on the spatial distribution and ratio of habitat units, channel width to depth ratios, and frequency of woody debris are analyzed by valley segment.

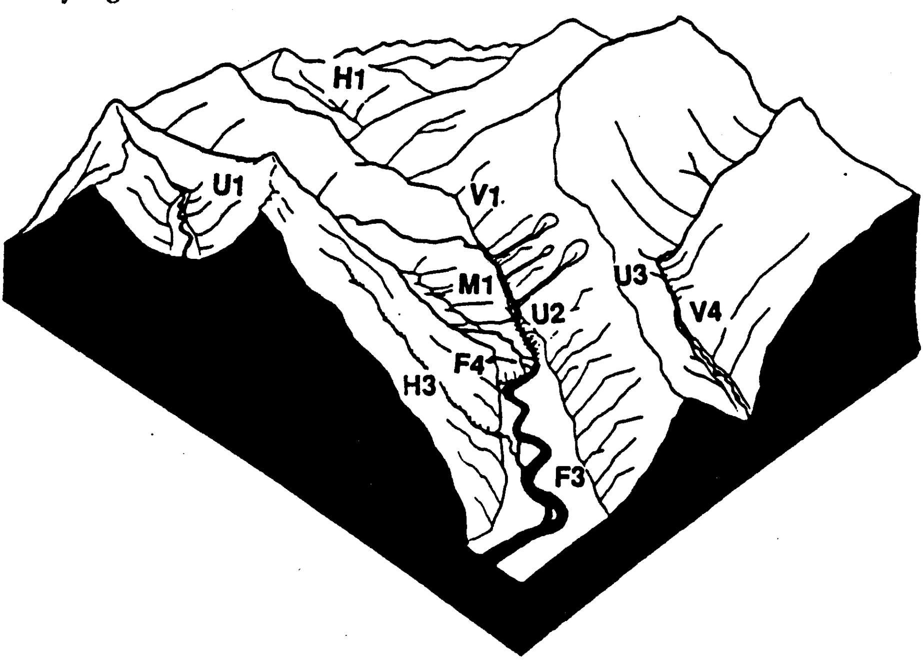

Figure 2.
OBLIQUE VIEW OF A HYPOTHETICAL WATERSHED SHOWING COMPONENT VALLEY SEGMENT TYPES.

Table 1.
VALLEY SEGMENT CATEGORIES

TYPES	*CHARACTERISTICS*
F	nearly flat x-section; 5th order or larger
M	gentle to moderate gradient; large 2nd to 4th order
V	V-shaped profiles; found in lower to middle reaches of tributaries; usually incised in glacial terrace deposits
U	U-shaped in profile; found in mid to upper reaches of tributaries; associated with alpine glaciation
H	V- to weakly U-shaped; 1st to 2nd order; high gradient

After Cupp, 1989

Recent development of stream classification schemes has emphasized geomorphology and a stream's relationship to its watershed across a wide range of scales (Lotspeich and Platts, 1989; Rosgen, 1985; Frissell, et al., 1986; Naiman, et al., 1990). Use of the classification scheme will allow intra- and inter-basin comparisons of instream habitat across a number of diverse ecoregions (Omernik and Gallant, 1986) and valley forms. The classification systems allows comparisons between streams with similar valley segment configuration but with different disturbance histories. With periodic surveys of selected sites distributed throughout the forested ecoregions of the state, we hope to understand better the relative sensitivity of watersheds to disturbance, assess basin-specific cumulative impacts, and enhance our ability to prescribe specific timber management practices to mitigate for potential impacts to public resources. Coupled with a geographic information system and information from related applied research projects, this new knowledge should suggest whether changes are needed to the current forest practices rules and regulations to ensure protection for public resources.

The hierarchical framework is useful because it provides for integration of data from diverse sources and at different levels of spatial resolution, and it allows the scientist or manager to select the level of spatial resolution most appropriate to the objectives. Such a system can give an organized view of spatial and temporal variation among and within stream systems.

It should also provide a tool for comparing in-channel and stream habitat patterns among different basins or regions. Opportunities include a means to subsample from the available forested streams and, due to similarity in habitat character, to extrapolate results of habitat monitoring from one area to another of similar valley segment configuration.

ACKNOWLEDGEMENTS

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PUGET SOUND RESEARCH '91

EVALUATING RISK: ECOLOGICAL AND HUMAN HEALTH

Session Chair:

Marsha L. Landolt, University of Washington

INTRODUCTION

Marsha L. Landolt[1]

If you attended the sessions yesterday and some of the ones today, you know that there is quite a lot of activity underway to take measurements and to get a sense of the state of the Sound. The ultimate goal is to answer questions such as "So what? What does it all mean? How do we interpret these numbers?" One of the ways we interpret the numbers is to use them to get an estimate of risk. That risk might be to the health of animals, it might be to the health of the ecosystem, it might be to the health of human beings.

I was talking just before the session with Dave Jamison about the different elements that go into risk. Dave pointed out that there are basically four steps. One step is risk identification, and that is what we are doing right now — starting the process of gathering numbers. Another step is description of the risk. The step after that is risk analysis. Hopefully, that will lead to the final step, risk management.

In the five papers to be presented in this sessions we will see different approaches to evaluating risk, both from the human health side and the environmental health side.

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INTERPRETING CONFLICTING BIOLOGICAL AND CHEMICAL RESULTS FROM A PUGET SOUND SEDIMENT DATA SET

Ronald L. Shimek, Timothy A. Thompson, Thomas H. Schadt, and Donald E. Weitkamp[1]

INTRODUCTION

In the Puget Sound region the determination of contamination effects has become an important component of environmental investigations. An evolving series of regulatory protocols has been developed (Tetra Tech, 1986, 1987) and incorporated, either in whole, or in part, into management plans and regulations (see, for example, Tilley et al., 1988). In investigations regarding marine benthos, these regulatory protocols are based on a sequential "triad" approach using three types of data to characterize effects in marine benthic sediments (Long and Chapman, 1985).

The sediments are first characterized chemically to determine if significant chemical contamination is present. Secondly, at least two different bioassays are then conducted on the sediments. The third type of examination is the determination of the benthic infaunal assemblage found at the site. Because of the relative costs, the analyses are "tiered" or sequential, with the chemical tests and bioassays completed first. Only if there is reason to doubt or, occasionally, a need to confirm those findings is the benthos actually examined.

At some sites, particularly where extreme conditions exist and comparisons are of sufficient magnitude to be obvious, this approach may work (Becker et al., 1990). However, using this tiered approach with intermediate sites, sites with sediments unsuitable for the bioassay organisms, or sites with unique chemical properties, will likely provide data leading to inappropriate conclusions.

We herein document a site with sediment metals concentrations and bioassay mortalities that exceeded regulatory guidelines. Aside from some relatively small nearshore areas showing contamination effects, this site also has thriving, well-developed, and "healthy" marine benthic assemblages. It contains the most taxon-rich marine communities described from Puget Sound.

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MATERIALS AND METHODS

The site was offshore of the Asarco smelter on Commencement Bay. We sampled 32 stations ranging from 35 to about 350 feet in depth. Five additional reference stations were sampled nearby (Parametrix, 1989a,b, 1990). Each sample was chemically characterized, the bioassays completed, and the benthos determined. Samples were collected during 1988, 1989, and 1990. Comparisons between stations were made, assuming changes between years were less than changes between stations. Most stations were sampled repeatedly for chemistry and some stations were sampled more than once for the bioassays. Except for reference stations, no benthos station was sampled twice (Parametrix, 1989a,b, 1990).

As the initial surveys showed little organic chemical contamination, chemical sediment analyses done by Asarco, Inc. concentrated on five metals: arsenic, copper, lead, mercury, and zinc (Parametrix, 1989a). Standard benthic sampling and analytical techniques were employed (Buchanan, 1984; Tetra Tech, 1987; Parametrix, 1989a, 1989b, 1990).

Three bioassays were conducted using standard protocols (Tetra Tech, 1986, with subsequent modifications; Parametrix, 1989a,b, 1990). The 10 day sediment test using the amphipod, *Rhepoxynius abronius*, and one of two larval bioassays were conducted on each sample. In 1988, larval oysters (*Crassostrea gigas*) were used. Subsequently, we used larval sand dollars (*Dendraster excentricus*), as that organism gave results with significantly less variance.

We correlated bioassay results with the benthic infaunal factors: total number of taxa, total abundance, and wet-weight biomass. Additionally, for the reference areas we correlated bioassay results with the number of taxa and sampled individuals for each bioassay major taxon: amphipods, echinoderms, and bivalves. All mortality data are in excess of control mortality and were transformed by arcsine square-root method. This transformation did not alter any correlations, and decoupled the mean and variance for subsequent analyses (not presented here). Correlations were made using STATGRAPHICS (STSC, 1986-1989). Stations were considered to be the treatments for the statistical analyses. Each replicate was treated as an independent sample from each treatment. If the comparative data sets from any station were unequal in number, the data were randomly paired. If only one datum from a given set was available for a given station, it was compared to the mean of the other factor.

Correlations between stations were done using the entire station array (37 stations), a reduced data set excluding 8 nearshore and 5 reference stations, and a further reduction containing only 5 offshore slag-dominated stations. Nearshore stations were designated as those adjacent to the shoreline; off-

shore stations were defined as all others. Slag stations were defined as those stations with more than 50% of the collected sediment particles greater than 2 mm in diameter. All raw data have been previously published and are not presented here (Parametrix, 1989a, b, 1990).

We performed the following correlations on a sample-by-sample basis. The bioassays were cross compared,and each was compared with: the total number of taxa found in the sample, the total number of animals enumerated from the sample, the total wet-weight biomass, the total metals concentration for the station, and the percent of the sediment with a particle size diameter exceeding 2 mm. Correlations with a probability ≤ 0.05 were considered statistically significant. The number of amphipod taxa and individuals was compared with amphipod bioassay results for the offsite reference stations. Similarly, the total number of bivalve taxa and individuals was compared with oyster bioassay mortality, and the number of echinoderm taxa and individuals was compared with echinoderm bioassay results.

RESULTS

The correlation data are summarized in Table 1 (Parametrix, 1989a, b, 1990).

Table 1.
RANGES OF PHYSICAL, CHEMICAL, AND BIOLOGICAL CHARACTERISTICS OF THE STATIONS SAMPLED NEAR THE ASARCO SMELTER.

	Offshore	Nearshore	Reference
Number of Stations:	24	8	5
A. Physical Characteristics			
Coarse sediments	0.1 to 48.7%	0.5 to 39.3%	0.1 to 61.9%
Total volatile solids	1.0 to 4.0%	1.5 to 17.7%	1.1 to 2.3%
B. Chemical Characteristics			
Total Metals (ppm)	176 ± 33,323	145 to 38,546	51 to 760
C. Biological Characteristics			
Number of Taxa	90 to 245	76 to 194	126 to 220
Number of Animals	912 to 9,860	1,216 to 12,682	1,168 to 9,982
Total Biomass(g/rep)	2.2 to 25.7	1.4 to 25.1	1.3 to 20.7
D. Bioassay % Mortalities			
Amphipod	0.0 to 44.0	5.9 to 76.4	0.0 to 33.3
Oyster	44.9 to 73.2	62.99 to 74.87	50.46
Echinoderm	4.8 to 52.6	25.3 to 87.3	18.7 to 44.0

Only 12 statistically significant correlations from independent variables were found (Table 2).

The total metals concentration was significantly correlated with any other factor only twice. The amphipod bioassay mortality increased with increasing metals concentration at all stations, and at the reference stations the number of echinoderm taxa decreased with increasing total metals concentration. No other biological factor correlated significantly with the total metals concentration.

Bioassay mortality significantly correlated to some factor in only 9 cases. Amphipod bioassay mortality was not correlated with either larval bioassay mortality. However, the two larval bioassay tests were significantly positively correlated (Table 2). Total metals concentrations did not correlate with any biological factor except the number of echinoderm taxa at the reference stations.

Out of 17 tests, amphipod bioassay mortality significantly positively correlated with benthic biological environmental factors 4 times and physical factors once (a response rate of 29.4%). Echinoderm larval bioassay mortality correlated with benthic biological factors 3 times, and did not correlate significantly with physical factors (a response rate of 17.6%). The oyster larval bioassay mortality negatively correlated with benthic biological factors once and did not correlate with the physical factors (a response rate of 5.9 %)(Table 2). Physical environmental factors correlated with taxon-specific abundances 3 of 32 times for a response rate of 9.9%. One correlation was negative.

Table 2.
STATISTICALLY SIGNIFICANT CORRELATIONS WITH INDEPENDENT VARIABLES.

Variables: First	Second	Correlation Coefficient	Probability	Number
A. Correlations using data from all the stations:				
Amphipod Mortality	Metals Concentration	0.793	<0.001	N=37
	# Animals/Rep.	0.235	<0.001	N=149
Echinoderm Mortality	Oyster Mortality	0.439	0.007	N=37
B. Correlations using data from the reference stations only:				
Echinoderms(#/m²)	Percent Coarse Sediments	0.250	0.001	N=23
Total Metals Conc.	Echinoderm Taxa (#/rep.)	-0.437	0.037	N=23
% Coarse Sediment	Echinoderm Taxa (#/rep.)	0.431	0.040	N=23
C. Correlations using data from all offshore stations excluding reference stations:				
Amphipod Mortality	# Animals/Rep.	0.237	0.020	N=97
Echinoderm Mortality	Wet-weight Biomass	0.257	0.005	N=85
	# Taxa/Rep.	0.312	0.004	N=85
	# Animals/Rep.	0.295	0.006	N=85
D. Correlations using data from all offshore slag stations only:				
Amphipod Mortality	# Animals/Rep.	0.627	0.005	N=18
Oyster Mortality	Wet-weight Biomass	-0.924	0.025	N=5

DISCUSSION

The total metals concentrations did not predict, nor were they correlated with biological responses; no correlations occurred between metals concentrations and any of the normally measured biological factors. For example. there was no significant depression of organism or taxon numbers at any of the offshore stations, while the total metals concentrations at some stations was striking—many individual samples contained over 10,000 ppm of the metals. Most offshore stations with high metals concentrations contained in excess of 175 taxa, and in excess of 5,000 animals/m^2 (Parametrix 1989a, b). Except for nearshore stations, no station showed any depression in biological factors clearly attributable to contamination.

Total metals concentration was a good predictor of amphipod bioassay mortality. However, metals concentration was not correlated with the number of taxa, the number of individuals, or the wet-weight biomass. The data herein covered a wide range of biological parameters; for example, the number of taxa per station varied from 90 to 245, and the abundance varied from about 900 to about 10,000 animals/m^2. Given the range of data and the number of stations, the lack of good correlations is striking.

The bioassay mortality data also do not correlate well with any benthic biological factors. Additionally, except for the oyster mortality test which was negatively correlated with wet-weight biomass, all the bioassay mortality correlations were positive. Using the data from all the stations, *Rhepoxynius abronius* mortality was highly significantly positively correlated with total metals concentration, and the number of animals/replicate. It was not correlated with any other factor examined. Excluding the nearshore and reference stations, amphipod bioassay mortality was significantly correlated only with number of animals/replicate and this correlation was positive. Thus, at the Asarco site, as mortality increases so does the number of animals collected.

This pattern, or rather this lack of a pattern, was repeated with *Dendraster excentricus* larval mortality. In only 3 cases did the echinoderm larval bioassay mortality correlate with benthic indicators. All these correlations occurred at the offshore stations and all were positive. Increases in echinoderm larval death were highly significantly correlated with increases in wet-weight biomass, the number of taxa/sample, and the number of individuals/sample. Larval oyster tests were the only bioassays to be significantly negatively correlated with the benthic biological factors. Test mortalities were negatively correlated with wet-weight biomass using all the data and only the offshore stations. No other correlation was found.

Chemical concentrations and bioassays are commonly used as benthic "health" predictors. If they are valid predictors, they should be generally and signifi-

cantly negatively correlated with the factors that measure increased taxonomic diversity, abundance, and biomass. These latter measures are relatively crude measures of benthic assemblage "health", yet they are generally and broadly accurate. In the offshore environments near the Asarco smelter, the chemical concentrations and bioassay mortalities were either inversely predictive of the properties of the benthic assemblage, or totally non-predictive.

CONCLUSIONS

The lack of general correlations between the sediment chemical and biological parameters, and the bioassay mortalities indicates that the tiered triad approach to determine contamination effects was not appropriate to this site. There was no indication that sediment chemical concentrations were negatively related to any biological factor in the offshore stations. Similarly, no bioassay was sufficiently correlated with any negative trend to be useful as a regulatory or determinative tool.

Except for at nearshore stations at this site, the metals are apparently insoluble and unavailable to the organisms (Crecelius, 1986; Parametrix, 1989a,b 1990). Organism distributions are related to the physical distribution of the slag which provides additional habitat for epibenthic and burrowing organisms. The slag physical properties reduce amphipod bioassay survival (Shimek et al., in prep.).

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A RISK ASSESSMENT APPROACH TO CLASSIFYING CONTAMINATED SEDIMENTS IN ELLIOTT BAY

Michael Riley[1], *Robert Matsuda*[2], *Sidney Munger*[2], *Pat Romberg*[2], *Vicki Ridge-Cooney*[2], *Rick Cardwell*[3] *and Daniel Hinckley*[3]

ABSTRACT

Contaminated sediments have been identified throughout Elliott Bay. However, comparisons of sediments to existing state standards by other investigators have not indicated the areal distribution of contaminated sediments with respect to their toxicity. The objective here was to develop a toxicity index for the sediments based on parameters used in environmental and human health risk assessments. The analysis utilized sediment-water partitioning coefficients, bioaccumulation factors, dose factor, and environmental half life to compute a toxicity index for each sediment sample. The sample locations and the toxicity index were used to map the areal distribution of contaminated sediments by contours of relative toxicity throughout Elliott Bay.

The toxicity index contours were then used to classify potential remediation sites in Elliott Bay. A map of property and DNR lease holdings was superimposed on the toxicity index contour map and then each property/DNR lease unit was rank ordered according to the maximum toxicity index value found in the unit. The relative toxicity level was used as part of the evaluation criteria by Metro to determine the preferred sites for remediation in the immediate future. The approach provides a quantitative method based on risk assessment both for evaluating the relative environmental and human health toxicity levels at different sites and for determining the preferred sites for remediation.

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RAPID METHODS FOR QUANTITATIVELY ASSESSING ECOLOGICAL AND HUMAN HEALTH RISKS IN CONTAMINATED SEDIMENTS

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ABSTRACT

The intent of this project was to quantitatively determine the risks posed to aquatic life and human health by contaminants in Elliott Bay sediments, and to relate those risks to cleanup cost options in a risk management context.

More than 250 Elliott Bay sites were ranked for their hazard potential using a spreadsheet-like model that considered the individual and cumulative toxicity of the contaminants, their biomagnification potential, their environmental persistence, and their estimated concentrations in both sediment interstitial water and seafood. Separate rankings were developed for aquatic life and human health. Site selection was based on toxicological, engineering and other criteria.

The actual risks posed by the contaminants at the selected sites were evaluated using more sophisticated risk assessment procedures. Expected environmental concentrations (EECs) in all media of interest were estimated using Mackay's environmental fate (fugacity) model. For the aquatic ecological risk assessment, the EECs were related to concentrations known or estimated to be acutely and chronically toxic to a variety of species comprising the communities at risk. Uncertainties were incorporated into the probabilistic risk estimates.

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PROBABILISTIC-BASED METHODS FOR AQUATIC ECOLOGICAL RISK ASSESSMENTS

Rick D. Cardwell[1]

INTRODUCTION

The purpose of this paper is to review approaches for assessing the ecological risk to aquatic life from exposure to toxic chemicals (aquatic ecological risk assessments, or AERAs). The principles discussed are generally applicable to evaluations of sediment, wastewaters, and surface waters. Special attention is given to quantitative methods because they are indispensable to uncertainty analyses and probabilistic-based risk assessments.

Risk assessment, as a quantitative methodology, is becoming popular because of its role in risk management. Risk management is the process of managing risk by controlling exposure, and in water pollution control, exposure is usually controlled with a financial investment to treat or otherwise remediate a pollution source. Figure 1 shows how the continuum of risk estimates generated through an assessment can be equated to cleanup costs as part of risk management.

In this paper risk is the probability of adverse effect. Risk comprises assessments of hazard (which defines toxicological potential) and exposure (which defines what concentrations will be encountered *in situ*). Put simply, there is only risk when there is exposure. In the case of aquatic organisms, for toxicity to become manifest a chemical must enter an organism at a rate faster than the chemical can be detoxified, excreted, or both.

This paper reviews state-of-the-art risk assessment at the species, population, and community levels. Particular emphasis is placed on exposure and hazard assessment methods that use existing data and extrapolation techniques, such as quantitative structure-activity relationships (QSARs). QSARS relate a chemical's physical properties to its capacity to elicit toxicity or facilitate either bioaccumulation or biodegradation. Nirmalakhandan and Speece (1988) and Walton and Mill (1988) review QSARs and their theoretical basis.

This review is divided into three major sections. In the first section, the history of risk assessment, as it pertains to aquatic organisms, is briefly reviewed. The second section addresses three AERA components: the exposure assessment, hazard assessment, and special considerations/supporting techniques. The latter addresses uncertainty analysis, AERAs of complex mixtures that

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typically occur in sediments and wastewaters, calculation of exposure and risk when expected environmental concentrations of the chemicals fluctuate either over time or in response to spills, and methods for estimating bioconcentration, bioaccumulation, and biomagnification in aquatic plants and animals.

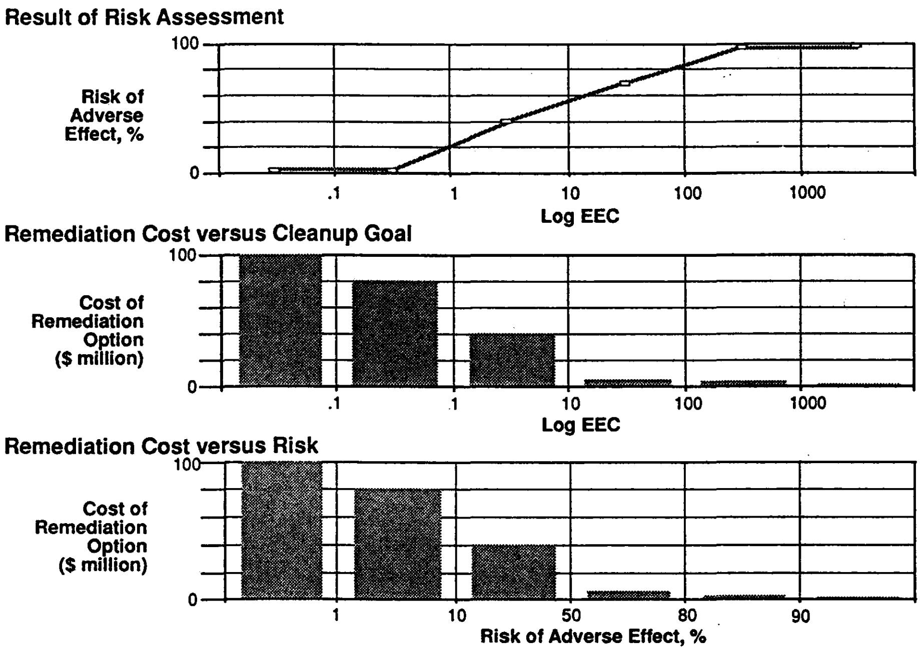

Figure 1.
LINKAGE OF CLEANUP COSTS TO RISK ASSESSMENT IN A RISK MANAGEMENT PARADIGM. *The top curve (1a) relates risk to chemical concentration. The middle curve (1b) relates cleanup cost to chemical concentration, and the bottom curve (1c) relates risk to cleanup cost.*

HISTORICAL NOTES

In the field of aquatic toxicology, risk assessment is rooted in hazard assessment, which was developed in the 1970s by a group of aquatic toxicologists working under the umbrella of the American Society for Testing and Materials (ASTM). In 1984 ASTM adopted a formal methodology for conducting hazard assessments (ASTM, 1985), completing a process started more than a half decade earlier (e.g., Cairns et al., 1978). These efforts focused on assessing risk to single species, although John Cairns and his colleagues have strongly advocated evaluating risk to communities of species using empirical methods such as toxicity tests (Cairns, 1986).

There is no striking difference between the hazard assessments of the 1970s and current risk assessments. Risk assessment simply expresses hazard potential in strictly quantitative, probabilistic-based terms; for example, there is a 20 percent chance of reducing growth by 50 percent at 5 μg/L of chemical.

Risk assessment as a methodology received a major boost in the early 1980s in conjunction with the cleanup of hazardous wastes in the United States. Methods were needed to determine the degree of risk posed to the environment from chemicals *in situ* so that risk could be compared to cleanup costs and used to assign cleanup priorities. The U.S. Environmental Protection Agency (EPA) published a series of methods, and those most relevant to aquatic ecological risk assessments included the exposure (EPA, 1984, 1988), human health (EPA, 1985), and endangerment assessments (EPA, 1985). Endangerment assessments are simply exposure, human health, and ecological risk assessments rolled into one.

In 1980, as part of its process of deriving water quality criteria for the protection of aquatic life, the EPA embraced many principles of probabilistic-based risk assessment. It did so by identifying toxicant concentrations regarded as "safe" to different percentages of the species tested. Implicit in the method was the assumption that the assemblage of laboratory test species represented a balanced, indigenous community of aquatic organisms. Principles and references are given by Stephan et al. (1985). A branch of the EPA, the Office of Pesticide Programs, has also published an ecological risk assessment methodology. That document describes EPA's process for estimating toxicity and comparing it to estimated environmental concentrations (Urban and Cook, 1986). Though quantitative, EPA's methodology is not yet probabilistic-based.

Parallel AERA approaches were developed by others in the 1980s. Drs. Larry Barnthouse and Glenn Suter of the Oak Ridge National Laboratory instilled a distinctly probabilistic basis to aquatic ecological risk assessment. They did so by addressing the problem of extending risk assessment from whole organism and species-level toxicity test data to feral populations of aquatic life (Barnthouse et al., 1986a, 1986b, 1987).

Research in the 1980s has greatly expanded the use of QSARs for estimating various biological properties, including acute and chronic toxicity, bioaccumulation, and biodegradation. The use of QSARs and other extrapolation techniques has gained great favor because they provide a means for predicting the behavior of chemicals for which the only data available pertain to homologues. Studies employing these techniques are discussed below.

RISK ASSESSMENT METHODOLOGIES

Risk assessment has three fundamental components: exposure assessment, hazard assessment, and risk characterization. The exposure assessment defines the pathways by which a chemical is distributed in the ecosystem and the concentrations expected to occur over time in the matrices (e.g., sediment, water) of interest (Figure 2). These concentrations are normally called *expected environmental concentrations* (EECs) or *predicted environmental concentrations*. The hazard or toxicity assessment defines the types of deleterious biologic responses expected, given exposure to the range of toxicant concentrations (Figure 2). The biota (receptors) considered in the toxicity assessment are those identified as at potential risk as a result of the pathway analysis conducted under the exposure assessment. The risk characterization is a juxtaposition of the EECs and concentrations known to be toxic. (Figure 2).

EXPOSURE ASSESSMENTS

Defining the concentrations to which aquatic life are exposed is usually the most difficult aspect of an AERA. Its objective is to define where (e.g., sediment, water) aquatic life will be exposed to the chemical, what range of concentrations will be encountered, and when these concentrations will be encountered (e.g., persistence).

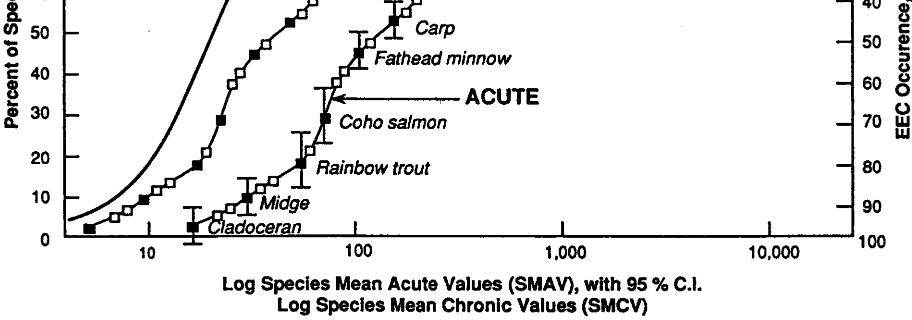

Figure 2.
***RISK CHARACTERIZATION INVOLVES COMPARISON OF THE RESULTS OF THE EXPOSURE ASSESSMENT** (shown here by the EECs) with concentrations eliciting acute or chronic toxicity.*

Predicting exposure is usually the most difficult and uncertain aspect of risk assessment because chemicals are typically subjected to a variety of transformation and dispersal processes after they enter surface waters. Collectively, the transport and fate processes not only change the concentrations of the chemical, but also dictate how much of the chemical will be mineralized, transformed, and deposited in the sediments and tissues of aquatic life. A number of publications summarize the processes for a variety of chemicals (e.g., Callahan et al., 1980; Smith et al., 1988).

Estimating EECs in water, sediment, biota and air requires either field measurements or models. Although field measurement is preferable, models are generally used instead because of the need to forecast either future conditions or EECs resulting from various remediation alternatives (Figure 1b). The models may be simple or complex, and model selection should depend on the level of risk anticipated, the value of the resources at risk, and the financial resources available. Models of various sophistication are available (e.g., Ambrose et al., 1988; Mackay and Peterson, 1982; Reinert, 1987; Reuber et al., 1987; Southwood et al., 1989).

In the past several years special attention has been directed at estimating concentrations of chemicals in the tissues of both aquatic plants and animals. These are covered below in the final section which concerns supporting techniques and applications.

TOXICITY ASSESSMENTS

Species—Toxicity assessments generally evaluate risk to single species or generic communities of aquatic life using laboratory toxicity tests of single species. Evaluations of feral populations are rarely attempted, due to the cost of data acquisition. The data requirements and methods for generating required data are reviewed below.

For decades, aquatic toxicologists have focused on the evaluation of risk to single species from exposure to various concentrations of a single chemical. The main research tool has been the toxicity test, used to define the relationship between concentration and response (Figure 3). This relationship directly translates into risk to the species population under consideration, provided the chemical concentrations to which the species is being exposed *in situ* are accurately defined and compensatory processes in natural populations are disregarded. The toxicity test allows risk to be measured directly, at least under the circumstances of the test. These tests can be conducted in a laboratory, or more realistically onsite, to define the interaction between water quality and toxicity and to account for any acclimation of the local species to the toxicant (Carlson et al., 1984). Most assessments assume implicitly that toxicity, predicted from laboratory tests, will manifest *in situ*

with the same exposure. Several lab-field studies support this assumption (Geckler et al., 1976; Lee and Jones, 1983; Broderius and Matthiessen, 1990).

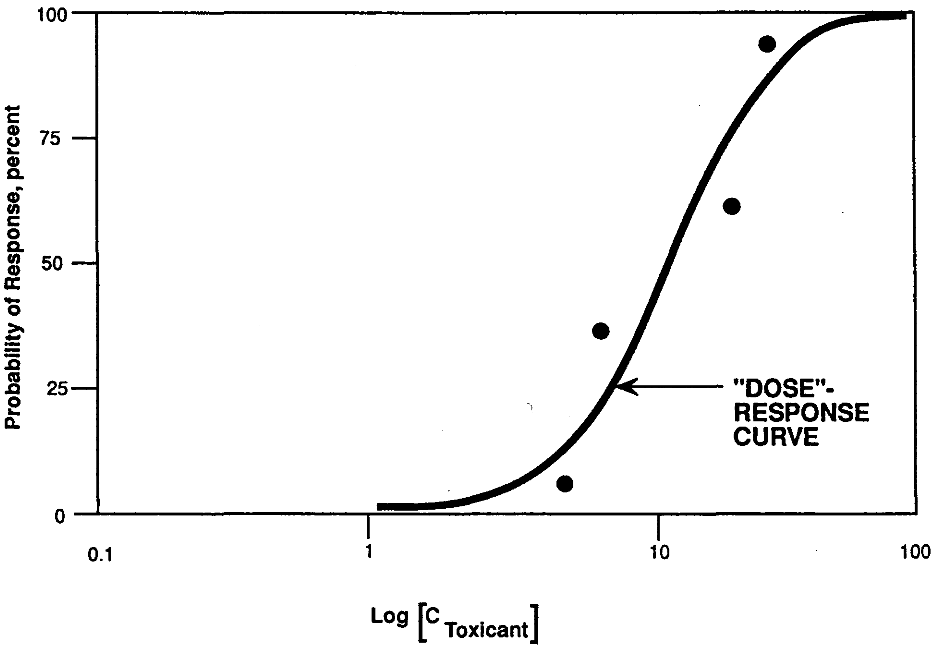

Figure 3.
***USE OF BIOASSAY "DOSE-RESPONSE" DATA** to estimate effects of different chemical concentrations of the species population of interest.*

Direct testing—whether it be single-species toxicity tests, microcosms, mesocosms, or field studies—is the best means of assessing risk in a particular ecosystem. Nevertheless, infrequently are the circumstance, time, or financial resources available to obtain the empirical data essential to predicting risk or comparing remediation options.

Owing to insufficient empirical data, it is usually necessary to employ a combination of existing data, QSARs, and extrapolation techniques to accomplish the assessments. Toxicity can be estimated for some chemicals on the basis of the following:

1. Median lethal doses to mammals or fish (Hodson et al., 1988; Wallace and Niemi, 1988)
2. Extrapolation between phylogenetic groups (e.g., fish to fish, fish to invertebrates) of aquatic organisms (Doherty, 1983; Ewell et al., 1986; Suter et al., 1983; Suter and Rosen, 1986; Volmer et al., 1988)

3. Extrapolation from acute to chronic toxicity (Call et al., 1985; Carlson et al., 1984; Mayer, 1990; Stephan et al., 1985)
4. Octanol-water partition coefficients (Kows) and/or molecular weight (Clements et al., 1988; McCarty, 1986; Sloof et al., 1986; Veith et al., 1983).

Several of these properties—e.g., water solubility, Kow, and bioconcentration—are highly correlated. Equations have been constructed linking water solubility and Kow to such properties as toxicity and bioconcentration (e.g., Clements et al., 1988; Kenaga and Goring, 1980). The QSARs work best for moderately hydrophobic chemicals, including such polar organics as substituted phenols and surfactants. Because the current QSARs are less reliable for predicting toxicity of metals, highly polar compounds, and probably organometallics, it is important to determine if the QSAR can reasonably be applied to the compound being considered. In general, it is advisable to use QSARs to predict toxicity or bioconcentration of chemicals with similar structures or modes of action.

Communities of Species—The estimation of the acute and chronic effects of a chemical on a community of aquatic species can be accomplished with actual testing or interspecies extrapolations. Although unheralded, the EPA's water quality criteria defined a method for assessing risk of acute and chronic toxicity to communities of aquatic life using either generic (Stephan et al., 1985) or site-specific laboratory toxicity data (Carlson et al., 1984). In EPA's water quality criteria approach, it is assumed that the existing acute toxicity data adequately represent the sensitivity of aquatic life in general. There are minimum data requirements ensuring a measure of statistical and ecological representativeness in the database. The data (e.g., 96-hour median lethal concentrations or LC50s) are plotted as probability distributions to represent the distribution in sensitivities of all species, as shown in Figure 2. The acute data are divided by the mean acute-chronic ratio for the chemical to generate a distribution of estimated chronic toxicities (Figure 2) (Stephan et al., 1985). The plotted data can be used to estimate the percentage of species expected to be affected with exposure to one or a series of concentrations.

Feral Species and Populations—Little work has been devoted to developing models that consider how chemicals influence the natural rates of mortality, growth, and reproduction of aquatic life *in situ* (Daniels and Allan, 1981). The Electric Power Research Institute sponsored a workshop on this subject in which many participants concluded that such impacts could not be reliably predicted (Anderson, 1986). Suitable computer models remain to be developed; Lassiter (1986), Anderson (1986), and Barnthouse et al. (1986a, 1986b) reveal the problems facing design of suitable models.

Barnthouse et al. (1986a) set forth a methodology for modelling effects on feral species and populations. They acknowledge, however, that uncertainties

are enormous because precise, reliable estimates for many parameters are simply unavailable. For this reason they recommend assessing relative risk—e.g., comparing risks of different chemicals or as influenced by differential environmental circumstances—rather than relying on actual risk levels. The difficulty with estimating contaminant effects on populations of, for example, striped bass, is the requirement for information on how the population is functioning naturally, specifically natural mortality rates, and the extent to which mortality rates change in response to the extent of mortality (i.e., compensatory mortality). Although this information may be available for a few species managed intensively by fish and wildlife agencies, it often will have to be synthesized from data on size of standing stock, age structure, or fecundity. For less managed species or for a given body of water, these data will either have to be collected or replaced with assumptions. Both data collection and synthesis are expensive. Clearly not at hand is a feasible technology for estimating toxicant effects on rates of growth, mortality, and reproductive success of natural populations.

At least one extrapolation method, however, is available for predicting chemical effects on natural populations based on laboratory toxicity test data. Sloof et al. (1986) regressed acute toxicity data for chemicals to their no effect concentrations in multi-species test systems, and observed a correlation of 0.77. This regression was less variable than one relating the sensitivity of one type of organism taxon to another in acute toxicity tests. This led the investigators to suggest that predicting chronic effects generally may be more reliable than attempting to predict acute toxicity from one taxon to an unrelated one.

SUPPORTING TECHNIQUES AND APPLICATIONS

Uncertainty Analysis

Uncertainty analysis is simply a statistical technique for adding the probability distributions of two independent parameters that have compatible distributions (e.g., lognormal) and additive variances. While the basic components of uncertainty analysis are given in standard statistical texts, major reviews of the subject appear in Morgan (1984) and Rish (1988). Computer software is becoming available as well to ease the computation (e.g., Palisade Corporation, 1989).

As a methodology, uncertainty analysis is useful for defining, in terms of probabilities, variabilities in chemical concentrations and contaminant effects, regardless of whether the uncertainty is measured or estimated. Although the magnitude of these uncertainties may index reliability, the reliability or accuracy of these predictions can only be defined through field validation studies. Because aquatic ecological risk assessments traditionally

possess significant uncertainty (e.g., Barnthouse et al., 1986a; Sloof et al., 1986; Volmer et al., 1988), it is important that they be quantified so that decision-makers can weigh the aggregate uncertainty comprising each of their choices. Uncertainty analysis is used to account for variability (i.e., probability distributions) of parameters used in a series of calculations, such that the estimate of risk reflects the data's aggregate uncertainty.

Cumulative Toxicity from Toxicant Mixtures

Risk assessment is typically performed on single chemicals, but techniques are available allowing the assessment of the chemical mixtures that typify sediments and wastewaters (e.g., Alabaster and Lloyd, 1980; Konemann, 1980, 1981; Voyer and Heltshe, 1984). These techniques allow the cumulative effects of chemicals to be examined. The methodologies are based on the observation that the effects of most chemicals appear to be additive. Synergism, antagonism, and less-than-additive interactions between chemicals occur less frequently, but do occur (e.g., Spehar and Fiandt, 1986). Voyer and Heltshe (1984) provide a quadratic equation that will address interactions that are not strictly additive, but the nature of the interaction must be known.

Toxicant interactions need to be distinguished from chemical interactions, e.g., the typically antagonistic effect of water or sediment quality on the toxicity of many chemicals. Antagonistic effects, arising from complexation or binding of the chemical with ligands or particulates, partially define a toxicant's bioavailability. In the case of hardness, antagonism manifests through competition between the toxicant and calcium and magnesium ions.

Continuous vs. Time-Variable Exposure

Most models of toxicant exposure assume that exposure is continuous. In nature, however, exposure is known to vary greatly over time due to a variety of transport and fate process (e.g., dilution, degradation rates). Mancini (1983) and Breck (1988) present detailed methodologies for evaluating the effect on toxicity of spills or time-varying chemical concentrations.

Bioaccumulation and Biomagnification

Estimating chemical residues in fish and macroinvertebrates is a fairly straightforward process for chemicals assimilated directly from the water (bioconcentration). However, it is more difficult to estimate the uptake of chemicals from sediment, food (dietary accumulation), and transfer through several trophic levels (i.e., biomagnification).

Bioconcentration in aquatic animals can be determined through lab studies, readily estimated for untested species using published bioconcentration factors, or it can be determined from a variety of QSARS (e.g., Kenaga and Goring,

1980) and models. The QSARs are based generally on the strong relationship between Kow and bioconcentration for many organic chemicals, particularly those with Kows above 1000. The QSARs are most reliable when one specific to a group of structurally related chemicals is used to predict the bioconcentration of an untested compound (Schuurmann and Klein, 1988).

Recently, a number of increasingly sophisticated models have been developed to predict bioconcentration, bioaccumulation, and biomagnification. Gobas and Mackay (1987) and Gobas et al. (1989) developed bioconcentration models specific to compounds metabolized very slowly by the organism and possessing very high Kows (e.g., greater than 1,000,000). Estimating bioaccumulation—tissue residues arising from both bioconcentration and dietary accumulation—has been limited by little data and understanding of the processes. The initial model development was undertaken by Thomann (1981, 1989) and continued by Clark et al. (1990). These models allow biomagnification to be assessed because they incorporate both bioconcentration and dietary accumulation for user-defined trophic levels.

Crude sediment-tissue bioaccumulation models have been proposed (Connor, 1983; Breck, 1985). However, they may be inaccurate because the models neglect exposure pathways and the uptake from the interstitial water versus uptake from feeding on sediment organic carbon sources.

For determining the uptake of chemicals by plants, algae, and other microorganisms, researchers need to use models that differ from those used to test fish and macroinvertebrate uptake. In algae and other microorganisms, uptake is a function of at least two processes: bioconcentration and sorption to the cellular surface. It may be more appropriate to use sediment-water partition coefficients (Kocs) than BCFs to estimate chemical residues in microorganisms, because sorption appears to be more important than assimilation. Trapp et al. (1990) have recently set forth a fugacity model for differentiating foliar from root bioconcentration of organic chemicals based on the chemical's Kow, Koc, and Henry's law constant (an index of a chemical's air-water partitioning tendency). Wolf et al. (1989) presented predictive models to study the dynamics of bioconcentration in aquatic plants.

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LIMITATIONS ON USE OF FISH LIVER NEOPLASMS AS INDICATORS OF HUMAN HEALTH RISK

Robert A. Pastorok and Rosalind A. Schoof[1]

INTRODUCTION

Over the past decade, several studies of bottom-dwelling fish in Puget Sound have established that the prevalence of liver neoplasms (i.e., tumors) in English sole is positively correlated with concentrations of certain contaminants in sediments (Malins et al., 1984, 1987, 1988; Schiewe et al., 1988). This correlation is strongest for polycyclic aromatic hydrocarbons (PAHs), which are aromatic hydrocarbons with two or more benzene rings. Laboratory studies have also suggested that PAHs may induce neoplasms in fish and mammals (Schiewe et al., 1988). Liver neoplasms in English sole (*Parophrys vetulus*) and other liver lesions in a variety of fish may serve as indicators of contaminated sediments that pose some health risk to humans. It is not clear, however, how to accurately assess the risk of contaminated sediments to humans. This paper discusses issues and limitations on the use of data on fish liver neoplasms as indicators of human health risk from contaminated sediments. First, the association of liver neoplasms with high contaminant concentrations in Puget Sound sediments is illustrated. Second, fish and humans are compared relative to exposure pathways and routes, neoplasia development, and modifying factors. Available evidence is briefly reviewed to show that PAHs may induce neoplasms in fish by the same mechanism that causes neoplasm induction in mammals. Third, the implications of differential fish and human exposure pathways for the assessment of human health risks associated with contaminated sediments are discussed.

FISH LIVER NEOPLASMS AND CONTAMINATED SEDIMENTS

The possible association of liver neoplasms in bottom-feeding fishes with chemical contamination of sediments was reported as early as 1964 (Dawe et al., 1964). Subsequent studies have confirmed and expanded these observations. Couch and Harshbarger (1985), Mix (1986) and Becker and Grieb (1987) reviewed field studies conducted throughout the United States that suggest an association of liver neoplasms in certain fish species with sediments contaminated by potentially carcinogenic chemicals.

In Puget Sound, attention has focused on the association between organic contaminants in sediments and the prevalence of liver neoplasms in bottom-feeding fish. Malins et al., (1984, 1987, 1988), Mix (1986), and Becker and Grieb

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(1987) reviewed previous studies of liver disease in fishes of Puget Sound. Liver lesions, including neoplasms, have been documented in four species of bottomfish from polluted areas of Puget Sound: English sole (*Parophrys vetulus*), starry flounder (*Platichthys stellatus*), rock sole (*Lepidopsetta bilineata*), and Pacific staghorn sculpin (*Leptocottus armatus*). In general, the highest prevalences of most liver abnormalities were found in major urbanized areas for all four fishes. Lowest prevalences generally were found in nonurban areas. The prevalence of liver neoplasms in English sole from urban embayments was 5-24 percent, whereas no neoplastic lesions were typically reported in nonurban areas (Malins et al., 1987). Studies within several urban embayments (i.e., Commencement Bay, Elliott Bay, and Port Gardner) demonstrate that the spatial distribution of neoplasm prevalence correlates with contaminant distributions (e.g., Figure 1).

Chemicals detected at high concentrations in most urban Puget Sound sediments included aromatic hydrocarbons, nitrogen-containing aromatic compounds, polychlorinated biphenyls (PCBs), chlorinated butadienes, and heavy metals (Malins et al., 1984, 1987, 1988). Among these chemicals, the aromatic hydrocarbons had the strongest positive correlation with the prevalence of liver neoplasms in English sole. A weaker positive correlation was noted for selected metals, and no significant negative correlations were found.

In spite of the strong correlation between aromatic hydrocarbons and liver neoplasms, the concentrations of these compounds in muscle and liver tissue of English sole were generally below detection limits (Malins et al., 1987). Low tissue concentrations of these compounds suggest that they are being metabolized by the fish, a conclusion supported by the finding that more metabolically resistant chemicals such as PCBs and chlorinated butadienes were present in fish muscle and liver tissue at concentrations higher than those found in sediments (Malins et al., 1987). A significant positive correlation was also found between liver neoplasms in English sole and the concentrations of metabolites of aromatic hydrocarbons in the bile of these fish (Malins et al., 1987).

COMPARATIVE ASPECTS OF FISH AND HUMAN NEOPLASIA

The evaluation of the relationship of fish liver neoplasms to human cancer risk is based primarily on comparison of each of the following factors between fish and humans (or other mammals):

- Exposure pathways
- Mechanisms of neoplasia induction and development
- Modifying factors that affect quantitative extrapolation (e.g., differential sensitivity due to differences in metabolism, diet, lifespan, and environmental agents other than chemicals).

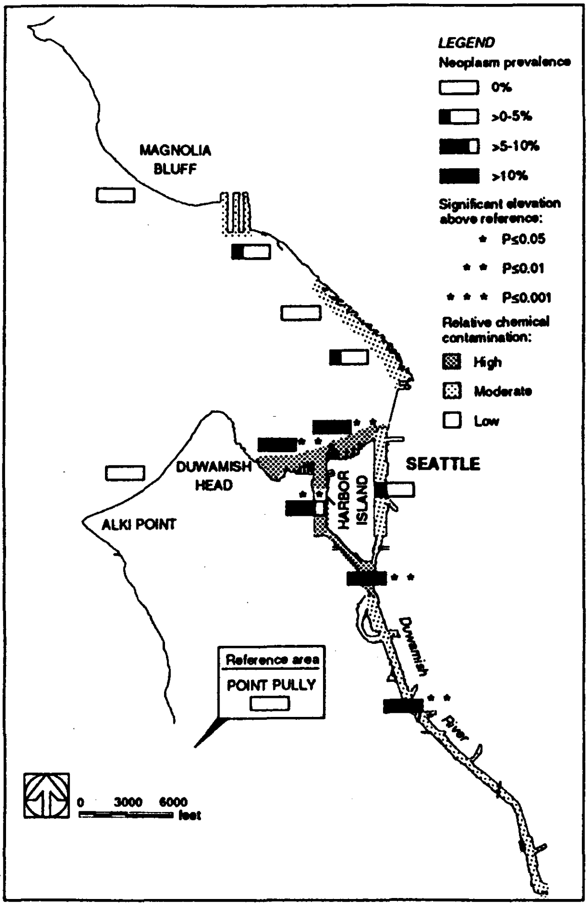


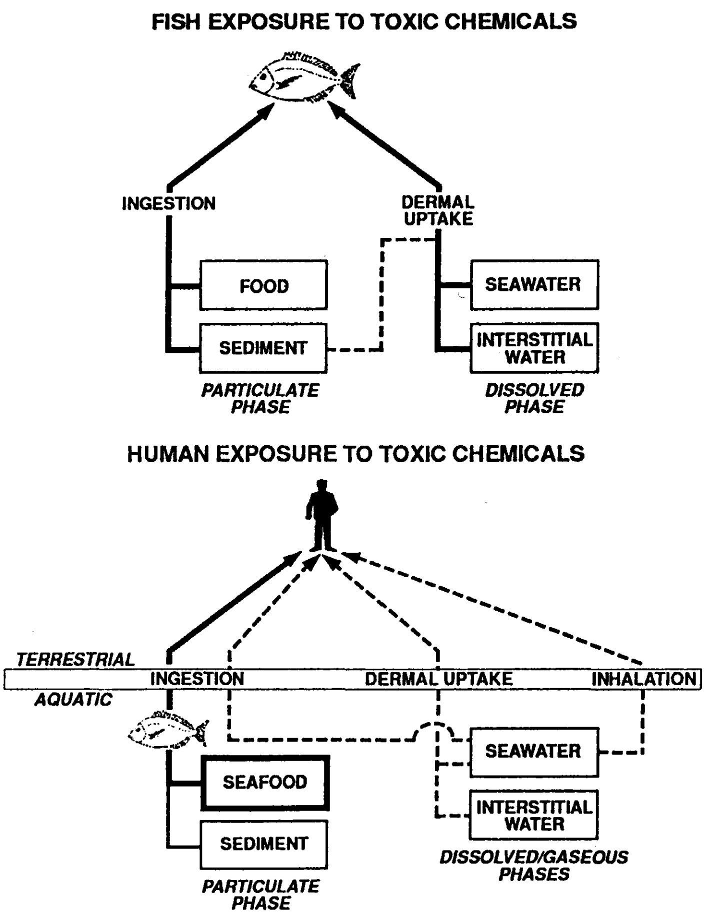
Figure 1.
SPATIAL DISTRIBUTION OF LIVER NEOPLASM PREVALENCE IN ENGLISH SOLE AND CONTAMINATED SEDIMENTS IN ELLIOTT BAY *(data from Beller et al., 1988).*

This paper is not intended to be a detailed evaluation of neoplasia in fish and humans. Rather, the following discussion focuses on key issues that may affect use of fish pathology data in regulation of contaminated sediments based on human health concerns.

Exposure Factors

Differences in potential exposure to toxic chemicals in sediments limit extrapolation of data on fish liver neoplasms to predict human health effects. Exposure pathways and routes for fish and humans are illustrated in Figure 2.

Fish are exposed to particulate-phase contaminants primarily through ingestion of food and sediments. Chemical uptake across the body surface, particularly the gills, is the most important route of exposure of fish to dissolved-phase contaminants. For humans, ingestion of fish or shellfish associated with contaminated areas is the primary route of exposure to contaminants in sediments. Direct exposure of humans to contaminated sediments is expected to be limited to incidental ingestion or dermal contact during recreational activities. For most of the human population, chemical uptake resulting from such recreational exposures is expected to be significantly less than exposure via the food chain.



NOTE: Bold line indicates primary pathway and route. Dashed line indicates minor pathway and route. Note that exchange pathways between particulate phase and dissolved/gaseous phase are not shown.

Figure 2.
EXPOSURE PATHWAYS AND ROUTES FOR CONTAMINANTS IN SEDIMENTS.

As noted above, PAH concentrations in fish tissue are very low, suggesting that exposure to PAHs from ingestion of these fish does not pose a significant risk to humans. If PAH metabolites in these fish were absorbed after ingestion of the fish, the metabolites are likely to be deactivated and excreted. In contrast to fish, shellfish such as clams, oysters, and crabs have minimal ability to metabolize PAHs and, therefore, do accumulate these compounds in their tissues (Mix and Schaffer, 1983a,b; Pruell et al., 1984). Bivalves may also have sediment in the gut when consumed by humans. Thus, humans may be exposed to PAHs from contaminated sediments either by direct exposure to the sediments or by ingestion of shellfish associated with the sediments. For chemicals other than PAHs that accumulate in fish as well as in shellfish (e.g., mercury and PCBs), food chain exposures will also be important.

Guarino (1987) compared fish and humans (and laboratory models) with respect to exposure and absorption of toxic chemicals. Guarino noted the general lack of information on the potential for gastrointestinal absorption of toxic chemicals by fish and the need for studies that separately quantify chemical uptake rates via gills, gut, and skin. The obvious differences between the aquatic habitat of fish and the terrestrial habitat of humans has major implications for the pathways, routes, magnitude, and duration of exposure to toxic chemicals associated with contaminated sediments.

Although the exposure factors just discussed preclude quantitative extrapolation of data on fish liver neoplasms to humans, they do not limit the use of such data to assess qualitative or relative human health hazards from contaminated sediments. One consideration in interpreting the exposure of fish to contaminated sediments that bears on qualitative extrapolations is the issue of fish movements, including long-distance migrations. If fish travel great distances, then association of observed neoplasms with specific areas of contaminated sediments is severely limited. Because English sole have been well studied, appear to be sensitive to chemical carcinogens, and tend to associate with fine-grained, organically rich habitats that have a high potential for contamination, this species is best suited for assessment of contaminated sediments in Puget Sound. It is clear from data on the spatial distribution of liver lesions and contaminants in tissue that individuals of this species exhibit somewhat limited movements along shorelines. Based on the distribution of lesions observed in the Elliott Bay and Commencement Bay studies (Becker et al., 1987; Beller et al., 1988), it may be speculated that the "home territory" of English sole covers on the order of 1-2 km of shoreline. Thus, the use of liver lesions in this species as an indicator of potentially contaminated sediments is appropriate for areas on the order of the East or West Waterways of the Duwamish River system (e.g., Figure 1) or the individual waterways of the Commencement Bay system.

Comparison of Neoplasia in Fish and Mammals

Most of the available information on mechanisms of carcinogenesis and on stages in the development of neoplasms in humans is based on studies of rats and mice as models of humans. Cellular and subcellular mechanisms of carcinogenesis may be common to diverse species of animals. For example, the mechanisms by which certain aromatic hydrocarbons may induce cancer in mammals have been studied intensively for the last 40 or 50 years, resulting in a fairly detailed understanding of their mechanism of action. The carcinogenic PAHs are higher molecular weight compounds with four or five aromatic rings. Carcinogenic PAHs such as benzo(a)pyrene must be activated by metabolic enzymes before they can induce neoplasia. The parent compound is therefore called a procarcinogen. The active metabolite is called the ultimate carcinogen. In any particular individual or species of animal, the ability of PAHs to induce neoplasia will depend partly on the relative abundances of activating and inactivating enzymes involved in the detoxification process.

Once a PAH compound has been activated, it may interact with DNA to form a DNA adduct. DNA adducts can lead to mutations. Two mutations appear to be required for PAHs to induce cancer (ICF-Clement, 1988). In all species and tissues examined, PAH metabolites have been found to bind to DNA, regardless of the route of administration. PAH-DNA adducts have been detected in both wild and laboratory-exposed fish (Dunn et al., 1987; Varanasi et al., 1987), supporting the hypothesis of a common mechanism of PAH carcinogenesis in fish and mammals.

Available information on comparisons of neoplasia in fish and rodents (i.e., rats or mice) indicates that stages in the morphological development of liver neoplasms in fish are similar to an established series of liver lesions induced in rodents by exposure to chemical carcinogens in the laboratory. Myers et al., (1987) provide comprehensive documentation of close morphological similarities between liver lesions in feral fish and the well-known sequence of lesions in laboratory rats and mice.

Modifying Factors

The relative sensitivity of fish and humans (or other mammals) to carcinogens has not been well studied. Janardan et al., (1984) generally found high ($r > 0.7$) correlations between the acute toxicity of organic U.S. Environmental Protection Agency (EPA) priority pollutants to fish (bluegills and fathead minnows) and to rats. These authors suggested that the high correlations indicated a similar mode of nonspecific (physical or narcotic) toxic action for certain chemicals among species. However, these results may have little bearing on relative sensitivity to carcinogens. Rainbow trout (*Oncorhyncus mykiss*) are known to be particularly sensitive to known human carcinogens,

but the sensitivity of English sole and other Puget Sound flatfish relative to humans is unknown. It is likely that sensitivity to carcinogens differs greatly among fish species and between certain fish species and humans. Differential sensitivity of homeothermic (constant body-temperature) species is thought to be related, in part, to metabolic rate. The relative body surface areas of two mammalian species may be used to approximate their relative metabolic rates. Crouch and Wilson (1979) demonstrated that humans are more sensitive to carcinogens than rats and mice based on similar dose rates per unit body weight (e.g., mg carcinogen ingested per kg body weight per day). Corrections for relative metabolic rates of rodents and humans are made by regulatory agencies that perform human health risk assessment by scaling doses to relative body surface areas. Such simple extrapolations cannot be made between fish and humans because fish are poikilotherms (variable body temperature) and their metabolic rates cannot be directly related to those of homeotherms (mammals).

Other factors that are not well known for many toxic chemicals include 1) comparative aspects of metabolism (e.g., conversion of procarcinogens to an active form, and detoxification and elimination of toxic chemicals), 2) target sites in the body, 3) relative carcinogenic potency in fish and humans, and 4) physiological processes that affect the validity of quantitative extrapolation of data on fish neoplasms to humans. The particular site of appearance of neoplasia in the body depends on the chemical, the route of exposure, and the species-specific metabolism. The similarities in metabolic functioning between fish species and mammals (Guarino, 1987) and the limited observations available on chemical causes of liver neoplasms in feral fish (Myers et al., 1987) suggest that chemicals that induce neoplasms in the livers of fish may also be capable of inducing liver neoplasms in humans.

The rate of appearance of spontaneous neoplasms (i.e., not induced by chemicals or other applied agents) in fish and mammals must also be considered. Spontaneous neoplasms are common in certain laboratory strains of rats and mice. Although hybrids of certain fish species are susceptible to spontaneous neoplasms in the laboratory, naturally occurring fish species may have a low background incidence of neoplasms. This appears to be true for rainbow trout (Hendricks et al., 1984) and English sole (Becker and Grieb, 1987).

Other modifying factors that may affect the incidence of neoplasms in both fish or human populations exposed to chemical carcinogens include diet, viruses, and genetic composition. Water quality variables such as salinity and temperature may also affect incidence in fish. The general role of these modifying factors is probably similar in fish and humans (or other mammals as models for humans). However, the quantitative influence of each factor on the prevalence of liver neoplasms in fish is unknown. Comparative studies of

the influence of modifying factors on neoplasia in fish and mammals have not been conducted. Relevant fish studies include documentation of the influence of diet (Bailey et al., 1984), viruses (studies summarized by Black, 1984), temperature (Kyono-Hamaguchi, 1984; Hendricks et al., 1984), and genetic susceptibility (Cooper and Keller, 1969).

CONCLUSIONS AND RECOMMENDATIONS

Quantitative extrapolation of information on fish liver neoplasms to assess potential human health effects from contaminated sediments is limited by the lack of comparative data on dose-response relationships and by differential exposure factors. The primary human exposure route for chemicals in sediments is through the food chain. In contrast, fish may be exposed by many pathways, including direct contact with sediments, contact with overlying water, or ingestion of contaminated prey. Prediction of human health risks or dose-response relationships for contaminated sediments based on fish histopathology data is clearly not warranted at present. Nevertheless, the ability to use data on fish liver neoplasms as indicators of potentially carcinogenic material in the environment is promising. Therefore, it is recommended that relationships between prevalence of liver lesions in bottom fish and contaminated sediments be developed further. In the long-term (e.g., over the next 5-10 years), it may be possible to develop guidelines for unacceptable levels of contaminants in sediments based on relationships between fish neoplasms and sediment chemistry. These guidelines could be used in conjunction with short-term tests for mutagenicity and carcinogenicity to assess potential human health hazards and to rank sediments in terms of priority for regulatory action. However, the limitations of using fish data to assess health hazards, even in a qualitative manner, must be recognized. Moreover, the relevance of toxicological endpoints other than neoplasia in fish and human food chains (e.g., Rogan et al., 1986; Humphrey, 1988) warrants further development of comparative interspecies data on birth defects, embryo and fetal toxicity, and corresponding short-term tests to assess contaminated sediments.

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PUGET SOUND RESEARCH '91

CITIZEN, SCIENTIST AND LAWMAKER IN GOVERNANCE

Session Chair:

James Long, Washington State University

INTRODUCTION

James Long[1]

Welcome to the session entitled "Citizen, Scientist and Lawmaker in Governance."

I'm Jim Long from Washington State University. I would like to compliment the Puget Sound Research '91 Steering Committee for adding this panel on "governance" of a public resource—the waters of Puget Sound.

Imagine a triangle. At each point of the triangle we have one of three people. We have the Citizen at one point. We have the Lawmaker who tries to translate a consensus among Citizens into legislation at the local, state or federal levels. And we have the Scientist at another corner in that triangle, to inform our thinking about current policies and the likely consequences of alternative policies for the future.

Our focus of the presentations and the panel discussion then, today, is the interrelationships among these three points in the triangle. It is not complete; we could add others—the Educator, the Industrial Manager, the Resource Manager. But today we will be looking at the relationships among the Citizen, the Scientist, and the Lawmaker.

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STATUS AND MANAGEMENT OF PUGET SOUND'S BIOLOGICAL RESOURCES: NOW YOU SEE IT, NOW YOU DON'T

John W. Armstrong[1]

INTRODUCTION

It's not an easy task to determine how well our state resource management agencies (and in some cases federal agencies and Indian Tribes) are managing the species for which they are responsible in Puget Sound. In fact, one could argue that the public only receives periodic glimpses of what some of these agencies' activities are, and that the opportunities to learn about and influence agency priorities are minimal at best. This paper will discuss approaches to inform the interested public, biologists, and water quality managers of some of the resource agencies' species management and broader activities in Puget Sound. While this paper is written regarding efforts underway in Washington's Puget Sound area, its recommendations have much wider applicability.

Puget Sound has received a flurry of activity in recent years; for example, Environmental Protection Agency (EPA) funding for technical studies and management tool development exceeded one million dollars per year from 1984 through 1990. These funds have been made available by EPA's National Estuary Program and have been focused on better understanding Puget Sound's environmental problems and the causes of these problems. At the same time, the Puget Sound Water Quality Authority (PSWQA) has been developing the Puget Sound Water Quality Management Plans (PSWQA, 1988; 1990; 1991) for water quality protection in Puget Sound.

As researchers began to gather information on abundances of several Puget Sound species, it became apparent that although many species in the Sound were "managed," reports which described the management approaches and their level of success were generally unavailable. In the absence of adequate information on the past and present management of various species, one cannot tell if observed trends in species' abundances or harvest levels are caused by natural or man-caused changes in the environment, changes in management strategies, or a combination of all of these factors.

TECHNICAL INFORMATION SHARING

In an attempt to help the resource agencies better inform biologists, resource managers, and the interested public about management programs and re-

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source status, a two day forum was held in Seattle in 1989 (Armstrong and Copping, 1990). The objectives of the forum, entitled "The Status and Management of Puget Sound's Biological Resources," were:

- To provide information and a chance to discuss the status and trends of Puget Sound species
- To highlight the management agencies' responsibilities and priorities
- To discuss emerging problems and issues in the management of Puget Sound species
- To outline management changes that will address these emerging issues.

The forum was designed to: (1) "encourage" the organizing and analyzing of species-specific data which in some cases had never been analyzed; (2) informally share the results of these analyses with the interested public and other resource managers; (3) provide an opportunity for resource managers from various agencies (and various departments within agencies) to talk face to face with one another; (4) determine how species management might be affecting species abundances over time; (5) raise some new or emerging management issues (such as the increasing harvest of unregulated species of marine fish and invertebrates); and (6) facilitate the development of status and trends summaries in the future. Having once summarized and documented species management issues and trends, the updating of this information every year or two would be a relatively simple matter.

As the forum was being planned, several steps were taken to ensure that it was successful. These steps, which are listed below, may be useful to others attempting similar conferences.

- Tentatively decide which topics or species should be included, and who the most appropriate speakers/authors would be, and ask the resource management agency directors to have their staff participate in the conference.
- Encourage the authors to write a thorough paper, and ensure a wide distribution of the information being prepared and presented by widely advertizing the conference and publishing a conference proceedings.
- Send each author an outline of the things to be addressed in the written presentation (Table 1).
- Hold the conference at a comfortable facility and keep registration inexpensive.
- Provide box lunches to encourage attendees to remain at the conference site, both to facilitate informal discussions among attendees and to minimize attendees returning late from the lunch break.
- Prepare report format information for the authors.
- Schedule an extended period of time for questions after each presentation (20 minutes for this forum) and have moderators prepare some questions in advance for each speaker to help "warm up" the audience.

- Conclude the forum with a panel of resource agency directors or assistant directors speaking about their agencies' legislative mandates, priorities, etc.
- Request that conference attendees complete a survey form on what they liked and didn't like about the conference.

ATTENDEES SUGGESTIONS ON THE STATUS AND MANAGEMENT FORUM

The survey conducted at this conference's conclusion indicated that nearly all attendees (about 85%) were very pleased with the conference. Another indication of its success has been the number of requests for copies of the proceedings—over 600 have been distributed to date. Highlights of the comments from the attendees on things they liked about the forum, as well as ways to improve it, are listed below.

Technical Issues

Attendees supported or appreciated:

- discussions on pressures facing Puget Sound species and management goals
- understanding how species management responsibilities are partitioned between agencies
- gaining insight into the goals of species management
- explanation of each agency's mandate and priorities
- making or renewing personal contacts with other biologists and managers

Attendees suggested the following conference changes:

- have additional discussions on agency policies and how management decisions and priorities are made (i.e., discuss why a particular resource is managed by a small staff and has a small budget for enforcement)
- have speakers provide conference attendees with a one page summary of their most important points

Procedural Issues

Attendees supported or appreciated:

- keeping speakers and the overall program on schedule
- allowing a fairly long time (20 minutes) for questions after oral presentation

Attendees suggested the following conference changes:

- simplify and improve the quality of graphics
- have speakers use the microphone more effectively

Table 1.
OUTLINE FOR WRITTEN PRESENTATIONS FOR THE FORUM "STATUS AND MANAGEMENT OF PUGET SOUND'S BIOLOGICAL RESOURCES."

I. Briefly describe resources being managed
- Species
- Areas harvested commercially and recreationally
- Rough dollar value of resource - commercial and recreational

II. Briefly describe resource management program
- Approximate level of program - manpower and dollars (i.e., 2 people, $100,000)
- Data gathering effort/techniques and frequency/locations of data gathering
- Interactions with other programs within your agency (i.e., for managing other species or for managing the same species in other areas)
- Interactions with other agencies for management purposes (state, Federal and/or Canadian agencies)

III. Discuss temporal trends in resources (most important species or individual indicator species)
- Trends in overall Puget Sound and in specific areas
- Changes in overall resources available and harvested (i.e., salmon or waterfowl)
- Changes in individual species
- Possible causes, observed correlations

IV. Management Issues
- Is the state of the resources being managed a concern (i.e., is the decline, or increase, of a particular species of fish or seaweed of concern)?
- Is more data collection/management effort warranted (i.e., is the management effort for these resources adequate) and if so, how would the collection of additional information be used to improve the management of these species?
- Are new harvest or capture methods being developed?
- Are new species being harvested?
- Are new areas being harvested?
- Are changes in regulations being considered to improve the existing management approach?
- Is natural habitat protection being addressed, could/should habitat protection receive more attention?

V. Enforcement Issues
- Describe the enforcement program (manpower, approximate budget, approach...)
- Recent enforcement actions
- Trends in enforcement actions
- Is the enforcement program adequate to protect resources?
- Are new ideas/geographic areas being considered/targeted for enforcement?

VI. Conclusion
- Overall summary of management program, areas of concern, emerging issues
- Ties with the Puget Sound Ambient Monitoring Program, plans (or lack of plans) to send data to the Puget Sound Water Quality Authority
- Ties/interactions with other agencies - are they adequate?
- Emphasize interactions among state and federal agencies regarding resource management
- Have the panel of agency assistant directors speak first instead of last, or both first and last

- try to encourage shorter "statements" from some of the audience as they ask questions

Ideas for Future Conferences:

Attendees suggested:

- include habitat and water quality issues with species that are managed
- ask speakers to address what could be improved to assist their management efforts and the general condition of the resource they manage
- discuss the status of items critical to the resources being managed (ie., prey items, primary productivity)
- emphasize recent or current management problems and how they were or are being dealt with
- discuss how local government policies affect various biological resources
- address the ways citizen involvement can help protect resources and assist management agencies
- ask the resource managers to discuss the effectiveness of the current agency policies on the management of specific resources

BROAD PROGRAM AND PRIORITY INFORMATION SHARING

Based on the results of the forum survey, the attendees strongly supported a follow-up conference in the fall of 1991 or 1992. It appears that other than through the conference described above, the resource management agencies don't seem to be getting technical information on Puget Sound biological resources management out to the public. Furthermore, one could ask whether the agencies are providing the public with more general information on the agency's activities, helping to build an environmental ethic and developing and maintaining a constituency that strongly supports resource management agency programs and actions. Resource management agencies could do a better job of informing and educating the public, although some are at least aware that they need to do more and are beginning to develop plans to correct this situation.

The 1987, 1989 and 1991 Puget Sound Water Quality Management Plans (PSWQA, 1987; 1988; 1990) each have a major program for improving/increasing education and public involvement opportunities concerning the long term management of Puget Sound and its resources. However, these Plans seem to stress educating and involving a limited, interested public on specific issues, rather than informing a broad audience on agency responsibilities, priorities and limitations. Some state agencies, such as the Washington Department of National Resources (DNR), are reviewing their needs for better communication with the public. DNR recently commissioned a public opin-

ion survey (Elway Research, Inc., 1990) to aid its Aquatic Lands Division in identifying and measuring public opinion with regard to aquatic lands issues. DNR wanted to know if the public recognized the significance of state-owned aquatic lands as a public resource, and whether DNR's role in the management of these state-owned lands was clearly understood. Based on the needs identified by the survey, the Aquatic Lands Division is presently developing a detailed strategy for increasing the breadth and scope of its public information, education and involvement activities.

Generally, state resource management agencies receive public input regarding their broad programs largely through advisory committees and through public hearings and meetings on specific issues or actions. News conferences, press releases and occasional newspaper guest editorials are used to reach broader audiences. Mailing lists are maintained for groups and individuals interested in specific topics. Some agencies have newsletters or magazines describing their activities, but many agencies find these publications to be too expensive. Technical studies and progress reports for various agency programs are poorly advertized, often being distributed through mailings to a relatively small number of individuals or by word of mouth. Inventories or catalogues of technical studies which are underway or have been completed are largely non-existent. Finally, regulations for recreational harvesting of resources are generally readily available (through the regulations for harvesting marine seaweeds in Washington are not) but are often not very easily understood.

Given that the public can play a strong role in assisting resource management agencies both by being a strong constituency for the agency and by fostering and spreading a strong environmental ethic, there appear to be some approaches to informing and educating the public that are not being utilized. At the same time, questions about some existing tactics (How well do advisory committees represent the public's views? Are existing mailing lists merely "preaching to the choir?" Does involving people in small environmental projects reduce the need to make them aware of broader policy issues?) suggest that they should be reviewed for their effectiveness.

As we try to maintain the quality of Puget Sound and other areas and the health and abundance of their biological resources, the management agencies should consider the following approaches to getting and improving public interest, understanding, and support of their programs and policies:

- Conduct public opinion surveys. Do public priorities conflict with or support agency legislative mandates and existing agency priorities?
- Periodically issue reports for the public that indicate: (1) what each agency's main responsibilities are, what types of programs it manages, what its priorities are, and where its funding comes from; (2) what the agency has

done over the past year or two, how priorities and funding have changed and what the major work products have been; and (3) the ways, if any, that the public has influenced agency priorities and activities.

- Convene an annual or biennial technical conference to discuss the items mentioned above and/or more technical species management issues.
- Ensure information for the public (such as the fishing and hunting regulations) is easily understandable and available.
- Publicize the reasons behind the fishing and hunting regulations so the public understands the reasons for abiding by the regulations.
- Make various agency technical reports more readily available to the public.
- Consider consolidating articles and other information from several resource management agencies into a single, multi-agency magazine to decrease the cost and effort of having a single magazine for each agency. Alternatively, encourage agency staff to write articles for the magazines or newsletters of other agencies.
- Encourage agency staff to make more frequent oral presentations at local gatherings and conferences.
- Encourage newspapers to consolidate environmental news into a single environmental "section" or column in local newspapers.
- Consider establishing agency "electronic bulletin boards" for news releases, public information and activity calendars.
- Make better use of television and radio news and "talk" shows, spot announcements and documentaries.
- Encourage public input to, and requests from, resource management agencies by maintaining a free (800) telephone line to the agency.

CONCLUSIONS AND RECOMMENDATIONS

While many agencies are currently attempting to increase their public information, involvement and education activities, they may not be doing so in the most effective ways. A large, perhaps disproportionate amount of effort seems to be going into "involving" the public, through the development and initiation of numerous small scale projects (i.e., beach debris cleanup, or one-shot water quality monitoring on a small scale). Although these projects certainly get small numbers of people involved in constructive projects, the greater public's overall understanding of resource agency programs, priorities, and limitations may not be increased very much.

Well thought-out and planned conferences like the one described earlier in this paper are an excellent way to encourage resource management agencies to analyze and share the results of their management activities with each other and the informed public. In addition, a broader effort (as outlined above) is

also required to reach a larger, less technically-oriented audience. Educating this larger audience is crucial to the constituency-building required for the long-term success of all agencies. Finally, the public needs this broader information to ensure that each agency's programs and priorities reflect the public's priorities, and so that it knows the condition of the environment and resources these agencies have been directed to protect and enhance.

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WATER QUALITY GOVERNANCE FOR PUGET SOUND: AN ASSESSMENT

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WHAT SHOULD WE LOOK FOR WHEN EXAMINING HOW AGENCIES MAKE WATER QUALITY MANAGEMENT DECISIONS?

A cornerstone of water quality management is the ability to generate reliable scientific and technical information which illuminates the nature of water quality problems and their probable causes, and points the way toward techniques and approaches for their resolution. But as Mark Sproule-Jones observes, water quality management takes place in a political and institutional context which also provides a framework in which the differing objectives of members of society are reconciled, and policies which reflect the dominant values are developed and implemented (Sproule-Jones, 1980). The success of this institutional framework in providing effective water quality management may well be related to its ability to assure that appropriate scientific and technical information is utilized and that important scientific uncertainties are addressed. But a number of studies suggest that success may also be related to the approach these institutions take to the twin tasks of balancing competing objectives and addressing the sometimes conflicting claims of interest groups (Leschine and Quinn, 1987).

Like Bish (1982) and Hennessey (1987, 1988), we use the term 'governance' to refer to the institutional arrangements by which water quality problems are identified and evaluated, and solution strategies are delineated, analyzed, selected and implemented. In the words of Norman Meyers, governance can be broadly construed as "the aggregate of processes, systems, relationships, both governmental and nongovernmental, by which human communities interact" (Meyers, 1988). Studies of water quality governance focus not only on laws, regulations, and programs, but also on the organizations and individuals both within and outside government who influence the development of water quality programs. Those who participate in or influence the various phases of planning and management define not only the specific institutional arrangements to be utilized in subsequent program phases, but also who participates in those phases, and under what rules (Majone, 1976).

The institutional arrangements required to develop and implement water quality programs can be thought of as existing on several distinct levels (Kiser and Ostrom, 1982). Basic mechanisms and authorities are created at the "constitutional" level, perhaps in the form of new public laws. The state law

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creating the Puget Sound Water Quality Authority (Chapt. 90.70 RCW), and subsequent decisions about exactly how the newly created Authority would be organized, provide examples. At the "collective choice" level, the specific nature of authority for attacking specific problems is determined. Will state agencies develop new rules and regulations directly, or will the job be passed on to counties, cities or towns with state agency oversight? Such decisions are "collective" in the sense that they are motivated by the belief that individuals are behaving in ways which harm the collective good, and governmental action is required to induce changes in that behavior. Finally, at the "operational" level the individuals affected by the decisions made at other levels act in response to the new institutional arrangements or rules they face.

In this conception of decision making, only at the operational level do actions in the physical world follow directly from decisions (Kiser and Ostrom, 1982). Here is where programmatic actions impinge directly on the behavior of the intended target population (and perhaps on the behavior of others as well). The actions taken by decision makers in implementing or redesigning programs, if effective at all, will change the distribution of resources over the affected community (perhaps broadly construed). Some individuals may pay more in taxes or fees, while others may pay higher operating costs in order to maintain environmental controls. Still others, perhaps including those who pay, may experience new benefits associated with enhanced water quality.

These real-world changes will generate a variety of feedback effects throughout the institutional hierarchy, ranging from changes within the affected community itself (e.g., in spending patterns or attitudes) to "signals" about program effectiveness, acceptability, and so forth sent to higher institutional levels. Such signals may be delivered directly and immediately in the form of complaints and/or accolades with regard to the programs themselves, or indirectly and over the longer term through such mechanisms as voting. Direct information on what effects programs are having and how acceptable their outcomes are is thus but one, albeit important, aspect of feedback. Program managers may modify operational decisions in response, but such higher level actors as program directors, other agencies with overlapping authority, or legislators may also intervene to restructure programs in more fundamental ways, through changes in their basic (i.e., constitutional) rules of operation (Kiser and Ostrom, 1982).

For a variety of reasons, organizations will tend to be structured so that they have within them decision units which their members believe to be most appropriate for solving the kinds of problems they typically face (Thompson and Tuden, 1959). Studies of organizational decision making reveal that different types of problems (and by inference, different conceptions by organization members of just what types of problems "typical" problems are) appear to require different decision strategies for their successful resolution.

If decision makers believe that the underlying causes of water quality problems are well understood and that the preferences of affected individuals and groups are in harmony (or alternatively if they choose to ignore the complications posed by lack of social consent), they may expect problems to be resolved by what Thompson and Tuden refer to as the "decision-by-computation" strategy. In such situations we might expect to see heavy reliance on regulatory-driven and standards-oriented permit systems, in the belief that a succession of decisions to grant or deny permits, made by appropriate specialists, is sufficient to achieve program ends.

If, on the other hand, the organization believes that typical problems display, as a dominant characteristic, an absence of scientific and technical information which establishes clear cause-and-effect linkages, then the organization may be expected to support decision units which attack problems through collegial judgments by panels of experts. Finally, if the organization believes that the need to achieve consensus among social groups with differing preferences is the primary defining characteristic of the problems it must resolve, then it may also emphasize support for decision units whose aim is to facilitate bargaining among affected interests (Thompson and Tuden, 1959). The "negotiated rulemaking" process now being utilized by some federal agencies, and the creation of special units within these agencies to facilitate such an approach to rulemaking, exemplify this last approach.

Of course in the real world many problems will be of mixed type requiring mixed or *ad hoc* approaches. Also, in complex arenas like water quality management, organizations simultaneously may face problems which members recognize to span the full range of types noted above. But as Thompson and Tuden caution, "the attitudes and expectations of members may make it difficult for organizations to create *ad hoc* or alternative decision units to deal with problems for which ... [the] traditional structures are ill suited." (Thompson and Tuden, 1959). By observing the performance of organizations in problem-solving situations over time, we can begin to infer what their dominant tendencies and strategies are. The selection of an approach to decision making by an administrator may, as Thompson and Tuden note, be as significant as actually making the decision.

The importance of the collective choice aspect of governmental decision making aimed at improving water quality stems from the "collective (or public) goods" nature of water quality itself. As Sproule-Jones observes, "a multiplicity of individuals and organizations (both government and private) will contribute in different ways towards the production and consumption of water quality" (Sproule-Jones, 1978).

Because water quality is both jointly produced and jointly consumed, maintaining or enhancing it presents difficulties for governmental decision makers

beyond those already noted. No one can be excluded from the benefits of cleaner water (the joint consumption aspect of the problem), implying that there may be "downstream" beneficiaries of water quality programs who do not bear their share of cleanup costs imposed on upstream polluters. As a result, those upstream may balk at paying anything at all. In addition, because a large number of individuals and activities may be contributing to the problems of concern (the joint production aspect), it may be relatively difficult to match the scope of agency jurisdiction, and the "functional" scope of the regulatory tools the agency has at its disposal, to the geographic scope and functional requirements of the problem the agency is trying to resolve.

Organizational decision-making style, the aspect of problem solving we have already discussed, may exacerbate difficulties associated with the organization's size, geographic coverage, scope of authority and functional responsibility in relation to the demands implied by the problems it faces (Bish et al., 1975). As new types of problems confront the organization, its members may have a hard time recognizing just how mismatched the organization is to dealing with them in its present configuration.

APPLICATION TO WATER QUALITY PROGRAMS FOR PUGET SOUND

To assess how governance arrangements have developed and evolved in relation to the institutional considerations developed above, we examined three important problem areas. These are: the problems of nonpoint pollution found to exist throughout rural areas in the Puget Sound region; the program to develop, under PSDDA, a system of dumpsites within Puget Sound to receive dredge spoils; and the development of standards to guide decisions on contaminated sediment remediation. In order to assess the way in which change occurred in governance of water quality in Puget Sound, we surveyed activities in each problem area in three time periods: the early 1980s, when heightened awareness of Puget Sound water quality problems and difficulties in addressing them through existing institutional arrangements was leading to calls to create new authority focussed specifically on Puget Sound; the mid-1980s, when the Puget Sound Water Quality Authority (PSWQA; the Authority) was working to develop its first Water Quality Plan; and the late 1980s, during which time the Authority's second Plan was being developed and the question of the future of the Authority was coming into prominence on the region's political agenda.

The Rural Nonpoint Pollution Program

Shott (1991) describes the evolution of governance arrangements to address problems of non-point pollution in Puget Sound. The Washington Department of Ecology's (DOE) initial attempt to deal with non-point pollution showed a reliance on tools with which it was most familiar—an expansion of

its NPDES program to activities responsible for nonpoint pollution (for example, through the Dairy Waste Management Plan). Until DOE began to focus its program efforts on the Burley-Minter Early Action Watershed, it did not attempt to develop and apply approaches tailored to the problems of Puget Sound. DOE, as an agency with state-wide authority, tended to apply the new controls it developed on a statewide basis. Moreover, because of the patchwork nature of the authority it had, its ability to deal with some problems with existing tools was sometimes limited. For example, regulations for the control of on-site sewage systems exempted those installed before 1979. DOE did look comprehensively at the problem of shellfish protection. But preparation of its 1984 Shellfish Protection Strategy emphasized in-house expertise, an approach appropriate to an organization whose strength lay in a staff of largely technical specialists.

Later, under the Authority's prodding, and as a result of lessons learned in the Burley-Minter program, efforts to control rural non-point pollution underwent a substantial shift. Not only did the Authority emphasize the need for a program matched in geographic coverage to Puget Sound per se, but it further urged disaggregation of decision making down to the county and watershed level, where both the problems and the immediately affected population were. The Burley-Minter experience had not only shown that affected individuals need to have a direct say in the design of controls whose cost they would bear, but also showed, as collective choice theory predicts, that the perception that the benefits of control would mostly accrue to "free riders" who would not share in the costs (in this case shellfish growers) would leave little support for doing anything at all. Of course, the cost of not controlling pollution would be borne by shellfish growers and consumers.

The initial DOE approach to problems of rural nonpoint pollution placed emphasis in program design on the decision strategies referred to earlier as computation and in-house collegial judgment, and only came to incorporate a bargaining component following the failure of its first Burley-Minter program (Shigenaka, 1987). The Authority, however, pushed the program toward a mix which emphasized bargaining and accommodation on a scale more matched to the scale of the problems it was designed to address. While local Watershed Action Committees utilize computational tools developed by Ecology in ranking watershed problems, they follow consensus decision rules in developing the elements of programs intended to address the problems identified.

The Puget Sound Dredge Disposal Analysis Program

From the standpoint of institutional analysis, the PSDDA process, which emerged as an accommodation among agency directors following the controversy over Seattle's "Four Mile Rock" disposal site (Leschine, 1990), is very

much one of collegial judgment by a multidisciplinary panel of experts. A remarkably stable coalition of state and federal agencies has developed. The Puget Sound focus appears to have been the catalyst to bring together a number of normally single-purpose agencies to deal with a complex multiple resource problem in a nearly unprecedented way. The PSDDA idea seems actually to have emerged as a technical staff initiative. But new bargaining arrangements among agency heads, precipitated by the emergence in the mid-1980s of the Authority as a new player, made the creation of PSDDA, at what we referred to earlier as the "constitutional level", possible. The appearance on the scene of the Authority seems to have had a catalyzing effect of sufficient power to replace the long-running series of *ad hoc* and poorly coordinated decisions that had become the region's *de facto* dredge disposal policy in the 1970s (Smith, 1988) with an innovative and so far successful new arrangement. More recently, when PSDDA has been challenged by some shoreline communities near PSDDA's Phase I dumpsite nominees, the Authority has acted as a go-between in the name of preserving the momentum PSDDA has established.

Sediment Quality Standards and the Authority's Future

Appropriate standards for sediment remediation decisions became an issue in the early 1980s when DOE and EPA Region 10 formed a partnership to deal with Superfund investigations in Puget Sound. The approach was again dominated by collegial judgment, and it generated a large number of technical analyses. As Kruger (1989) notes, the creation of PSWQA provided the impetus for DOE to develop state standards for sediment quality. In its 1987 Water Quality Management Plan, PSWQA directed DOE to form an advisory group of all the affected interests to help in the development of standards which would apply to a large number of Puget Sound discharges, including stormwater and CSOs as well as municipal and industrial point sources. The Authority's Plan also declared the goal for the program's sediment quality component to be "no adverse effects from sediments" in Puget Sound.

In the case of sediment standards, the Authority's normal adroitness in developing new institutional arrangements to embrace more general problem conceptions is less evident. The proposed coalition strategy, compromised in the view of some industry spokesmen by what they saw as premature judgments by the Authority on the program's scope, failed to attract meaningful industry participation. Instead, "feedback" became the dominant signal in the system of institutional arrangements which had evolved to deal with pollution in Puget Sound, and the Legislature acted once more to reconfigure constitutional authority for dealing with the problems of Puget Sound.

The independent Authority which operated through the second half of the 1980s was an organization with an impressive ability to redefine the nature of

decision-making approaches when it believed warranted by the scope of pollution problems in Puget Sound. The problem-solving strategies it favored appear to occupy a region between collegial judgment and bargaining. By contrast, the Department of Ecology, under whose aegis the "new" Authority will operate, has shown itself in the past to favor decision strategies that lie in the region between computation and collegial judgment. In many of the priority areas identified by the "old" Authority, Ecology now has considerable momentum to press on with solution strategies which will not be likely to differ greatly from the general outlines now on the horizon. But whether the Ecology-run Authority ultimately has the "look and feel" which citizens have come to associate with PSWQA will depend on how Ecology chooses to deal with problems of social consent which increasingly dominate the "hard" problems of pollution control.

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WHAT THE PUBLIC NEEDS TO KNOW: THE ROLE OF THE SCIENTIST IN PUBLIC INFORMATION

Andrea E. Copping[1]

As scientists, we are trained to question, to be skeptical, and to postulate hypotheses that can only be disproved, never proved. We are taught to deal only with scientific facts and not to involve ourselves in policy issues. Researchers prudently decline to share their results, except with their closest colleagues, until the work is completed. Researchers who go to the media with their findings are generally considered by their peers to be sensationalistic and perhaps unsound as scientists.

Meanwhile, momentous public policy decisions on the use of the environment, the design and construction of weaponry, and the creation of new products, are being made with minimal scientific input or comment. The public cries out for basic information about some of the issues put before them as voters and are all too ready to accept the information provided by politicians, planners, and managers. When scientific results are made available to the public, the complexity of the issues, contradictory scientific findings, and highly technical language limit their usefulness. Managers, planners, and other officials are forced to make decisions with information they can glean in a short period of time from the few accessible technical and scientific personnel.

This paper will briefly review three examples of Puget Sound natural resource management issues where scientists can and should play a significant role by providing information to the public, and by voicing their concerns on environmental issues. In addition, this paper cites an example where the scientific community attempted to participate in the decision-making process, with unsuccessful results.

SEAFOOD RISK ASSESSMENT

For over a decade scientists have been measuring elevated levels of contaminants in the edible muscle tissue of bottomfish caught in the urbanized bays of Puget Sound. These contaminants include PCBs and heavy metals. The levels of some of these contaminants may potentially cause harm to humans eating the fish.

There is no exact science to assessing human health risk from food; several techniques are available and none are universally accepted. Most of the Puget

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Sound work in this field has followed procedures set out by the regional office of EPA and their contractors (Tetra Tech, 1986). By following these procedures and assuming a typical PCB level in fish tissue found in a contaminated area, managers would determine that consuming 12.3 grams of the fish daily, over a 70 year lifespan, could increase an individual's risk of cancer by 10^{-5}. This type of determination is accurate within the limitations of the model assumptions and the quality of the data. However, unless accompanied by lengthy explanations and extensive caveats, this determination does not produce helpful information or advice to the public for reducing their risk of cancer.

The outcome of publicizing this type of information might have one of two effects: the public might panic and cut down or eliminate bottomfish (or all Puget Sound fish) from their diets, or they might ignore any implied warning as unintelligible. The scientific community could serve the public better by preparing health advisories describing the probable risk from consuming contaminated seafood and providing advice on how to change individual lifestyles. For example, the Washington State Department of Health issued a health advisory last summer for Lake Roosevelt whitefish. The advisory stated that pregnant women and children under 40 pounds should avoid consuming the whitefish, while healthy adults should limit their consumption to one whitefish meal a week. Such a communication should also note that scientific evidence shows positive health effects from diets higher in uncontaminated fish than certain alternatives, such as meat.

WETLAND LOSS

Nearshore, riverine, and upland wetlands are being lost at an alarming rate in the Puget Sound basin, as well as in most other parts of the country. Environmental activists, managers, and a handful of the scientific community speak out for the need to preserve existing wetlands for stormwater detention, fish and wildlife habitat, groundwater recharge, and erosion control. Developers are often supplied with contradictory information about the damage caused by construction within, or near wetlands. The result is that the public is left confused, with no clear concept of the importance of wetlands, of the state of knowledge of wetland functions, or of the efficacy of creating new wetlands and mitigating the damage or destruction to existing wetlands. Because they understand the need for jobs and economic development, it comes as no surprise that the public frequently votes on the side of human development and industrialization over the need to preserve wetlands.

The scientific community must band together to advocate the need to preserve wetlands of all varieties until further information is acquired to establish the value of different wetland types and locations. Researchers should provide clear, concise public information about wetlands. In addition, the scientific community could assist funding agencies to set goals for wetlands research

that clearly demonstrate the applicability of the research to wetland management. Further, the scientific community must find a strong voice to advocate state, federal, and private funding to carry out monitoring and research into wetland functions. (The Center for Urban Water Resources Management at the University of Washington undertakes to provide some of these functions).

MARINE FISH STOCKS

The public receives little information about the status of fish and wildlife populations until a crisis occurs; a recreational run or season is closed or restricted, commercial seasons or licenses are severely limited, or record low returns of fish are noted. Scientists and managers attempt to share information about fisheries and wildlife regulations with the public through annual public meetings and reports. However, these mechanisms are not readily accessible to most people and seldom address the status and causes of change in fish and wildlife populations.

The Washington State Legislature closed the area south of Admiralty Inlet to all commercial bottom trawling in 1989, due to concerns over environmental impacts of bottom trawling and declining catches of recreational fish and crab. The area remains closed, and monitoring of marine fish stocks commonly caught by bottom trawl has been suspended. Without fish population abundance monitoring or catch statistics, fisheries managers have no information with which to judge the status of these marine fish stocks. The fishery may remain closed indefinitely without such information. Additionally, much of the information that has historically been used to manage these and other fisheries has been based on harvest, not the actual status of the stock. Without information on fish populations, fishing pressure, contamination, and habitat damage, managers cannot adequately determine whether a decline in fish stocks has actually occurred (as opposed to changes in fishing effort), or the underlying cause of the decline.

Pacific cod has been one of the most popular fish caught by recreational anglers in Puget Sound. The commercial fishery in parts of the Sound has been eliminated and recreational catches have dropped in recent years (Schmitt, 1990). During the 1989 and 1990 season, Pacific cod stocks in the Sound dropped dramatically. Without additional information, fisheries managers cannot sort out whether the decline was caused by natural environmental factors, such as shifts in water temperature, or overfishing. Fisheries managers may reduce the catch of Pacific cod in order to preserve the fish stock, but they do not have the information to know whether their efforts are effective.

Fisheries researchers have a better record of involvement in management issues than many other members of the Puget Sound scientific community, yet few prepare public information for dissemination. Puget Sound human

residents are hungry for accurate information about one of their favorite subjects: fish. Researchers could work in conjunction with funding and management agencies to produce frequent information updates on the status of fish and wildlife populations for public dissemination. If the scientific community would speak with a strong and unified voice, it could focus attention and funding on the plight of Puget Sound fish, and that of fisheries managers attempting to manage resources with little useful information.

SECONDARY WASTEWATER TREATMENT IN PUGET SOUND - HOW THE SCIENTIFIC COMMUNITY GOT BURNED

In one notable example, many members of the Puget Sound scientific community involved themselves in a major public policy issue. In 1985 thirty scientists, including oceanographers and fisheries biologists, signed a petition to the Washington State Legislature. The petition stated that, in their scientific opinion, upgrading the existing municipal wastewater treatment plants to secondary treatment was unlikely to benefit water quality in Puget Sound. The proposed upgrades to secondary treatment will eventually cost the public billions of dollars, charged largely to the ratepayers.

At that time, much of the Puget Sound scientific community felt that the weight of evidence was on the side of the scientists who participated in the petition and subsequent hearings. However, there has been tremendous scientific controversy concerning the benefits to marine water quality from various wastewater treatment processes. The input provided by the Puget Sound oceanographers and fisheries biologists was too little too late. The issue of secondary treatment upgrades had been removed from the scientific arena to the public policy arena, and the treatment upgrades had been nationally mandated in the Clean Water Act reauthorization of 1972. Because their outfalls were in tidal waters, Puget Sound wastewater treatment plants were eligible to apply for five-year waivers of the secondary treatment requirement; however, the eventual upgrade to secondary treatment was inevitable. The Puget Sound scientific community was not able to provide a united voice at a time when their input might have been effective.

CONCLUSIONS AND RECOMMENDATIONS

Scientists must be willing to speak out and assist in making public policy decisions related to their areas of expertise, often without having completed the definitive research. Otherwise managers or the public will be left to make those decisions. Managers frequently have limited and often outdated technical expertise. The public may directly (through the initiative process) or indirectly (through electing public officials) make decisions with little scientific understanding of the consequences.

Scientists can help form responsible public policy by preparing and disseminating scientific results in a manner which is understandable and accessible to the public. These results could address threats to biological resources, risks to human health, and the trade-offs between development and protecting critical areas. Armed with good information, the public can make astute and responsible decisions.

In order to directly impact policy decisions, scientists should organize themselves to provide timely and effective participation in the decision-making process. This would allow them to speak out to slow or eliminate the loss of irreplaceable resources until definitive information on the resources can be obtained, and to actively lobby for funds for monitoring and research of critical resources and processes.

There is currently no mechanism to allow the scientific community to provide timely and effective input to policy decisions in Puget Sound, or throughout the state of Washington. The creation of a science advisory board (SAB) to the Governor of the state of Washington could provide such a mechanism. The SAB could undertake studies to advise the Governor and the Legislature on the scientific merits of policy actions and could act as a forum for resolving scientific controversy. The scientific community could play a key role advocating the formation of the SAB. Responsible researchers in the universities and research institutes should make a commitment to participate in the SAB.

The effective dissemination of public information, and the creation and effective use of the SAB, could help to narrow the gap between the needs of the public and managers to adequately protect resources and human health, and the wealth of knowledge made available by scientific research.

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NON-GOVERNMENTAL ORGANIZATIONS AND ESTUARY PROTECTION: ROLES, STRATEGIES, AND EXPERIENCE FROM AROUND THE COUNTRY AND PUGET SOUND

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INTRODUCTION

This paper presents the interim results of a project being conducted by the Institute for Public Policy and Management of the University of Washington Graduate School of Public Affairs to determine ways to strengthen non-governmental efforts to protect Puget Sound. Information has been drawn from nearly 200 interviews with representatives from the environmental, academic, scientific, business, government and funding communities in the Puget Sound area and other regions with major estuaries. The project included site visits to Chesapeake Bay, Narragansett Bay (Rhode Island), Boston Harbor, the Great Lakes, San Francisco Bay, and Santa Monica Bay. The interviews were not intended to yield statistically valid data. Rather, they have been used to paint a composite picture of what representatives of various groups believe.

BACKGROUND

As recently as eight years ago Puget Sound had no organization championing its cause or planning for its long-term management. In 1984 the Puget Sound Alliance was formed as the first non-governmental organization specifically dedicated to the protection of Puget Sound as a whole. It advocated the creation of the Puget Sound Water Quality Authority, a government agency which the state established in 1985 to develop and oversee the implementation of a comprehensive management plan for the Sound.

Major strides were made over the succeeding five years, including the adoption and partial implementation of the nation's model estuary management plan. However, lack of political support for implementing the management plan and business opposition to some stepped-up regulatory programs resulted in legislation in 1990 which weakened the Puget Sound Water Quality Authority. With the increasing pressures of rapid population growth, the absence of an organized constituency for the Sound raises the question of whether efforts to protect the Sound can be augmented and sustained.

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INFORMATION FROM OTHER REGIONS

The purpose of site visits to other regions of the country was to learn how non-governmental organizations and efforts had succeeded (or not) in supporting estuary protection efforts.

East Coast Interviews

Interviews on the East Coast focused on three geographic areas—Chesapeake Bay, Narragansett Bay (Rhode Island), and Boston Harbor/Massachusetts Bay.

Non-governmental organizations are important and highly effective in both Chesapeake and Narragansett Bays. Each area hosts a dominant non-governmental organization—the Chesapeake Bay Foundation and Save the Bay, respectively. In Boston, a small organization, Save the Harbor/Save the Bay, is facing an uncertain future.

The Chesapeake Bay Foundation has an annual budget of more than $6 million, a membership of approximately 75,000, and a staff of about 100. Save the Bay has a budget of just over $1 million, a membership of about 15,000, and a staff of approximately 25. At the other end of the spectrum, Save the Harbor/Save the Bay has a budget this year of about $76,000, a membership of 2500, and a staff of two.

The Chesapeake Bay Foundation and Save the Bay occupy similar niches—both are advocacy organizations with strong education programs and broad-based support in the community. Chesapeake Bay has an especially wide variety of other non-governmental and governmental organizations, each occupying different and, for the most part, complementary niches. Another significant non-governmental organization focused on the Chesapeake, the Alliance for Chesapeake Bay, plays a facilitator/convener role, mostly in direct support of the governmental Chesapeake Bay Program.

Major themes of the East Coast interviews were:

> Effective non-governmental groups are very important. Advocacy has been important in all cases; there are various niches to be occupied and styles to be employed.
>
> Broad-based community support, including from people in the business community, is very important.
>
> It helps when there is a visible crisis or problem.
>
> Organization-building (fundraising, visibility, strategy) is a top priority.

Multi-year funding is very important for start-up; a strategy to sustain both action and fundraising is necessary.

Vision and leadership are essential for success.

"Wins" or other definable successes are the best way to sustain funding and build organizations.

It's good to have some young staff who don't know that some things are impossible or ridiculous to try.

California Interviews

Two areas where estuary protection activities are very active—San Francisco and Santa Monica Bays—were the focus of interviews in California. Heal the Bay in Santa Monica and the Save San Francisco Bay Association are the central non-governmental organizations in each case.

In Santa Monica, all interviewees agreed that the Heal the Bay organization has been crucial in focusing attention on the issues and getting government to respond. There is an effort underway to forge more formal and coordinated working relationships between Heal the Bay and other organizations. This coincides with Heal the Bay becoming a fully staffed organization. Business cooperation and involvement has not been a major factor, with the exception of the tourist industry.

In San Francisco, there was a strong consensus among interviewees that it was critical to have both an organization with a single focus on the Bay (Save San Francisco Association) and a variety of other organizations with narrower and broader interests and expertise. The Save San Francisco Bay Association has taken a long time to move from an exclusive focus on the problem of filling in the Bay to a broader involvement in Bay quality issues, but their 30-year history and large, broad-based membership give them clear leadership on Bay protection. There is now a formal effort led by the Association to develop and implement a coordinated long-range strategy, or "campaign," among a large number of organizations interested in aspects of Bay protection.

While recreational and fishing interests have worked very cooperatively with environmental advocates for San Francisco Bay, relationships between the business community and environmentalists are poor. In both Santa Monica and San Francisco, the scientific credibility of the organizations was criticized by some.

The San Francisco Foundation was singled out as a very important funder of environmental protection organizations in the Bay area.

Great Lakes Interviews

The Great Lakes region is huge, compared to Puget Sound and the other estuary areas examined in this study. Major environmental organizations are involved in the effort to protect the lakes, and much of the policy "action" is at the federal and international levels.

There is not a dominant organization for the region analogous to the Chesapeake Bay Foundation or the Save San Francisco Bay Association. Quite a few groups coordinate their activities and feel they have divided the "turf" amicably and effectively. Great Lakes United, an international umbrella organization of advocacy groups, serves as a network and a coalition. The Center for the Great Lakes, a non-advocacy convener/communicator organization with strong ties to the Great Lakes Governors, was seen by most interviewees as helpful but not crucial. There has been significant success in bringing together non-governmental efforts across the U.S-Canada border, exemplified by the international composition of Great Lakes United. Interviewees were strong advocates of the coalition approach.

Major regional foundations have been essential funders of Great Lakes protection activities by non-governmental groups. Business interests have not been significant players in the effort to protect the lakes, despite early efforts to connect the issues of economic revitalization with environmental quality. State governments have allied themselves in significant respects with advocates for the lakes through the Center and several other quasi-governmental mechanisms, although these groups have shied away from controversial parts of the protection program—some of the toxics issues, for example.

PUGET SOUND AREA INTERVIEWS

Current vs. Desired Efforts

Almost all interview respondents believe strongly that there is a need for greater non-governmental citizen action to foster the protection of the Sound. Respondents generally believe that while local community efforts around Puget Sound often are effective, there is an absence of a non-governmental voice or conscience for Puget Sound as a whole, and there is no coordinated strategy among non-governmental groups. Interviewees generally perceive the biggest unmet needs as advocacy for and education about the Sound.

Interviewees generally judge non-governmental groups as very ineffective in lobbying and translating concern about the Sound's well-being into political action and policy change. Many elected officials and agency and legislative staff people noted the lack of lobbying on the issue of protecting Puget Sound.

Respondents generally believe that an entity working to protect the Sound must have stature and credibility. Some interviewees also believe that such an organization should have a broad and large membership (between 10,000 and 30,000 members). Many believe that a clearly stated mission is very important for the success of any effort to protect the Sound.

Interviewees expressed varying ideas about the functions a Puget Sound organization should perform, most often stressing advocacy and education. Legislative lobbying, "watchdogging" government agencies, media outreach, and litigation were among the strategies and tools of advocacy discussed. Respondents vary in their opinions about the style and strategies of advocacy, especially in the use of litigation. Overall, almost all interviewees believe that the primary functions of a non-governmental Puget Sound organization should be education, advocacy, organizing citizens, lobbying, and maintaining pressure on polluters to stop polluting and on public agencies to do their jobs.

Interviewees believe that an "ideal" organization's board would possess "clout," and the staff would be capable of providing legislators and the public with reliable information, utilizing the media, and raising funds for the organization. Some respondents associated with the Puget Sound Alliance stated that the Alliance is being revitalized and could be the core non-governmental organization to protect the Sound. Other interviewees point out that the Alliance will have to be significantly expanded and strengthened if it is to play a central role in organizing citizens to support the Sound. Some interviewees believe a new organization should be created, designed at the outset to be as effective as possible. Others stressed that this might lead to unnecessary confusion and fragmentation of effort. Among interviewees who didn't have a strong opinion about exactly how the effort should be structured, there was a view that "whatever works" should be implemented.

Some organizations dealing with other issues were mentioned in the interviews as possessing qualities to be emulated, such as the ability to gather and maintain public support, to organize fruitful discussions around important issues, to work cooperatively with their members, to keep clear missions in focus, and to achieve overall political clout and stature.

There was considerable interest in including Canadian interests in an effort larger than the protection of Puget Sound, but differences in opinion about when or how this might be structured.

Constraints and Opportunities

Interviewees articulated many constraints and challenges facing an effort to mobilize an effective non-governmental organization: the lack of a visible crisis; other important environmental issues competing for attention; ani-

mosity and tensions around Initiative 547; size and diversity of the Puget Sound region; need to address growth issues directly; difficulties of raising money; fragmentation of the environmental community; and reluctance of the business community to get involved in such an effort.

On the other hand, opportunities and strengths were cited by interviewees: significant pro-Sound interest and energy in the community; potential leaders in communities all around the Sound; broad-based concern and support for environmental protection; business interest in supporting environmental protection; the recent visibility of the Soundkeeper program; and other recent success stories, such as the Washington Wildlife and Recreation Coalition and the Timber, Fish and Wildlife Agreement.

FINDINGS

Regardless of the non-governmental organizational structure that is developed in the Puget Sound area, there are key functions that need to be performed: (1) focus on Puget Sound; (2) advocacy, including lobbying of elected bodies and officials, and monitoring or "watchdogging" Puget Sound-related issues and agencies; and (3) public awareness and education.

Organizational characteristics that were consistently stressed in the interviews and observed in the most successful organizations: (1) clarity of mission and message; (2) strong leadership, credibility, and expertise of board and staff; (3) large membership base; (4) significant initial funding, and a long-term funding strategy; and (5) strong roots in the communities all around the Sound.

OPTIONS

Options to organize non-governmental efforts focussed on the Sound are not mutually exclusive. Our "working list" includes:

1. Maintain the status quo.
2. Strengthen the Puget Sound Alliance.
3. Create a new, broad-based organization as an advocate for Puget Sound.
4. Establish a "Campaign for Puget Sound" as a new organization, with a major purpose of working with existing organizations around the Sound to develop and implement a coordinated strategy to advocate protection of the Sound.
5. Create a new organization as an advocate for Puget Sound as part of a larger mission, for example, including contiguous Canadian waters.
6. Establish an organization to bring together environmental, business and

other interests to develop and focus on a common agenda for the protection of Puget Sound.

7. Establish a "Friends of Puget Sound" organization as a way to organize support from the business community for fundraising, awareness and education activities.

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PANEL DISCUSSION

James Long (Washington State University, and the moderator) and the speakers, John Armstrong (EPA), Tom, Leschine (University of Washington, School of Marine Affairs), Andrea Copping (Puget Sound Water Quality Authority), and Katherine Fletcher (University of Washington, Graduate School of Public Affairs) were joined by Rich Shikiar (Battelle Seattle Research Center), Marcia Landolt (University of Washington, College of Oceans and Fisheries Sciences), Robert Bish (University of Victoria, School of Public Administration), and Daniel Jack Chasan (Vashon Island Groundwater Management Advisory Committee) for a discussion of governance issues with the audience. Professor Long began by recognizing Dr. Leschine.

Tom Leschine: Maybe I promised too much, but let me take a stab at what I said with regards to new versus old Puget Sound Water Quality Authority. First of all, let me start with the classic academician's disclaimer. Do I have a predictive model? Certainly I don't. I think Bob [Bish] was talking about that this morning. This is an empirical study. We had a theory that creates a set of expectations, as opposed to predictions. And I think we have found a fair number of the expectations verified in our study of how various problems were handled through the course of the 1980s. So in some ways what I will provide you with will be questions, rather than answers. In other words, "What would I look for in this new organization that would answer the question for me about how it is, compared to the old one?" Let's try it that way.

Let me say a few things. Just to underscore what some of that framework suggests, I think the point that Kathy [Fletcher] made about having an organization that is focussed on Puget Sound really is fairly essential. The theory says it is, and it seems like some of the things that happen certainly only happen because of that Puget Sound focus. What I said about PSDDA, for example—those were organizations that in theory could have always done what they did, but never really did because the problem of dredging policy was so entangled through [the involvement of] many agencies and even say, a particular agency like the Corps of Engineers. That is, what the Corps of Engineers had to say about dredging disposal policies in Puget Sound was related to the policy for the Corps nationally. There was no incentive for them to break that linkage and sit down and look at Puget Sound.

Well, we do credit the Water Quality Authority with providing the "energy of activation," if you will, to cause people to be willing to suspend their normal way of dealing within their own agency focus, to look at the problem on a Puget Sound level *per se*. So in terms of expectation, do I expect a Department of Ecology that covers the whole state to be able to do that as well over the long run? I guess I would say that I personally do *not* think they will do that as well.

Kathy also mentioned the question of the "watchdog." I think that is a very

important role that the Authority played. Maybe watchdog is too unkind a word; its more like the new kid on the block who doesn't necessarily play by the same rules because it is a new kid and doesn't have rules that go back decades. The Authority seemed to us to be willing to ask new questions, willing to explore the idea of attacking problems in new sorts of ways. And I will just say again, in terms of expectations, old dogs don't necessarily take on new tricks as easily, right? So, in terms of an expectation, no, I don't think over the long haul, speaking personally, that the Authority that sits in the Department of Ecology will be as adept at coming up with novel approaches to problem solving.

Now, I mentioned questions instead of answers. I would just ask, what was it the Authority really did? I wrote a paper last year about what I called agenda-setting for Puget Sound. One of the things that was very interesting about what the Authority has done is to be what I would call an "agenda-verifying organization." This is, they were very good at going out to the public and saying, "What's on your mind?" And then when they thought they had the list of the Puget Sound problems, going back [to the public] and saying, "Are you sure now? Is this really what is of concern to you?" In other words, very much of a consensus-building kind of operation.

Well, as a question, and not a criticism of the Department of Ecology at all, how will they take care of this in the future? How will new items appear on the agenda? Because one of the things in the game of pollution management is that what's on people's minds is constantly changing. How adept will they be at spotting new issues, and maybe even forcing it a little bit to get people to talk about things?

And then I would ask, as a last comment: How will they do when new problems come up? Let me give you a candidate, which may be going out on a limb a little bit. All of the storm destruction last month, to my mind, raised two questions: wetlands policies, and the positively feudal system of diking that exists in many areas. Its like in Northern Italy, in hill towns where someone builds a tower and somebody else builds a taller tower—that seems to be the policy for dike construction in Snohomish County. Well, this is a very ripe policy issue right now, and it is a Puget Sound issue. How is it going to be dealt with? I am just asking a question—I don't know.

I think there is another [example of an emerging problem]. I saw an excellent television special in North Carolina recently that was put together locally and showed what's wrong with all the shoreline hardening that has been done in that state. It was a brilliant presentation of what can go wrong. [We tend to think of shoreline hardening as an East Coast problem, but I don't any more.] I think it is our problem, too. We have hardened a lot of the Puget Sound shoreline with jetties, etc., and we have experienced a lot of exactly what the

models predict happens. When the really big storm comes, it goes around the dike and undercuts it. It destroys it, and then it wipes out [what's] behind it.

Now, what's your policy going to be? Rebuild the dikes even stronger, as I saw one guy in the paper announce he was going to do? Or are we going to rethink this whole policy, as they very courageously have done in North Carolina? I think the tests of the new Authority are going to be how it deals with these issues as they apply to Puget Sound. And I think certainly these two do have strong applicability right now. Are they going to quietly slide away? Or are we going to try to run with them? I am sure others on the panel have comments.

Jim Long: Are there responses from the panel?

Daniel Jack Chasan: Well, I will put this in the form of a question to start with. You were talking about the ability or the inability of the new group to keep abreast of what's on people's minds at the moment. I would ask to what extent the group should really be doing that? Should it be perpetually ready to change its focus? Can it really accomplish what has to be accomplished, looking at a task like preserving and protecting Puget Sound, if it does continually change its focus?

Tom Leschine: As I pass the microphone to Bob Bish, I'll simply say that I think in the long run you can't win without public consensus. But I agree with your point, that you can't keep changing the program to follow the whims of the public.

John Armstrong: I wanted to ask Kathy Fletcher a question. Talking about an advocacy group for the Sound, I guess I always thought that the Authority was an advocacy group for the Sound. I guess I could see some advantages of a private advocacy group. But from your unique position as former head of the Authority, are there things that the Authority should be doing that they are not doing now, that you would suggest they do?

Kathy Fletcher: To the first point, wasn't the Authority an advocate for the Sound, I think there is a crucial difference between what government can accomplish and what nongovernmental organizations need to be doing. What we saw over the 5 years of the Puget Sound Water Quality Authority was certainly an example of a government agency taking its job seriously, in terms of protecting the Sound and doing what it was charged to do, but also being unable, as a government agency, to withstand the counter pressures in the political environment without a nongovernmental advocate rising to the occasion. I think that is the crucial issue here, whether a government agency can ever, in the absence of effective public support, do its job or try its level best. I think that is the crucial difference, and I would say that an agency such as the Authority, in doing its job well and in being accessible and trying to

communicate effectively with the public, can foster that kind of constituent support, but can't substitute for it.

Bob Bish: I found it very interesting to hear Kathy's report on going, for instance, to Maryland to learn about the Chesapeake Bay Foundation, because when I went to the University of Maryland in the early 1970s they certainly would have been sending someone *here* to learn about the Washington Environmental Council. The kind of things that they are studying elsewhere went on here in the 1960s and 1970s to an unbelievably strong degree. When I looked at the list of attendees, here, I had the feeling that everybody had gone to work for the government! Nobody is left in all of the interest groups that used to be active in these things! And I mean that in a very serious way. The[re is a] lack of attendants [from interest groups] here today, compared to the 1983 Puget Sound water quality conference, where a *very* high percentage of the people were from the nonprofit interest groups and so on that had generated all that activity of the 1970s. I wonder how you get that back?

Secondly, Kathy [Fletcher] mentioned a problem of the specific interest versus the general interest. That is simply a long standing issue in politics. Consumers don't fare well compared to industries, general doesn't compare well to specific. The only way to alter that is to institutionalize the general interest in some way, and of course that's what the Puget Sound Water Quality Authority was attempting to do. That's hard to do in an ongoing [general] interest group. Its easier to keep a fishing club, a hunting club, a sailing club, a port authority's association [going, but] its really difficult to keep that private organization that is a general interest group [going]. Its just a little bit too broad, and we just have to recognize that as a constraint and try to keep these things institutionalized and cooperating with those special, narrower interests where that leads to a cleaner environment.

Q. *Ron Thom (Battelle)*: I have a question for Andrea Copping, relative to the scientist taking a more public role. As you know, the two things that a scientist has that are most valuable are data and credibility. Without that we have nothing. And so to develop an opinion and to go public, we need data in order to maintain our credibility. Recently, for example, I have been involved in several meetings regarding eelgrass issues in the state. Its becoming a real issue. In the last two years I think there has been approximately $100,000,000 worth of projects that have either been delayed or stopped, due directly to eelgrass issues. The question that comes up at these meetings over and over again is, "what constitutes a functional eelgrass patch?" In lieu of any research that has been done, the number of 10 sheets/meter^2 keeps coming up. We use that as a measure of a functioning patch. Well, that's based on no data. In fact, that was an opinion of Ron Thorpe's of about 15 years ago. He said 10 sheets/ quarter meter^2. So 10 sheets/meter^2 is a mistake! That keeps coming up, and we are having to deal with large projects with no data to really evaluate what a functioning patch is.

The point is, without any data a scientist really can't render an opinion. Research in general tends to be thought of as a nice thing to do, but nobody ever wants to fund it. With eelgrass, the agency's opinion is, "Well, the developer's developing, so it is their responsibility." The developer comes back and says "We don't want to do research because it affects our cost/benefit ratio," so nothing really gets done.

So, based on existing data, I would predict that research won't get done because nobody is really willing to fund it. This is just an example of why scientists have been unwilling to render opinions, because in many cases the questions haven't been addressed on a scientific basis. I think this gets back to what Marcia [Landolt] talked about on the first day. Really, the specific studies haven't been done. Do you have any comments?

Andrea Copping: I appreciate your comments entirely, and I agree. It is a very basic dilemma, and I agree with you. Without data and credibility, as scientists we are nothing. And I am not suggesting that scientists "wing it," and simply make up information for the public. What I am suggesting is that scientists must be willing to translate that information into something that is digestible and significant for the public. In many cases, and I think the wetlands issue is a good one, there has been so much written and said, but there have been very few clear indications that we *really* don't know how [wetlands protection] works. The only way we can be sure that we will have any of these wetlands for our grandchildren is to stop right now. And that's probably an extreme view for many people in this room.

I don't in any way [mean to] suggest that the research shouldn't be done, and I think the public information route is a very good one to get the public to understand that the research needs to be done. If we as scientists don't show the public that they are getting something for their research dollar, they are not going to put that dollar out.

Richard Shikiar: You mentioned speaking from data and restricting your comments to data. You also said that money isn't being spent on research in this country. This coming year the U.S. will spend approximately 150 billion dollars on research. That's almost as much money as we lost in the Savings and Loan crisis! But that is quite a bit of money. So, quite a bit of money *is* being spent on research. And I think it is the duty of scientists to make informed judgements both based on the data they have collected and as to the value of other research that is going on. It is better for scientists to make informed judgements and try to inform policy makers about their opinions than for the policy makers to make completely uninformed judgements based on no data whatsoever.

Daniel Jack Chasan: I would like to make a couple of points on that, too. I agree

with what you just said. Also I would say that people are going to be making judgements on the basis of what is, or is alleged to be, science. Some facts, or some alleged facts, are going to be out there, and the people who really know about the subject may as well "weigh in," because the decisions are going to be made with or without them.

Another point is that the specificity, the level of detail, that a scientist feels comfortable with in presenting his or her research to other scientists may be many times more precise and more sophisticated than public decision makers want or need. The needs [of scientists and public decision makers] are different. The fact that you don't have something out to the 4th decimal place yet doesn't mean it can't be used yet in a public decision-making context. And in fact, *usually* in a public decision-making context that level of precision is useless anyway.

Robert Bish: My own observation is that it is not simply a lack of research that leads to science not being used often in public policy. And I frankly don't know what the answer is, except that there is very little research or teaching about the use of science in public policy making. We are, in fact, searching for a faculty member who would have that particular kind of expertise; that virtually means an undergraduate, perhaps a masters degree, in science, plus a Ph.D. in public policy-making in order for it to become a true "area." There is not a lot on that particular problem. We know the problem is serious, but it seems to fall between the cracks.

I want to bring up an example [that Andrea Copping used] today. The [installation of] secondary [sewage] treatment in Puget Sound—someone seems to have the idea that the issue was how clean the water was. From reading the hearings prior to the 1972 legislation, which Senator Proxmire from Wisconsin chaired, it is clear to me that *his* concern was that any costs imposed on firms in Wisconsin also be imposed on firms elsewhere that might be competitive with firms in Wisconsin. It had nothing to do with the fact that there might be tidal environments where you didn't need to spend as much on sewage treatment. In Wisconsin you *did* have to spend the money on sewage treatment. So it had nothing to do with how clean the water was, it had to do with competitive advantage and disadvantage. I don't know what happened later on, after those hearings, but it is clear that that agenda carried through with a momentum that was, from my point of view as an economist, terribly wasteful of public funds.

Q. *Rod Pemble*: I am a high school teacher from Mount Baker district. I would like to make a couple of quick observations on points that the panel just made. First, there is a stumbling block which I deal with at the high school level as well as in general relationships with other people I know: the public's perception is that science equals proof. I think that is a major obstacle to solving many

of the complex issues that face us, in Puget Sound especially. I wonder if that hinders some scientists from entering the public arena, because they sense that perception. They know they can't come on to a television program and say, "Yes, I have proof, this is the way it is, without a doubt." And so they withhold whatever statement they might otherwise make.

Second, something that happened yesterday to me here is indicative of another problem. I was downstairs looking at one of the poster displays, and someone noticed my name tag and saw that I was from a high school. The first thing they asked me was, "Oh, Why are you here?" Who the person was, and what they were doing here is irrelevant, but it is a symptom of the fact that I am not sure the conference knows why it is here. I think there is a little schizophrenia about the purpose, and I think that led to not having the broad representation of people participating that the organizers were after.

Finally, a question for the whole panel. Given these situations—absence of really tough regulatory action over the last decade, arising complex issues like stormwater ... [lost tape] ... [with this] array of situations, [how can scientists] imagine themselves stepping into that, and having to compromise what they truly believe is the situation about a particular issue. Why do we expect them to do that? It would be amazing to me that somebody would jump into that, knowing that they almost certainly are not going to be able to stand on the data that they *have* collected.

Andrea Copping: I'll step into that one. I think the main reason to step in is that, scientists or not, we are citizens of the Puget Sound area. I am probably a little naive and idealistic in these things, but I think that we as scientists or you as a teacher, or whatever else many of us do in our professional lives, have to contribute what *we* have. Someone said that somebody is going to make those decisions, and if you want decisions made with scientific credibility surely the scientists are the best ones to step into it. It is very true that some of us are going to get bitten doing it, but I don't think that is a reason to stop.

Jim Long: David (Jamison), I don't mean to put you on the spot, but do you have any response to any of the earlier comments?

Dave Jamison: Well, thank you for putting me on the spot! Speaking from a scientific perspective, and from the kinds of conversations we have had prior to this meeting, I think the discussion is very healthy and that it leads in some of the directions we would like to hear. It has been very much of concern to us as to how to *translate* this information from the scientist to the policy-maker and back again. I think we are coming very close to identifying a variety of different elements that will create the solution. As I am sitting here today, my mind runs from one solution to another, and I don't think there is just one solution. I think there is a variety of solutions. The more [solutions] we put out

on the plate the more opportunity we will have of getting at least some that will tide us through this transition period between a time 30 years ago when we had no concern for the carrying capacity of Puget Sound and its viability, and some time in the future when we have the proper kinds of attitudes and we are designing the kinds of systems we would like to see operating.

Q. *Jeff Bowman (Clallam County)*: I posed this question at the watershed conference held here in November [1990], [but] this is a group to whom I think it is far better directed. Being from an agency responsible for implementing watershed plans and generating citizen involvement at a local level to try to deal with these kinds of issues, I find it fairly frustrating—and I would be interested to have your comments on the notion—that those of us who are responsible for fixing these problems, for resolving these issues of addressing the accumulated flotsam and jetsam of the past 30-40 or 100-150 years [have to defend our actions]. Why do we have to be the ones who have to prove beyond some level of doubt that a change in the way things are done is necessary? Why is the burden of proof on those of us who would try to maintain the natural systems or retrieve the natural systems? Shouldn't the burden of proof be on those would advocate the alternations and changes?

Daniel Jack Chasan: Well, I don't know whether the burden of proof should be on those of us who are trying to do such things—and I speak as somebody who has been involved in a lot of that kind of thing on a very local level myself—but that's certainly the way it has always worked. You say shouldn't the burden be on people who want to alter the natural systems, but inevitably, the way it works, the question gets turned around and the burden gets put on people who want to alter the current human way of doing things. Since we are working more in a political and social [context], for better or worse, than a biological context, I think that is the way it has to be.

Q. *Unidentified audience member*: I would like to comment on Andrea [Copping's] comments and the subsequent discussion about the role of scientists in making public pronouncements on policy decisions in particular. It seems to me that there are actually two issues involved, and I heard both coming from the panel. The first is whether scientists should have adequate peer review of pronouncements prior to making those pronouncements public. That is one issue, whether there should be adequate peer review, particularly through peer-reviewed professional journals and so forth. The second issue was what role should scientists have, generally, in advising or making public statements about policy. The two areas, I think, are distinguishable.

On the first hand, there is a lot of controversy and arguments about what level of peer review should be required before making public pronouncements, because it is all based on, essentially, scientific collegiality and consensus, and

agreeing on a particular statement of fact and what is fact. The second issue really has to do with the relation of scientists to a broader population—the public—and accountability and responsibility for those sorts of things. Both of those issues have been studied, at least for the past two decades that I know of, and prior to that probably, through the various social studies in the sciences. There is a lot of literature on what constitutes science, how scientific facts are agreed upon, ethnographic studies within the laboratory itself. I am not trying to discredit science as an entity itself, here; I am simply trying to raise the question of what the adequate role of scientists in relation to the public ought to be, and what the relations between science/technology and society are. I'll simply put that open, particularly regarding controversial areas which require public policy decisions being made.

Q. *Lon Freeman (Olympia)*: As you were talking I was think of a very thought-provoking article I read a couple years ago by Bill Clark at the Kennedy School about the roles of experts in public policy arenas. I think the point to underscore here is that we are talking about this issue as if there is a magic formula [that determines the] best way for a scientist to interact. The article really made the point that there is not. The reason that there is not is roughly as follows: basically, it is a bigger leap from the scientist, in his or her laboratory, to the real world than I think most scientists are aware of. That is, as you and others have properly pointed out, the scientist in the laboratory is fundamentally ruled by a peer-review system and whether or not the consensus of the scientific community is that the work is good work, the result is correct. But consider all of the other ways that a piece of scientific information going into the public arena can legitimately be evaluated. For example, if you are doing it as a piece of contract work for an agency, what the contract manager thinks becomes very important. But beyond that, when you get to the public, how does the public assess the value of science? Peer review may have nothing to do with it. [More important may be] a general perception of the validity of the person as a scientist like the public would get from reading the papers, and so forth. The newspapers may become all important.

You can go far beyond that, too. When you get into the really controversial areas, how is the science done? What was the role of outside commentary and even the public in the research? The best area I can think of is AIDS research. AIDS activists basically have demanded that they be part of the process of picking scientists to do the studies, [and have been] participating in studies, designing the epidemiological aspects of studies. In other words, citizens with a big stake in the problem essentially are demanding to do what scientists have always assumed was theirs to do. When you look at the problem of the scientist in society from that perspective, recognizing that there are many different, legitimate roles of criticism (of evaluation if you will) of the scientific result that is being inserted into the policy process, and when you recognize that there are many different groups in society that legitimately can pursue the question

from many different points of view, I think you come to realize that there just is no simple answer to this question. Different people will evaluate the correctness of a piece of science from fundamentally different perspectives that really don't clearly relate to one another.

Q. *Maura O'Brien (DOE)*: I want to build on some of the comments that were made, and ask your opinions and recommendations. Andrea Copping made the comment earlier about the role of scientists, and I think that it is very important that we as scientists—I am a geologist—learn to speak up and participate in decision making, especially in terms of land use decision making processes. At the same time, it is important to look at the other side. Communication is a dual process, and those decision makers need to look toward experts in the field. The field of geology [for example,] is incredibly large—you can't be an expert in volcanology, and in land slides, and in ground water, etc., etc. So our decision makers are not expected to be experts, but rather to seek advice from those people. I want to get it on record that the people in the decision making process should be encouraged to ask for guidance. That doesn't mean they have to take it all, but certainly it would be beneficial to have more active selection or sources of information for that decision.

The other point is that we are talking about Puget Sound, and somebody said in the hall that we don't even know where this conference is going. I think it is very significant that we are here today, giving up our Saturdays, because we owe it to Puget Sound. And I think it is very important that the panel that organized this [conference] get a clear, loud round of applause for their efforts as well as the knowledge that 200-300 people are going to carry home a much stronger commitment and understanding of how they can participate more actively in making Puget Sound improve its environmental integrity and quality. This goes back to an earlier statement by Professor Bish about the Federalist papers and Tocqueville. We have come through an era of the individual, and now we are starting to look back to the community, and this is what Tocqueville talked about. It was a struggle in the 19th century [of the] common person versus societal higher ups. I think we are at a point where we have to stop thinking so much individually and start looking collectively, as a community. And this is where I ask the Puget Sound Water Quality Authority, what would they like to see the next step? Do they want to recreate themselves? Do they want to see a non-government organization? What is the next step, and how can we more effectively get information to the media? How do we make that next movement?

Jim Long: Thank you. I would like to thank the panel, and to recall a quote from Thomas Jefferson, some 150 years ago. He said, "I know of no safe depository of the ultimate powers of society but the people themselves. And if we think

them not enlightened enough to exercise their control with a wholesome discretion, the remedy is not to take it from them, but to inform their discretion by education." I want to thank each of the panelists for helping to inform our discretion, and each of you who participated for helping us think more finely about each question.

* * * * *

PUGET SOUND

RESEARCH '91

WATERSHEDS: PROGNOSIS AND PRESCRIPTIONS

Session Chair:

David Somers, Tulalip Tribes

INTRODUCTION

David Somers [1]

It would be fair to say that the health of the physical and biological resources of Puget Sound is inextricably linked to the health of the Sound's tributary watersheds. The more than 10,000 rivers and streams within the Puget Sound basin discharge approximately 27 million acre-feet of fresh water annually (1986 State of the Sound Report). These same streams and rivers create great estuaries rich in fish, shellfish, and wildlife resources. They produce valuable runs of salmon and steelhead. We use their water for agriculture, for industry, for power, and for human water supply. They create an environment for human and non-human life which has always provided food and water in abundance.

Increasingly, we also use these watersheds to carry away our wastes. We expect them to be not only suppliers of valuable resources, but also repositories for unwanted products of our society. We also cut their forests, dike their floodplains, dredge their beds, and dam their courses. We allow our livestock to destroy their banks and pollute their waters.

We expect our watersheds to continue to serve our many needs. However, it is becoming increasingly clear that we cannot anticipate a future which provides the same resources we have enjoyed in the past unless we control our demands from these systems. The control of these demands presents many problems. Do we truly understand the effects of our mistreatment of watersheds? Do we even know what activities differentiate wise use from abuse? How can we use existing technology to study and understand river and stream networks? Despite the incongruous borders of watersheds and human political boundaries, can we effectively manage watersheds?

Today's panel of speakers has been convened to address these wide-ranging issues. They have been asked to share their experiences and knowledge with us regarding the study and management of Puget Sound watersheds.

Our first speaker will be W.T. Edmondson. Dr. Edmondson is well known for his long-term interest in Lake Washington, and his work on the effects of human activity in the watershed has been widely credited with precipitating the end to municipal sewage discharge into the lake. Dr. Edmondson will speak to us about his continuing studies and the persistent impacts of the growing human population within the lake's basin.

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Next, Cedar Cole and Nancy Hansen will describe the recent regulatory strategy adopted by the Puget Sound Water Quality Authority for management of non-point pollution sources within Puget Sound watersheds. This approach will be analyzed for its responsiveness to political, legal, and financial constraints as well as to water quality degradation and protection.

Roberta Feins will provide us with a case study of watershed analysis and management. In particular, Roberta will describe the development and use of a geographical information system (GIS) to facilitate the understanding of nonpoint pollution within Portage Creek, a tributary to the Stillaguamish River. She will also address the future potential of GIS in watershed management.

Carlyn Orians will continue the discussion of the use of GIS in watershed management. Carlyn has used GIS as a tool to project the likely state of the Portage Creek watershed, given our current expectations for human population growth within it. These likely scenarios can serve to guide development of the watershed in order to avoid future degradation of the system.

Finally, Oscar Soule and James Neitzel will discuss their experiences with the development of a plan to rehabilitate a small urban stream which has been severely degraded. This case study provides an excellent example of the difficulties in bringing together the resources necessary to accomplish stream rehabilitation. It also highlights the opportunities for watershed improvement made possible by the recognition by representatives of public and commercial interests of the potential biological and aesthetic values of a previously lost resource.

RESPONSIVENESS OF LAKE WASHINGTON TO HUMAN ACTIVITY IN THE WATERSHED

W. T. Edmondson[1]

INTRODUCTION

Lake Washington has shown considerable sensitivity in its response to natural, year-to-year variations in weather and to changes in its watershed produced by human activities. For example, the biological productivity and the abundance of planktonic organisms during a summer are strongly affected by the amount of rain, wind and sunshine during the preceding spring (Edmondson, 1988). Further, the lake has been subjected to several different kinds of disturbance in the watershed that have affected its condition. The purpose of this note is to review briefly three of these disturbances and to give new information about work in progress on the most recent one.

Eutrophication and Recovery

The best known episode of disturbance is the eutrophication with secondary sewage effluent from 1941 to 1968. Many chemical and biological features of the lake changed in response to the increased supply of nutrients. Planktonic algae increased in abundance and were dominated by blue-green bacteria (algae) from 1955 to 1973. These organisms can generate unpleasant conditions when abundant. However, because of effective public action, deterioration was not permitted to go far enough to make serious nuisances (Edmondson, in press a). The effluent was diverted by the Municipality of Metropolitan Seattle (Metro) during 1963-1968, and the lake promptly returned to a satisfactory condition. The blue-greens decreased progressively and have been relatively insignificant since 1976. The lake seemed to be in balance with the new circumstances (Edmondson and Lehman, 1981).

The *Daphnia* Era

Since 1976 the lake has been about twice as clear as had been expected. The small crustacean *Daphnia* suddenly became abundant, and it has dominated the zooplankton in summer ever since (Edmondson and Litt, 1982). Its feeding activity removes small algae and other particles from the water, causing the transparency of the lake to increase. Another favorable effect is that *Daphnia* now is a significant part of the food supply of the rainbow trout being stocked in the lake. This major change in the structure of the planktonic community appears to have been partly the result of a chain of effects of biological interactions that were indirectly made possible by an extensive program of flood control for the Cedar River (Edmondson and Abella, 1988).

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Increased Alkalinity

We continued to study the lake after the invasion by *Daphnia* in 1976 to see how the community adjusted to the new circumstances. For about ten years the lake seemed again to be in balance with its input. Chemical and biological conditions varied somewhat from year to year, but without definite trends. In 1987 the alkalinity in summer was about 4% higher than the year before. This was no greater than some of the previous interannual fluctuations, but the trend continued through 1988 with an additional 9% jump (Fig. 1). It was clear that the lake had entered a new state (Edmondson, in press b).

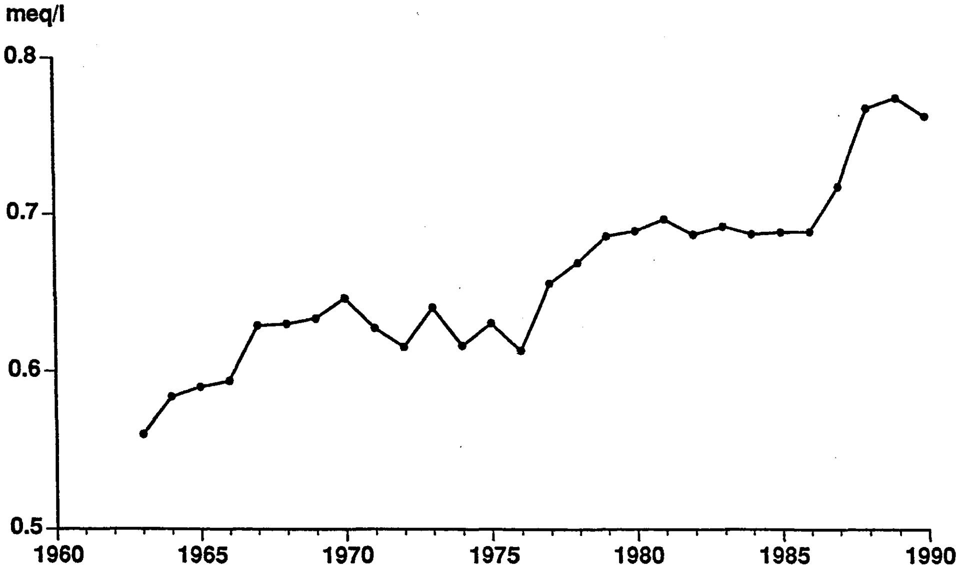


Figure 1.
MEAN ALKALINITY OF LAKE WASHINGTON DURING SUMMER (JULY-SEPTEMBER), 1963-1990.

Although the increase of alkalinity in 1988 was striking because of its abruptness, it was not unique. The alkalinity had risen during two previous periods, 1963-1970 and 1976-1979. Since no known chemical processes within the lake can account for the additional alkalinity, we looked for changes in external conditions. They can probably be found in increased land development and changes in land use in the drainage area. These changes involve converting formerly wooded areas to suburban or urban developments with concrete streets and concrete storm-water drains. The hypothesis is that the increases of alkalinity in Lake Washington have been caused by changes in the streams draining developed areas. Presumably the streams were fairly similar in their original, undisturbed state. Differences among the streams now should be

related to differences in the degree and kind of development in their areas. We reviewed the entire chemical record and established a new program to characterize the streams.

CHARACTERISTICS OF INLETS TO LAKE WASHINGTON

We are making a pilot study in two phases. The first phase is to obtain data on the chemical content of the streams. The second is to get information on the rate of increase in the area of developed land. Although this work has not been completed, it is possible to summarize the initial results.

Methods

For the first phase, we took samples for chemical analysis from most of the inlets at monthly intervals for more than a year, between January 1989 and May 1990. Most samples used in this report were taken at the mouths of inlets (Fig.2). In addition, we took samples above and below developed areas as well as in places where development is expected, thus getting data on the undisturbed condition. The methods are standard or widely used procedures. Alkalinity was determined in 100 ml samples by titration with 0.02N sulfuric acid to pH 4.3, measured with a glass electrode. Multiplication of the titration volume by 0.02 gives milliequivalents per liter, and by 10 gives the concentration of calcium carbonate that would be required to give the same alkalinity. For the second phase, information on land development was obtained from vertical infra-red or black and white aerial photographs. Five different categories of development were defined, from complete forest cover to complete urban cover.

Results

Water chemistry—In all inlets the measured properties vary seasonally, generally having highest concentrations at times of low flow (Fig. 3). Each stream differs from the others in the concentration of elements. The relation between sodium and magnesium is particularly interesting in connection with land development, as shown by the following selection of three inlets. In the Cedar River, which drains the least developed land of all the inlets, sodium is more concentrated than magnesium (by weight). The Sammamish River drainage has a larger proportion of developed land than that of the Cedar River; sodium is only slightly more concentrated than magnesium. The drainage of Juanita Creek has a still larger proportion of developed area, and the concentration of magnesium is distinctly higher than that of sodium during most of the year.

The relations among the elements and the watersheds are more easily seen by comparing the means of concentrations during the low flow summer period (Table 1, Figure 4). In general the most developed watersheds produce the

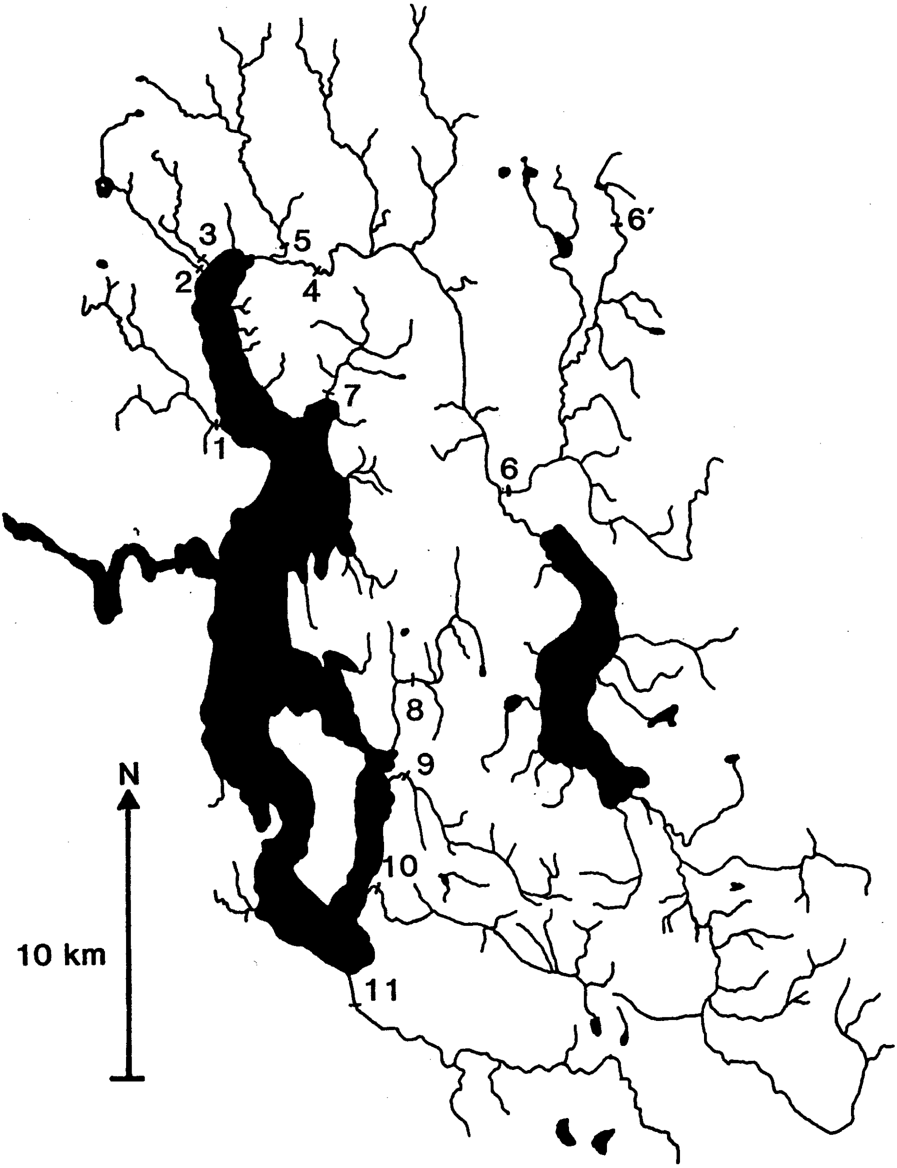
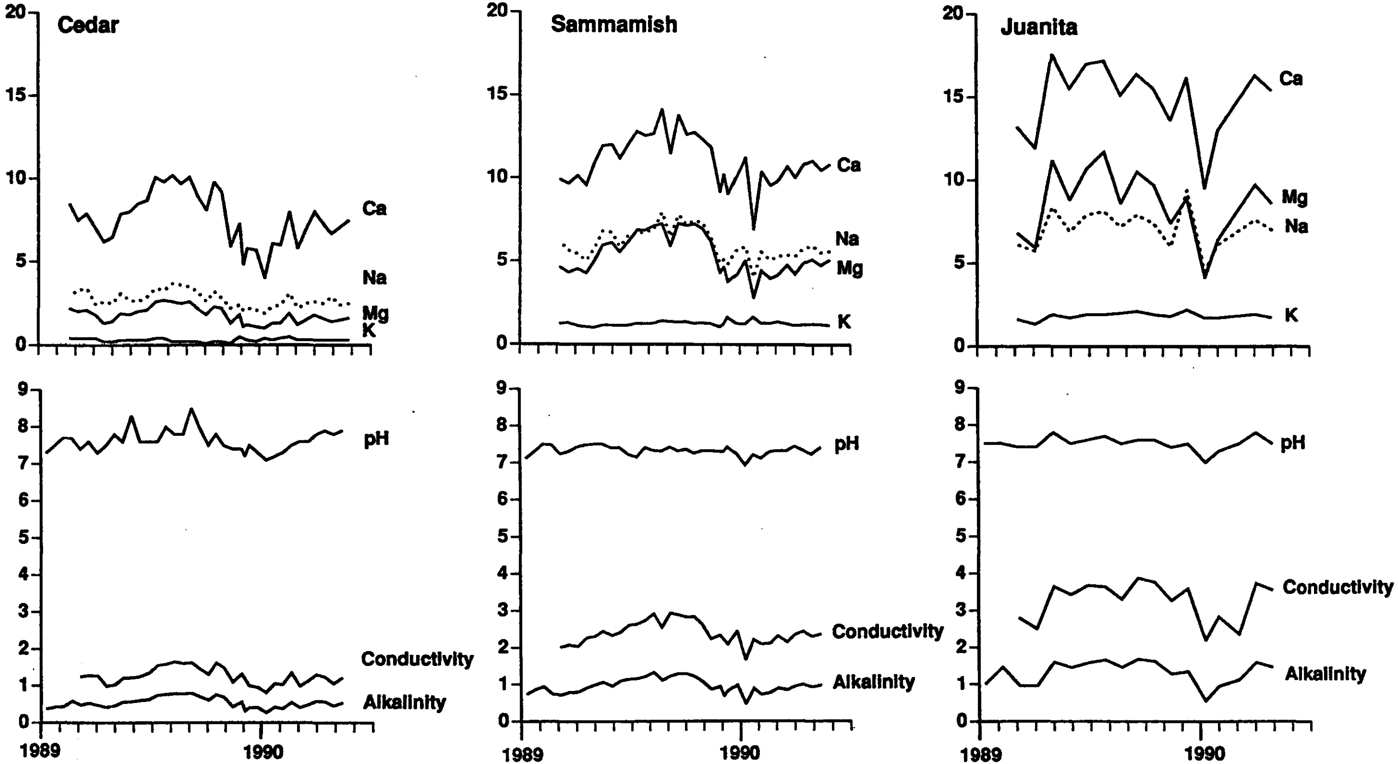
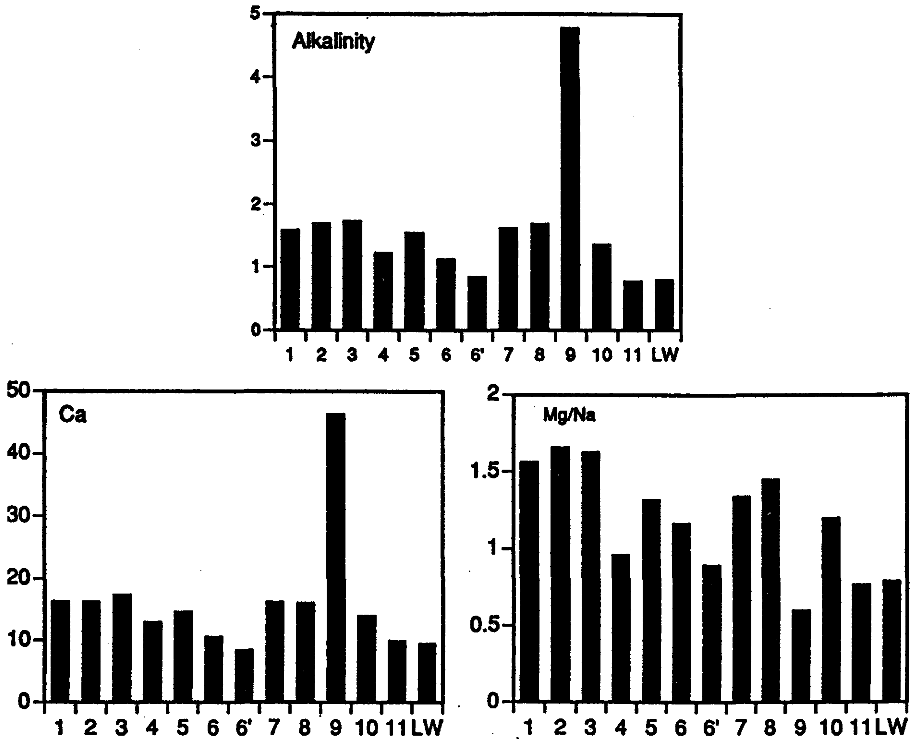


Figure 2.
MAP OF LAKE WASHINGTON AND ITS INLETS SHOWING THE LOCATION OF SAMPLING STATIONS NUMBERED AS IN TABLE 1. *All stations shown are at the mouth of the stream except for No. 6' which is 15.5 kilometers upstream from the mouth of Bear Creek (also known as Big Bear Creek). Note that the map does not include all of the watershed.*

Figure 3.
CONCENTRATIONS OF CATIONS AND OTHER PROPERTIES IN THE TWO LARGEST INLETS AND ONE CREEK. *Note particularly the differences in the relation of sodium (dotted line) to magnesium. Conductivity values have been divided by 50.*





-igure 4.
MEAN VALUES OF THREE PROPERTIES FOR ALL SAMPLING STATIONS AND THE SURFACE WATER OF LAKE WASHINGTON DURING JULY-SEPTEMBER, 1989.
See Table 1.

ıighest concentrations, but in the absence of flow data for most of the small streams, a calculation of loading is not possible. Sodium has a higher concenration than magnesium in only four of the streams presented here: Coal Creek, the Cedar River, the Sammamish River and Bear Creek. All the others drain areas with a larger proportion of developed land. Coal Creek differs greatly from all the others in almost every chemical property. It drains Cougar Mountain which is permeated by abandoned coal mine galleries. During the low flow season it receives most of its water from an underground drain that originates in the galleries.

Land development—So far we have data on land development in two small watersheds taken from seven series of aerial photographs (Fig. 5). The watersheds were chosen to represent extremes. The Juanita Creek area has little undeveloped land, while the Coal Creek area has a lot. This is, of course, too small a sample to test the development hypothesis fully, but the results are

Table 1.
AVERAGE VALUES FOR JULY-SEPTEMBER 1989. *Alkalinity is expressed in two ways, milliequivalents per liter (meq) and the corresponding values of calcium carbonate as milligrams per liter. Bicarbonate is calculated from alkalinity without correction for other ions. L. W. = Lake Washington. Cond. = Conductivity (mhos/cm at 10oC). Streams are numbered as in Fig. 2.*

		ALK. meq	$CaCO_3$ mg/l	pH	Cond.	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO_3 mg/l	Cl mg/l	SO_4 mg/l	Si mg/l
THORNTON	1	1.58	79.1	7.8	220	16.3	13.1	8.4	2.3	48.3	6.8	6.9	14.5
MC ALEER	2	1.69	84.4	7.9	197	16.2	12.4	7.5	1.9	51.5	6.7	4.8	11.4
LYON	3	1.73	86.5	7.7	201	17.3	12.5	7.7	2.1	52.7	5.9	5.0	13.1
SAMMAMISH	4	1.22	60.8	7.3	139	12.9	6.9	7.2	1.3	37.1	4.3	3.9	7.3
SWAMP	5	1.54	76.9	7.5	166	14.6	9.2	7.0	1.9	46.9	5.6	3.6	9.8
BEAR	6	1.12	55.8	7.8	114	10.5	6.4	5.5	0.9	34.1	3.3	1.8	8.6
BEAR'	6'	0.84	24.2	7.6	87	8.3	4.1	4.6	0.5	25.7	2.6	1.4	8.9
JUANITA	7	1.61	80.7	7.6	181	16.2	10.3	7.7	2.0	49.2	5.9	4.0	12.0
MERCER	8	1.68	84.2	7.6	178	16.0	9.7	6.7	1.7	51.4	5.2	3.6	11.1
COAL	9	4.77	238.3	8.4	587	46.2	30.5	50.8	4.4	145.4	9.0	39.6	10.4
MAY	10	1.35	67.7	8.0	168	13.9	7.9	6.6	1.5	41.3	5.1	4.2	11.3
CEDAR	11	0.77	38.4	8.0	79	9.8	2.6	3.4	0.3	23.4	2.2	1.5	5.8
L.W. Om		0.79	39.5	8.3	92	9.4	3.7	4.7	0.7	24.1	3.4	2.5	0.7

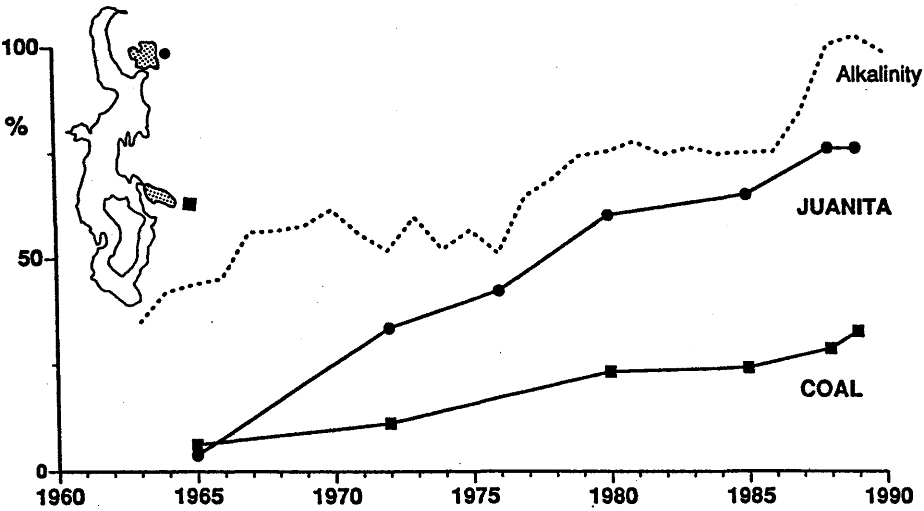
promising. In both areas, there was little development during 1980-1986, the same time when the alkalinity did not increase.

BIOLOGICAL CONSEQUENCES

Because of the diversion of sewage effluent, Lake Washington no longer has a large enough supply of nutrients to make algal nuisances with massive floating scums of the kind described for many lakes in midwestern North America and in Europe. Further, after 1976 only a small fraction of the plankton consisted of potentially troublesome blue-greens until the summer of 1988, the year of the jump in alkalinity. The small plankton population in 1988 was dominated by the blue-green *Aphanizomenon* which forms bundles of filaments looking like mini grass blades, about one eighth of an inch (3 millimeters) long. They are easily visible from a boat, especially in calm weather when the colonies float toward the surface.

It is thought that growth of this and some other blue-greens is encouraged by a combination of high alkalinity and a relatively low ratio of phosphate to nitrate during the spring. As it happens, in 1988 changes in the small inputs of nitrate and phosphate resulted in an unusually low ratio. In 1989 and 1990, the

Figure 5.
PERCENTAGE OF THE AREA OF TWO WATERSHEDS COVERED BY URBAN AND SUBURBAN DEVELOPMENT 1965-1989. *The dotted line shows the alkalinity of Lake Washington, repeated from Figure 1. The map shows the extent of the watersheds.*



ratio was considerably higher, and *Aphanizomenon* was scarce. Whether this combination of chemical conditions was responsible for the success of *Aphanizomenon* in 1988 or was simply a coincidence cannot be decided now. Even though the lake is unlikely to produce prolonged massive nuisance blooms, there could be a lessened productivity of the invertebrate animals that are an important part of the food chain leading to the valuable fish, the rainbow trout and the sockeye salmon.

DISCUSSION

From the information presented above, it seems certain that land development is responsible for at least part of the recent chemical changes seen in Lake Washington. In passing, it is worth noting an independent confirmation of the validity of this idea. A slide similar to Figure 1 was shown at a meeting of the North American Lake Management Society in September, 1989 and reproduced in a newspaper report of the meeting (de Yonge, 1989). Later I received a telephone call from Mr. Robert Taylor, a land developer and builder with experience in the area. He told me that he could see that the history of building activity was reflected in the shape of the alkalinity curve.

This work was started because of an abrupt change in the condition of Lake Washington. It was done as a small sideline to, but logical development of, our long-term study of the lake. We intend to complete the analysis of the stream

data that we have now and to publish the results in enough detail that they can be used as background by other people working on the same problem.

To complete the study of the material reported here, we intend to:

1. Characterize the watersheds and the differences between them by the chemistry of the streams. We will use appropriate statistical clustering techniques to measure the degree of similarity and difference among the watersheds.
2. Analyze the differences between upstream and downstream concentrations in relation to the land conditions between the stations. (See Bear and Bear' in Table 1).
3. Get more photogrammetric data on watershed development, with as much satellite assistance as possible.
4. Review historical data on stream and lake chemistry and special features of the development of the various watersheds.

ACKNOWLEDGEMENTS

Support for collection and analysis of water samples was provided by two grants for Long-term Research in Environmental Biology (LTREB) from the National Science Foundation (No. BSR-8516523 and BSR-8905774). The work was done by a group of expert assistants: Sally E. Abella, David E. Allison, Kathleen Frevert, Arni H. Litt and Mardi I. Varela. Their continued presence as a group was made possible by a grant from the Andrew W. Mellon Foundation. We gratefully acknowledge help with the aerial photogrammetry by Frank Westerlund and Miles Logsdon.

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RANKING OF WATERSHEDS FOR THE CONTROL OF NONPOINT SOURCE POLLUTION

Cedar Cole[1] *and Nancy Hansen*[2]

BACKGROUND

Developed by the Puget Sound Water Quality Authority (Authority), the 1987 Puget Sound Water Quality Management Plan launched a watershed management process to systematically address nonpoint source pollution throughout the Puget Sound Basin. It directed each of the Puget Sound counties to rank its watersheds in order of priority for developing action plans to control nonpoint pollution. The Authority also adopted a regulation, Chapter 400-12 WAC (the "Nonpoint Rule"), to govern the watershed ranking and planning activities. The rule became effective in April 1988 and is administered by the Washington State Department of Ecology (Ecology). Watershed ranking took place from October 1987 through December 1988 in the 12 Puget Sound counties.

Concurrent with watershed ranking was the establishment of the Centennial Clean Water Fund (CCWF) at the state level and the commencement of Early Action watershed planning. The CCWF is supported by a tax on cigarettes and provides funding for water quality projects sponsored by local governments, academic institutions, Indian tribes, and other interests throughout the state. Watershed action plans for nonpoint source pollution are eligible for funding under this program.

Twelve "early action" watersheds were funded in October 1987 to develop watershed action plans ahead of the results of the ranking program or the adoption of the Nonpoint Rule. These watersheds were selected for funding because of their important beneficial uses and strong local interest in controlling nonpoint pollution.

In accordance with the Nonpoint Rule, each Puget Sound county established a watershed ranking committee representing county and city governments and other appropriate interests and agencies in the county, including tribes. The committees identified the watersheds draining into Puget Sound and defined their boundaries. General criteria on which to base the rankings were provided in the Puget Sound plan and were further expanded into an optional ranking methodology provided by the Puget Sound Cooperative River Basin

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[2] City of Bellevue, 301 116th Avenue SE, Suite 2320, Bellevue, WA 98009

Team[1]. In each county, the final rankings were adopted by the committee, reviewed through a public meeting, and submitted to Ecology. These rankings help determine the order in which watershed action plans are funded through the CCWF and developed in each county.

METHODOLOGY

This paper summarizes a larger report[2] which evaluates the results of the watershed ranking processes. The information in the report was obtained primarily from written project reports submitted to Ecology by county staff and from a telephone survey of local watershed ranking staff. The full report with results of the survey, as well as a short summary of the ranking process conducted in each county, is available from the Authority.

GENERAL RESULTS OF EVALUATION

The Nonpoint Rule provided a broad outline—rather than detailed guidance—on the watershed ranking process in order to allow for local flexibility. This allowed each county to interpret and conduct the ranking task somewhat differently, although some similarities exist.

Ranking criteria were used and interpreted differently in each county. Some used the Puget Sound River Basin Study Team's process to obtain detailed data on the watersheds; others conducted a relatively simple analysis. A few counties conducted a detailed analysis for all watersheds; most chose to collect detailed information only on the higher ranked watersheds. Information about the watersheds being ranked was collected through a variety of methods, including best professional judgement of staff and committee members, technical committees, and use of outside consultants.

Size and structure of the ranking committees and the decision-making technique used by the committees varied from county to county. Ranking committees ranged in size from 8 to 44. Some committees had chairs or co-chairs elected from the committee, while others were lead through the ranking process by county staff. The Nonpoint Rule encouraged the use of consensus.

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[1] The Puget Sound River Basin Study Team includes personnel from the USDA Soil Conservation Service, the US Forest Service, and the Washington Departments of Ecology and Fisheries. The team provides technical assistance to counties in watershed ranking and developing watershed action plans. The team provided a two-level ranking process which would result in detailed watershed characterizations and a database useful for comparing watersheds.

[2] "Ranking of Puget Sound Watersheds for the Control of Nonpoint Source Pollution: An Evaluation Report." Available from the Puget Sound Water Quality Authority.

Table 1.
***TOP-RANKED WATERSHEDS** for prevention and control of nonpoint source pollution in the Puget Sound Basin.*

CLALLAM COUNTY
1. Dungeness Watershed Cluster
2. Port Angeles Watershed Cluster
3. Elwha Watershed Cluster
4. West End Watershed Cluster

ISLAND COUNTY
1. Oak Harbor/Crescent Harbor
2. Penn Cove
3. Dugualla Bay
4. Holmes Harbor

JEFFERSON COUNTY
1. Port Ludlow Watershed Cluster
2. Discovery Bay
3. Chimacum Creek

KING COUNTY
1. Lower Cedar River
2. Lower Green River
3. Bear/Evans Creeks/Sammamish R.
4. Issaquah Creek

KITSAP COUNTY
1. Dyes Inlet
2. Sinclair Inlet
3. Hood Canal Drainages/Port Gamble Bay
4. Liberty Bay/Miller Bay

MASON COUNTY
1. Lower Hood Canal Drainages
2. Case Inlet Drainages
3. W. Shore Hood Canal Drainages
4. Skokomish River

PIERCE COUNTY
1. Lower Puyallup R. Cluster
2. Tacoma Cluster
3. Gig Harbor Drainages
4. Lower Nisqually River

SAN JUAN COUNTY
1. East Sound
2. Friday Harbor
3. Westcott/Garrison Bays
4. Fisherman Bay

SKAGIT COUNTY
1. Nookachamps Creek
2. Padilla Bay/Bayview
3. Samish River
4. Mt. Vernon Watershed Cluster

SNOHOMISH COUNTY
1. North/Swamp Creeks
2. Quilceda/Allen Creeks
3. Marshland/French Creeks
4. Everett-to-Edmonds Drainages
5. Little Bear/Bear Creeks

THURSTON COUNTY
1. Deschutes River/Budd Inlet
2. Nisqually River

WHATCOM COUNTY
1. Drayton Harbor
2. Squalicum Creek
3. Lower Nooksak/Lummi Rivers
4. Fishtrap/Bertrand Creeks

This decision-making method was used by most committees, while others used a mix of consensus and voting.

Each ranking process was required to have an education and public involvement component to educate committee members and county residents about nonpoint pollution and to obtain public input on the ranking process. The counties varied in the types and extent of public involvement and education activities conducted. Activities included public meetings, bus tours, educational workshops, water quality questionnaires, slide shows, videos, newslet-

ters, and fair booths. Some counties conducted several of these activities, while others only performed one or two. All counties held public meetings to comply with requirements of the Nonpoint Rule.

The watershed ranking exercise set some definite priorities within the Puget Sound basin on where to take action on nonpoint source pollution in the near term and in the longer term. Most of the top-ranked watersheds (see Table 1) empty directly into Puget Sound. In several instances, consecutively ranked watersheds are adjacent to one another.

The highest ranked watersheds in Puget Sound counties contain a wide variety of resources that will be protected by nonpoint planning activities. These include protection of fish habitat, shellfish resources, and wetlands. The highest ranked watersheds include more lowland areas than higher elevation forested areas, concentrating initial planning efforts in areas of higher population density. Top selected watersheds also present a balance between prevention and remedial action needs.

The watershed ranking process engaged a large number of Puget Sound citizens and officials in water quality planning. Taken together, the 12 committees had 263 members representing community groups, state and local agencies, business interests, Indian tribes, agricultural and forestry interests, environmental groups, and citizens.

Overall, the county staff involved in watershed ranking felt that it was a worthwhile experience.

MAJOR ACCOMPLISHMENTS

County staff involved in the watershed ranking process were asked to identify the major accomplishments of the ranking project in their county. Their responses fall into four general categories: 1) public involvement and education, 2) building a water quality constituency, 3) guidance for planning, and 4) data collection.

Public involvement and education

Most surveyed ranking staff felt that education of the general public was a major accomplishment for the ranking process. This public education included school children, farmers, septic system owners, elected officials (such as County Council or Board of Commissioner members), citizens directly involved in the ranking, and others. The process got the word out that citizen involvement is needed, and as one respondent remarked: "[It] enlightened us as to how unenlightened we are."

Building a water quality coalition

Complementing public involvement and education of those not directly involved in the ranking activities was the building of a coalition to support watershed planning and nonpoint source control programs. A key accomplishment of the ranking process was bringing together disparate interests from various geographic areas and backgrounds into committees to address nonpoint issues.

Bringing together citizens, tribal representatives, local government officials and other affected parties in joint decision-making resulted in cohesive efforts to address problems. It was expected that development of shared goals and workable programs will save time, effort, and expense over the long run.

The watershed planning program adopted in the 1987 Puget Sound Plan was designed to address the lack of coordination among agency programs in controlling nonpoint source pollution. The ranking processes generally served to increase coordination between agencies. Creation of technical advisory committees and collection of data stimulated conversation and sharing of knowledge between agencies. This increased communication and should make action planning easier over the long term.

Guidance for planning

It seems logical that the most apparent accomplishment of the watershed ranking process would be the establishment of a clear priority list for watershed planning under the Nonpoint Rule. This was true in counties with little or no pre-existing nonpoint planning. Other counties had to integrate the watershed ranking exercise with established basin planning and other water quality programs. Regardless of the difficulties encountered by some counties (see "Problems Encountered" section below), there is general agreement that the ranking process provided momentum for water quality planning in the Puget Sound Basin.

Data collection

The extensive data collection that took place as part of the ranking task was a useful by-product. Each county developed watershed characterizations for the top-ranked watersheds.[1] These characterizations summarize social, biological, and water quality information. Collected data are currently being used to write grant applications, develop monitoring programs, support litigation/ mediation, scope projects, and are the basis for educational activities. To have

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[1] Watershed characterizations are contained in the written final reports published by each of the counties. These characterizations vary in detail depending on availability of data and ranking process used.

pertinent data in one place, such as in the written project reports, is proving extremely useful. In particular, the final reports serve as a reference tool for future action planning, eliminating the need to start from ground zero in preparing a watershed plan.

PROBLEMS ENCOUNTERED

County-level watershed ranking staff were asked if they believed the process to be worthwhile, overall. All respondents felt the watershed ranking exercise was worthwhile, but with varying degrees of enthusiasm. When asked if there was anything Ecology or the Authority could do differently to improve the process, the major theme was the need for more guidance and better clarity about the process.

According to most interviewed staff, better guidance could have been provided by the oversight agencies (Ecology and the Authority). For example, many staff members felt that more seminars, handbooks, and staff get-togethers would have been useful. Additional training could have been provided to cover dispute resolution, public involvement, and meeting facilitation issues. Those counties with little planning resources stood to benefit the most from training opportunities.

Special meetings were held on a quarterly basis for watershed ranking staff, but this may not have been sufficient for all participants. A staff retreat was held mid-way through the process. A number of staff mentioned the benefits of exchanging ideas with others at this retreat and lamented the lack of more frequent opportunities to meet fellow ranking staff. Many staff members found great assurance in discovering the procedures they were following were similar to other counties' procedures. This uncertainty on behalf of local staff reflects the lack of specificity in the Nonpoint Rule regarding ranking and the lack of detailed guidance from the oversight agencies.

Other problems encountered by ranking staff were understanding how the watershed ranking process would relate to future funding under the CCWF and how ranking should be coordinated with Early Action watershed planning efforts.

The deadline for submittal of applications to the first round of the CCWF occurred prior to completion of the ranking process. For some counties, this early deadline undermined the watershed ranking process. In order to make the application deadline, county governments had to file applications without knowing the ultimate priorities established through the ranking process, or delay the opportunity to acquire funding by one year. Similarly, several jurisdictions throughout the counties were submitting proposals for projects

addressing nonpoint pollution on a watershed basis without coordination with the ranking process.

In addition, some counties were simultaneously involved in Early Action watershed planning and watershed ranking processes. This dual planning both helped and hindered the ranking process. For example, having Early Action planning "whetted the appetite" by providing to county staff and ranking committees a clear purpose for ranking and a look at the benefits of receiving CCWF monies. On the other hand, Early Action planning usurped limited staff resources and technical expertise from the ranking process for some counties and resulted in a "tremendous staff drain" and "burn-out."

SUGGESTIONS FOR IMPROVING THE PROCESS

Puget Sound counties are required by the Nonpoint Rule to revisit the watershed rankings within five years of the initial rankings. County staff were asked to make suggestions about how the watershed ranking process could be improved if the counties were to do it over again, or if the ranking was repeated in another setting. A sample of these suggestions are listed below.

- Oversight agencies should have the process well thought through in advance and be prepared to answer questions before involving local agencies in the process. In addition, answers to questions should be better coordinated between oversight agencies.
- It should be explicitly stated that general public education on nonpoint pollution and water quality take place before watershed ranking begins. Education of committee members prior to ranking also would be beneficial.
- The relationship between the watershed ranking process and future funding procedures should be made clear from the start.
- Time lines should be sufficient and major planning activities sufficiently spread out.
- It should be recognized that watershed ranking may need to be integrated with pre-existing local planning programs.
- Oversight agencies should offer frequent training and workshops for the ranking staff. More technical assistance, such as that provided by the Puget Sound Cooperative River Basin Study Team, would also be helpful.
- Local staff should set clear ground rules for committee participation, meeting protocol, and decision-making procedures.

ACKNOWLEDGEMENTS

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EVALUATING NONPOINT SOURCE POLLUTION IN THE PORTAGE CREEK WATERSHED USING A GEOGRAPHIC INFORMATION SYSTEM

Roberta P. Feins[1]

INTRODUCTION

This paper summarizes the results of a cooperative project to evaluate non-point source pollution in a Puget Sound watershed. The project was also designed to evaluate the use of computerized geographic information systems (GIS) for nonpoint source pollution investigations and planning in the Puget Sound Basin. The project used existing agency resources and staff, but emphasized the integration of study results through the use of GIS. A more complete report on project results may be found in Feins (1990).

BACKGROUND

The Stillaguamish basin (most of which is in Snohomish County, Washington) is a Puget Sound Early Action Watershed (Puget Sound Water Quality Authority, 1988); a watershed action plan has recently been developed by an inter-organizational Watershed Management Committee (Snohomish County Department of Public Works, 1990.) Since the Portage Creek area has been identified as a major contributor of pollution to the Stillaguamish River (Snohomish County, 1974), the watershed plan recommended it as an area for further study.

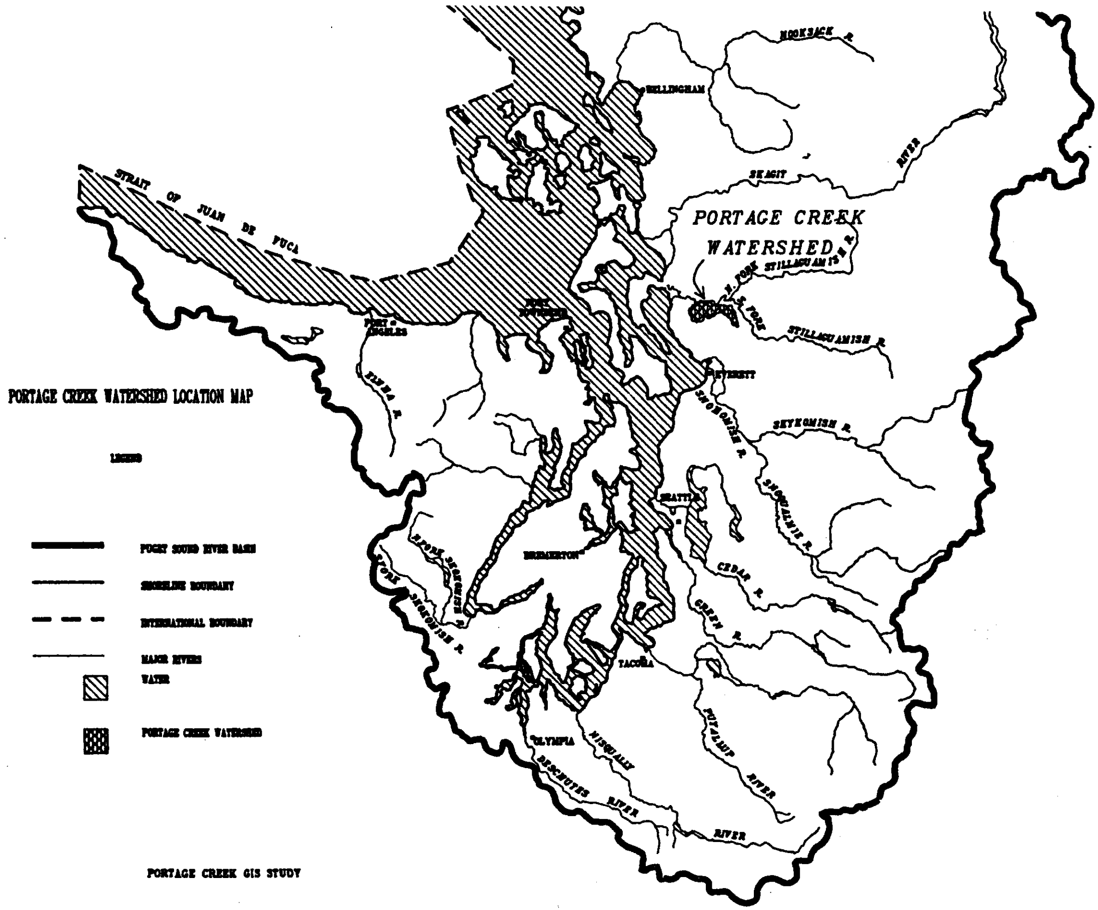
STUDY AREA

The Portage Creek watershed lies west of the city of Arlington in northwestern Snohomish County, Washington (Figure 1). Portage Creek is a tributary of the Stillaguamish River, entering the South Slough at river mile 1.7 near Sylvana. The watershed covers about 18 square miles (13,654 acres), with 92 miles of waterway (streams, drainage ditches and roadside ditches). Portage Creek flows to the northwest from highlands south of the city of Arlington, through agricultural lowlands. A major tributary, Fish Creek, drains the southwestern portion of the watershed and enters Portage Creek about 2 miles upstream of its confluence with the Stillaguamish River.

Elevations in the watershed range from 540 feet to 20 feet above mean sea level. Land use in the watershed follows distinct geographic patterns. Almost half (47%) of the land (largely the upper portions of the Portage and Fish Creek

[1] Puget Sound Water Quality Authority, MS PV-15, Olympia, WA 98504-0900

Figure 1.
PORTAGE CREEK WATERSHED LOCATION MAP.



drainages) is forested, while 29% is cropland or pastureland, located downstream. Most of the 28 commercial farms are located in the lower portions of the watershed, in the Stillaguamish floodplain. Twelve percent of the watershed lands are devoted to residential use and 3% to industrial use mainly in and around the City of Arlington.

STUDY GOALS

The goals of the project were to:

- characterize nonpoint source pollution problems in the Portage Creek watershed;
- identify geographic areas and land-uses that are potential contributors of nonpoint source pollution;
- develop and evaluate an approach for nonpoint source characterization in Puget Sound using GIS; and
- develop a baseline of information for long-term analysis of problems in Portage Creek.

STUDY DESIGN

Digital geographic data on rivers, streams, and soils were obtained at a scale of 1:24,000. More detailed information on streams and ditches, wetlands, and farm and field boundaries was digitized from aerial photos and from field investigations by the Puget Sound River Basin Team, the Snohomish Conservation District and the Tulalip Tribes.

A detailed survey of farm practices was conducted for each of the 28 commercial farms in the watershed by the Snohomish Conservation District; a more limited survey was done for the 202 non-commercial farms by the Puget Sound River Basin Team.

The Department of Ecology conducted a year-long water quality monitoring study (Plotnikoff and Michaud, 1990). The Tulalip tribes conducted a detailed inventory of stream habitat in 49 miles of watershed streams (Freeman, 1990). An analysis of projected growth in the watershed was conducted by staff from Battelle Human Affairs Resources Centers, Seattle (Miranda and Orians, 1990; Orians and Miranda, 1991 [this volume]).

Since there is no generally accepted methodology for quantifying the nonpoint source pollution caused by a given farm activity, a simple approach was developed to rank areas for their potential impact on stream water quality (Puget Sound Cooperative River Basin Team, 1990a). The approach was to simply count the number of activities considered potential generators of

nonpoint source pollution in each farm field. The activities counted included: poor livestock confinement practices, evidence of contaminated runoff from confinement areas, use of commercial fertilizers and chemicals, application of wastes during the wet season, grazing during the wet season, proximity of fields to streams or ditches, and livestock access to streams.

A scoring approach similar to that used for commercial farms was developed to rank an entire non-commercial farm for its potential impact on nonpoint source pollution (Puget Sound Cooperative River Basin Team, 1990b). For each non-commercial farm, activities considered potential generators of nonpoint source pollution were counted. These activities included: high animal densities, lack of livestock confinement, livestock access to streams, poor waste management practices, proximity to streams and ditches, and presence of poorly draining soils.

Using this approach produces a numerical score for each farm field (commercial farms) or farm (non-commercial farms). Presumably the higher the score, the greater the potential the farm has for creating a water quality problem. However, scores cannot not be used to conclude that the farms scoring lowest do not create water quality problems nor that those scoring highest do.

Use of GIS

A geographic information system (GIS) is a state-of-the-art computerized database that can manage information about the location and status of resources, boundaries, land uses, etc. Information on a map (e.g., the location of different farms in a watershed, or the location of streams and ditches) is carefully entered into the computer. This information can then be used to reproduce the original map, at different scales or in different formats, or to create new map combinations.

GIS was used for this project to develop a coordinated prototype geographic database for storing nonpoint source information. Detailed geographic information was collected and entered into several microcomputers running the PC Arc/Info GIS. The following types of data were computerized: watershed boundaries, rivers and streams, wetlands, soils, parcels, farm and field boundaries, residences, roads, land use/land cover, and stream habitat.

The GIS was used to create watershed maps, and for data analysis. Acreage of crop land and number of miles of stream were calculated, as were the relationships among data types (e.g., the distance of each residence from a stream). Information from the farm inventories was linked to the GIS so that the number of acres showing different types of farm practices could be calculated. Finally, the GIS was used to compute and map the rankings developed for assessing the severity of nonpoint pollution problems.

RESULTS

Water Quality and Habitat

Data from the 1988-1989 water quality monitoring study show spatial and temporal variations in pollutants in Portage Creek and Fish Creek (Plotnikoff and Michaud, 1990). Mean concentrations for fecal coliform, turbidity, and dissolved oxygen violated Washington State Class A water quality standards during both the wet and dry season. Activities such as grazing and manure or fertilizer applications in the central portion of the watershed were associated with increases in total suspended solids, total inorganic nitrogen, and fecal coliforms. Concentrations and loads from Fish Creek in both the wet and dry season were lower than for Portage Creek. Stream habitat surveys indicated that 49% of stream miles are affected or severely affected by nonpoint source pollution (Freeman, 1990).

Pollution Sources — Commercial and Non-commercial Farms

Nonpoint pollution seems to be coming from a variety of sources. A total of 3,495 cattle produce an estimated 11.6 million gallons of animal waste annually on commercial farms in the watershed. These farms often have the structural facilities (waste storage systems, animal confinement facilities, and fences) in place to control nonpoint source pollution from their substantial animal herds. However, the survey indicated that many of the facilities are not being properly used or that management practices are inadequate. For example, contaminated runoff from animal confinement areas was observed at 36% of the farms with 20% of the livestock.

The 202 non-commercial farms in the watershed have one-third as many animals as the commercial farms. However, many of these farms are "hobby farms" under 5 acres in size, with one or more animals (usually a horse). These farms have poor grazing and animal waste management practices. Such farms have limited space and capital with which to construct facilities for animal management; they have not traditionally been the recipients of cost-sharing grants from federal or state programs. The magnitude of the nonpoint problem is judged to be roughly equal for commercial and non-commercial farms.

Each field on each commercial farm, and each non-commercial farm was scored according to factors described in the Study Design. Table 1 and Figure 2 show the results. Many of the commercial farm fields (94) do not show significant potential for nonpoint problems, but 95 fields were judged to show two or more factors that may be contributing to nonpoint pollution. Ninety-six percent of the non-commercial farms showed 2 or more activities potentially generating water quality problems.

Table 1.
PORTAGE CREEK WATERSHED NONPOINT POLLUTION SCORES - 1989

# of activities potentially affecting water quality *	# of Fields	# of Acres
Commercial Farm Fields		
0 to 1	94	1,160
2 to 4	71	1,050
5 and greater	24	319
Total	189	2,529
Non-commercial Farms		
0 to 1	8	72
2 to 4	112	1,074
5 and greater	82	1,519
Total	202	2,665

* *See text for description of activities included.*

Projected Growth

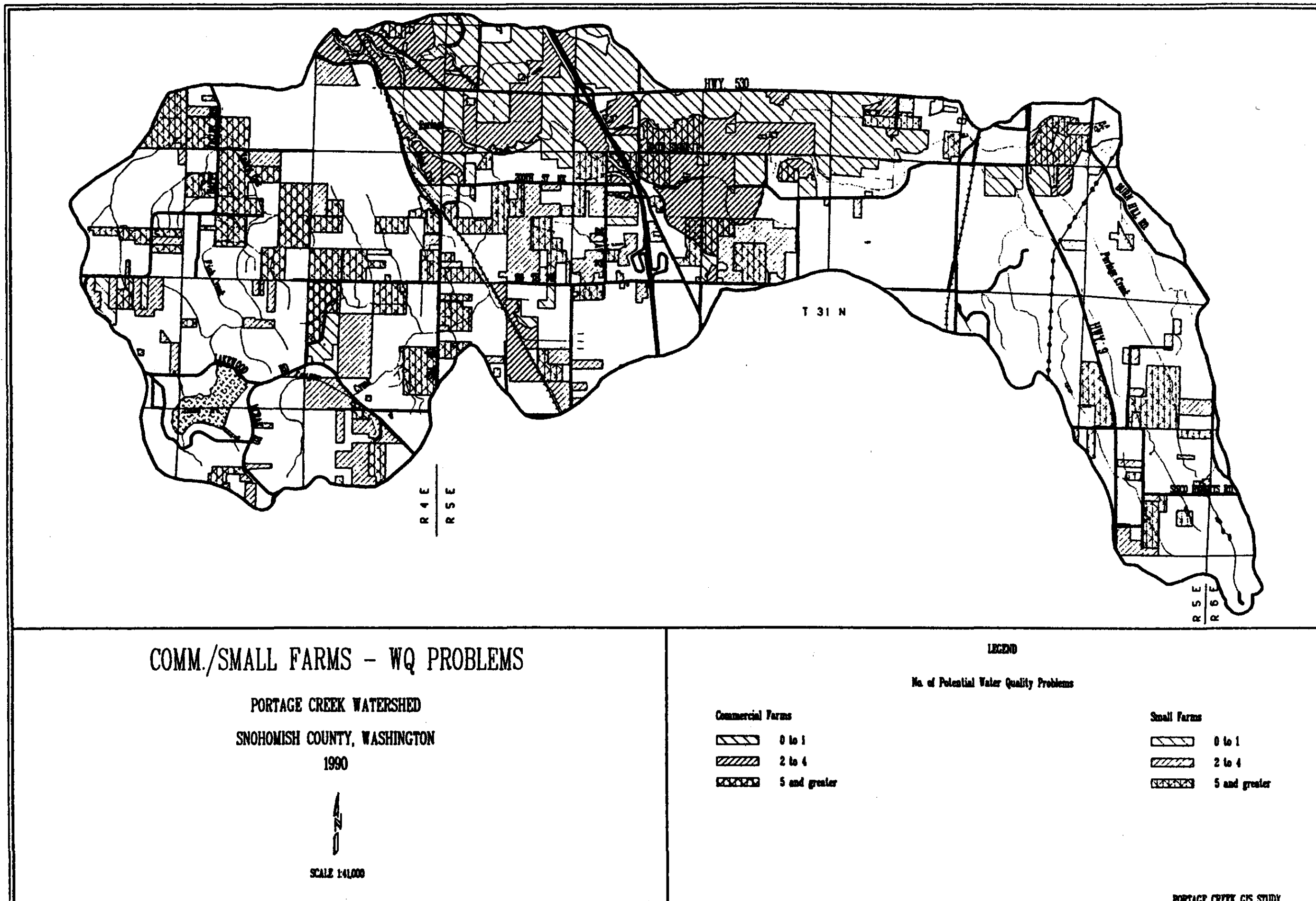
An analysis of projected growth in the watershed (Miranda and Orians, 1990; Orians and Miranda, 1991 [this volume]) indicates that while much growth is likely to be centered around the City of Arlington, there is substantial pressure for subdivision of land into 2-5 acre parcels, as designated in the Snohomish County Comprehensive Plan. These acreages are likely to become hobby farms; the contribution to nonpoint source pollution from these farms is likely to increase in the future.

RECOMMENDATIONS

More education on Best Management Practices such as waste management and pasture management is needed for commercial farm owners. The inventory shows that encouraging better management practices and better use of existing facilities is more important than building more facilities. Programs to encourage maintenance of confinement areas, better scheduling of manure disposal or manure application, rotation of herd grazing, and practices which restrict animal access to streams would be valuable in addressing the observed problems.

A much stronger effort must be made to reach non-commercial farms, since their contribution to nonpoint source pollution may come to exceed that from commercial farms. More restrictive regulations on keeping animals on small properties or educational programs targeted at these small non-commercial farms need to be considered.

Figure 2.
WATER QUALITY PROBLEMS ON COMMERCIAL AND SMALL FARMS IN THE PORTAGE CREEK WATERSHED.



EVALUATION OF GIS

The methods of this pilot study could be applied to studying nonpoint source pollution in other watersheds in Puget Sound. Cooperation among agencies in collecting, digitizing and sharing information made this project possible. Early involvement by project staff in the definition of the project database ensured that the data were usable for all of the analyses planned. Data storage and analysis were decentralized; geographic data were freely exchanged in digital format.

Substantial time and effort was expended in compiling a detailed database for this project, but only an estimated 28% (1,316) of the estimated 4,700 project hours was spent on GIS activities. Project time and effort can be better justified if the information and GIS are used for long-term analysis of the watershed. The existence of a detailed, geographically correct database would lower start-up time and costs for a variety of projects in environmental assessment and planning.

ACKNOWLEDGEMENTS

The project was a cooperative effort of the following agencies: Puget Sound Water Quality Authority, Puget Sound Cooperative River Basin Team, Washington Department of Ecology, Snohomish County Department of Public Works, Snohomish Conservation District, Tulalip Tribes, Washington Department of Natural Resources, Battelle Human Affairs Resources Centers (Seattle), U.S. Environmental Protection Agency, U.S. Geological Survey Water Resources Division.

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IMPLICATIONS OF POPULATION GROWTH IN A GIS ANALYSIS OF NONPOINT SOURCE POLLUTION

Carlyn E. Orians and Lynn E. Miranda[1]

INTRODUCTION

Nonpoint source pollution of water, usually defined as pollution that is not discharged from pipes, is caused by a variety of human activities, including both urban and agricultural land uses. Yet these land uses, and hence contributions to water quality degradation, do not remain constant over time. Of particular interest in the rapidly growing Puget Sound region, and the focus of this study, is the potential impact of population growth and the subsequent changes in land use on water quality. Too often, policies are developed in response to existing problems, with little thought given to how conditions might change over time. Effective policy development aimed at reducing nonpoint sources of pollution and improving water quality must target the type of land use that is contributing to the problem and must anticipate changes in those land uses. This paper addresses the need to model future land use scenarios in order to predict the potential consequences of urbanization on water resources within a watershed. Armed with knowledge of present conditions and likely future scenarios, policies can be developed that will be more effective in mitigating future nonpoint source contributions.

As participants in a GIS Pilot Study coordinated by the Puget Sound Water Quality Authority (Portage Creek Pilot Study, 1990; Feins, 1991 [this volume]), we used a geographic information system (GIS) to allocate population growth projections for the Portage Creek watershed to smaller planning areas within the watershed. This allowed us to estimate the location and magnitude of population growth. Other components of the study collected data to evaluate the relationship between land use and nonpoint source pollution. Combining these two types of information enabled us to identify areas of future concern. These include areas where residential growth is anticipated in unsewered areas, and where commercial farms are likely to be replaced by smaller hobby farms with potentially poorer management practices.

In this paper we present a brief history of the Portage Creek GIS Pilot Study and the local conditions which give rise to concerns about nonpoint source pollution. We then describe the method used to develop a future growth scenario and the expected impacts of that growth on the Portage Creek watershed. Finally, we discuss the implications of these findings for the development of

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policies, strategies, or regulations aimed at reducing nonpoint sources of pollution.

BACKGROUND

Today, most growth in the United States is occurring in the suburbs or rural areas. This pattern of urban development spreading from the city into previously undeveloped areas has exacted a high price on the quality of water resources. The rapidly growing Puget Sound region has not been left untouched by the adverse effects of growth and urban sprawl. One need only look as far as the local Seattle newspapers to determine the level of the local communities' concern regarding the environmental, social, and economic costs of spreading urbanization. In many areas, nonpoint source pollution stemming from the spread of urban land uses and construction activities has heavily contributed to the destruction of valuable wetlands, destabilization of the ecological balance of stream habitats, and contamination of important water resources.

Due to increasing concerns over water quality degradation, the Puget Sound Water Quality Authority selected the Stillaguamish, of which Portage Creek is a tributary, as one of 12 Early Action Watersheds in 1987. Portage Creek's role as a major contributor of fecal coliform bacteria to the Stillaguamish River (Portage Creek Pilot Study, 1990) was a major reason for recommendations of further study by the Stillaguamish Watershed Management Committee. The Portage Creek watershed lies west of the city of Arlington in northwestern Snohomish County, Washington. The watershed covers about 18 square miles (13,654 acres), with 92 miles of waterway. Land use within the watershed is mixed. Portage Creek flows north through terraced forest uplands into an area of mixed residential, commercial, and light industrial activity around the City of Arlington. From there it flows west into a predominantly agricultural area which lies within the floodplain of the Stilliguamish River. Fish Creek drains the western portion of the watershed where non-commercial farms dominate, although some of these are large operations. There is dense residential use around Lake Ki.

The goals of the multi-agency cooperative GIS pilot project were to characterize nonpoint source pollution problems in the Portage Creek watershed, identify specific geographic areas and land uses that were potential contributors of nonpoint source pollution, develop and evaluate an approach for nonpoint source characterization in the Stillaguamish basin (identify critical information, tools and analyses), and develop a baseline of information for long-term analysis of problems in Portage Creek. Another project goal was to explore the use and exchange of GIS data for natural resource management and planning. To meet these goals, project participants collected data on

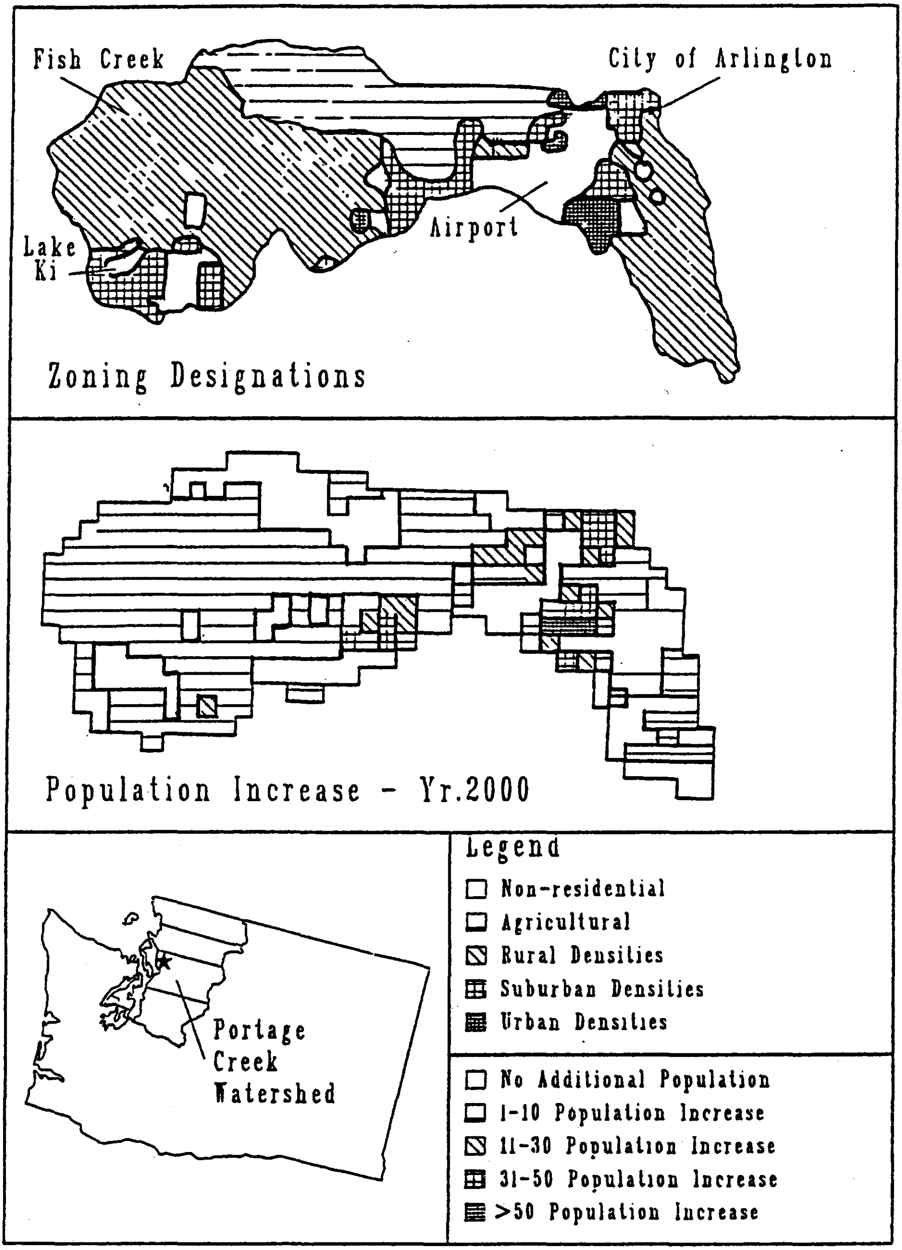

Figure 1.
CURRENT COMPREHENSIVE PLAN ZONING CLASSIFICATIONS FOR THE PORTAGE CREEK STUDY AREA AND THE EXPECTED POPULATION INCREASE PER 16TH SECTION BY THE YEAR 2000.

water quality, land use, soils, commercial and non-commercial farms, residential development, and stream habitats.

The authors collected data on tax parcels, zoning classifications, and population growth projections to analyze, using a GIS framework, the location and magnitude of future population growth in the watershed and its potential impact on nonpoint source pollution. The remainder of this paper focuses on that voluntary effort.

METHODOLOGY

As a GIS pilot project, the study was designed to evaluate the use of GIS for nonpoint source pollution investigations and planning in the Puget Sound Basin. The study team was able to take advantage of the fact that several participants had access to the same commercial GIS software, PC Arc/Info. This allowed each agency to contribute its information to a common, geographically referenced data base for a more comprehensive analysis of the entire watershed. The combined data base and analytic software programs of Arc/Info were then used to facilitate analysis of the data and cartographically depict the results.

Population growth projections were obtained from the Snohomish County Planning Department. Snohomish County has developed a computer model, POPUL, to allocate regional population forecasts to census tracts and then to 16th sections (40 acre sections). We were provided with population forecasts by 16th section for the years 1990 to 2000, which we then aggregated to the Portage Creek study area. We selected the year 2000 to develop a future land use and residential density scenario.

Current zoning designations were digitized from Snohomish County comprehensive plans (Snohomish County, 1977, 1982, 1985, 1987). As shown in Figure 1, much of the area around Arlington and the airport is zoned for residential, suburban and urban development, while the upper Portage Creek drainage is zoned rural. The Fish Creek drainage area is generally rural, allowing one dwelling unit per 2.5 acres, except for the densely residential area around Lake Ki. Existing dwelling units were digitized by the Puget Sound River Basin Team from aerial photographs taken by DNR in 1987 and updated through field survey in June, 1989. GIS capabilities were used to overlay zoning, dwelling unit and 16th section coverages and to combine attributes to produce data for further statistical analysis. While we elected to use 16th sections as our unit of analysis, the system can support smaller minimum grid sizes. Data resulting from the overlay process characterized the amount and type of zoning per 16th section and the existing number of dwelling units within each 16th section.

By multiplying the acreage counts of each zoning type by the maximum allowable residential densities (dwelling units/acre) permitted under current comprehensive plan zoning designations, we calculated the maximum number of dwelling units permitted in each 16th section. These counts were aggregated to determine the residential capacity of the entire study area. Subtracting from this the existing number of units, we obtained the additional number of dwelling units permitted in the study area. We then calculated the percentage of future population each 16th section could be expected to receive. This figure was obtained by dividing the additional capacity per 16th section by the additional capacity for the study area to determine each section's "share," then multiplying by the expected population increase for the entire study area.

Using the GIS, maps depicting expected areas of growth and a year 2000 future density scenario were produced. Figure 1 shows the current comprehensive plan zoning classifications for the Portage Creek study area and the expected population increase per 16th section by the year 2000. While this effort resulted in only a single future scenario, it was useful in identifying nonpoint sources of pollution that are likely to become a more serious threat to water quality as the area continues to grow.

RESULTS

The population of the Portage Creek watershed is projected to grow from approximately 5,250 in 1989 to 7,138 by the year 2000, according to Snohomish County estimates. This represents a 35% growth over the 11 year period or an average annual growth rate of 3%. According to Tim Koss of the Planning Department, this estimate is conservative (Snohomish County, 1990). The population of Snohomish County has increased faster than predicted over the last two years, especially in the northern portion of the county where Portage Creek is located. This trend is expected to continue. As shown in Figure 1, the greatest increase in population is expected in the already more densely settled area stretching from the City of Arlington in the northeast corner of the study area, southwest towards the Arlington airport, the freeway, and Smokey Point.

A review of the parcel maps for the study area showed that most growth is anticipated in areas already subdivided. However, conversations with farmers indicated extreme pressure for conversion to large acreage, residential development in the Fish Creek area. Most of the non-commercial farms over 20 acres in size were commercial operations 10 to 15 years ago, but have been forced out of business due to increased land values, taxes and an inadequate land base (Portage Creek Pilot Study, 1990). Development in this area will favor the proliferation of small farms. The Portage Creek Pilot Study found that small farms typically have the poorest water quality practices. The farms are

large enough to pasture a horse or other livestock, but small enough to discourage adequate livestock management and waste disposal.

Some of the area around the City of Arlington is sewered, and sewer expansion is planned. However, dense growth is projected to occur on the eastern and western edges of the city in un-sewered areas. In this area, and in most of the watershed, the ability to support additional septic systems is limited by the qualities of the soils. Additional urban growth without adequate consideration to this problem increases the potential for water quality degradation.

In summary, the anticipated threat to water quality in the Portage Creek watershed from increasing population density is of two types. The first is the proliferation of smaller hobby farms with potentially poorer water quality management practices. The second is an increase in private septic systems in an area with poor soils.

DISCUSSION

The future population scenario we have depicted can be described as a baseline case—what we might expect the population density and distribution to look like in the year 2000 in the absence of planning intervention. Given the information collected as a part of this project, our study identified specific areas posing future problems as nonpoint sources of pollution due to their potential conversion from rural to urban uses, based on current trends in the locations and densities of development. The significance of producing a baseline scenario lies in the ability to examine the consequence of taking no action.

In addition to zoning and current population distribution, other factors influence where growth is likely to occur. Infrastructure, such as water, sewer, and roads, is a prerequisite for development. Therefore, the location and capacity of infrastructure and public facilities could be included within the GIS framework. Employment opportunities and amenities also attract growth. By interviewing members of the community about pressures for future growth, willingness to sell, and recent activity in the real estate market, the baseline scenario could be refined to more accurately reflect local conditions.

Once an accurate baseline scenario depicting future growth is produced, a number of questions must be asked regarding its impact on water quality. Do we know what the impact is likely to be? Will this outcome be acceptable? What changes could be made to yield a future that would better accommodate growth without compromising water quality? Would these alternatives be acceptable? One of the original project goals was to use GIS to determine if a statistical relationship existed between measured water quality and observed land uses in the watershed. However, the limited size of the Portage Creek

watershed did not allow identification of an adequate number of sub-watersheds to be used as observational units in a statistical analysis. Nor was a time-series analysis possible because of a lack of historical water quality and land use data. An ongoing water quality monitoring system could support such analysis in the future if designed to properly capture changes in land use.

With a better understanding of land use and water quality relationships, alternative growth scenarios could be developed to explore the relative magnitude of potential impacts. For example, existing, planned, and potential areas of high urban densities could be evaluated in terms of their capacity for potential runoff using the Arc/Info TIN module (Triangular Irregular Network) to model their locations on slopes and within drainage systems. Based on this analysis, alternative sites could be proposed which are more suitable for development. High impact agricultural practices could similarly be examined in relation to drainage patterns.

Land use policies can mitigate the impact of development on water quality. Baseline studies project current land uses and policies to produce a future scenario. Based upon the results, decision makers have the option of changing the policies governing how development must take place, as well as the location of development, to mitigate potential nonpoint sources of pollution stemming from urbanization. A good example of this is the increasing need for sewage disposal. At this time only a small portion of the study area is served by sewer systems. Additional population pressures in areas with private septic systems may adversely affect water quality. One solution would be to require the extension of sewer systems, another would be to restrict development in the more sensitive areas. Regardless of the type of policy that is implemented, efforts between agencies with overlapping authority in the study area should be coordinated during policy development to ensure consistency among goals.

The true test of this type of analysis is whether policy makers and planners can use the findings to make intelligent decisions that will positively impact water quality in the face of a growing population and conversion of land to urban uses. This may be where GIS technology has the greatest potential. The ability to analyze, in combination, more variables than are easily addressed manually, coupled with the added benefit of clear graphics, argues favorably for the incorporation of GIS technology in the planning arena.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the contributions of all the participants in the Portage Creek Pilot Study. In particular, we wish to thank Roberta Feins of the Puget Sound Water Quality Authority and Terry Nelson of the Puget Sound

River Basin Team for recognizing the importance of examining population growth impacts, and providing a mechanism for data and information exchange to make such an analysis possible.

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URBAN STREAM REHABILITATION: INDIAN CREEK – A CASE STUDY

Oscar H. Soule and James Neitzel[1]

INTRODUCTION

In the Fall of 1989, the Habitats Coordinated Studies Program of The Evergreen State College was invited by the Department of Public Works, City of Olympia, to take part in the restoration and permanent protection of a fish habitat (Craig, 1989). The stream, Indian Creek, was to be the first in a series of urban stream enhancements carried out by the city's new Stream Team program. This project would combine a wide variety of participants with varied, but interrelated tasks (Table 1). We were to prepare the first piece of the puzzle: a site characterization to include the vegetation, soils, stream flow, water quality, stream bed, and in-stream fauna. The vegetation data were to be passed on to the landscape design class at South Puget Sound Community College for incorporation into their landscape design component of a site master plan. We completed the site characterization on schedule (Soule and Neitzel, ms).

Table 1.
PARTICIPANTS IN THE INDIAN CREEK STUDY AND THEIR INVOLVEMENT.

City of Olympia Department of Public Works	• restore salmon habitat and increase public awareness
Hulbert Pontiac/Cadillac auto dealership	• create a public amenity and develop more environmentally sound operating practices
Washington State Department of Fisheries	• support habitat enhancement and use TESC work to plan for in-stream improvements
Trout Unlimited	• take part in fish habitat enhancement and develop a program of public awareness with a PIE grant from PSWQA
The Evergreen State College	• prepare site characterization
South Puget Sound Community College	• use TESC work to develop landscape design plan
Washington State Department of Ecology	• environmental improvements related to flooding, water quality and human health
Washington State Department of Transportation	• support improvement of salmon migration pathways

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HISTORY OF THE SITE

Indian Creek is a post-Pleistocene drainage from a kettle lake, Bigelow Lake, to Budd Inlet at the extreme southern end of Puget Sound in Olympia, Washington. From its inception to the present, the Olympia waterfront has been under constant pressure to serve its inhabitants. This has resulted in the filling of wetlands and intertidal areas. One of those filled areas is East Bay, the head of which has always received the mouth of Indian Creek. The location of that juncture has moved over time and is now one mile north of its original position. This movement has raised the site to approximately 6 meters above current sea level. The original wetland surrounding the mouth was filled in the 1910s (Palmer, 1991) and now supports an auto dealership and motel. There is no way to identify the original stream bed, but the most recent one is culverted, except for a 100 meter stretch on the property of the Hulbert Pontiac/Cadillac dealer.

PROBLEM AND CAUSES

The City of Olympia was anxious to get its urban stream enhancement program off to a good start. The volunteer group, Trout Unlimited, was looking for a good case study to demonstrate effective urban stream enhancement. And the auto dealer was interested in deeding the stream and its bed to the city in exchange for the site becoming a community amenity.

All parties were aware of the history of flooding at the site, and storm drainage improvement was listed as a task in the original scope of work (Craig, 1989). Flooding occurs when severe rains increase the flow of Indian Creek and high tide acts as a pressure plug in the mouth of the culvert, where the creek flows into East Bay. When these two events occur, Indian Creek backs up, and the first release point is the open stretch at the dealership. It takes 4-4.5 hours for the creek to rise enough to overflow its south bank. The resulting flood is in the form of a smooth sheet of water up to 10-15 cm deep. To the observer, the flooding creek looks no different than the surrounding paved area. On January 9, 1990, a customer who had driven into the autodealership when the creek was flooding, turned left instead of right upon leaving and proceeded to drive into the creek. The driver and passenger were rescued from the partially submerged car. This event introduced liability into the dialogue between the City and the auto dealer and brought the project to a halt.

ALTERNATIVES

The preferred plan from the outset was on-site enhancement. However, suggestions from city engineers and those hired by the dealer ranged from walls, to berms, to fences around the site once liability became a factor (Currie,

1990; Godat, 1990). The possibility of culverting the open stretch of the stream (tightlining) and abandoning the site was discussed, but discouraged by the Department of Fisheries (Benson, 1990; Currie, 1990). The possibility of expanding the wetland at the site was discussed and dismissed because it would result in the loss of too much property by the dealer.

RESULTS, OBSERVATIONS, AND IMPRESSIONS

It is interesting to note that on September 15, 1990, the public kick-off for Olympia's new Stream Team program took place at the Indian Creek site on the auto dealer's property. Speeches by the Mayor, a Thurston County commissioner, a member of the Northwest Indian Fisheries Commission, and others mentioned in Table 1 proclaimed how the rehabilitation of Indian Creek was to be a model project (City of Olympia, 1990a; Dodge, 1990). A month later this was followed by a letter from the Mayor extolling the "truly successful celebration of the Indian Creek watershed!"(Derr, 1990). Apparently while these events were taking place, behind-the-scenes negotiations resulted in the abandoning of the preferred alternative (on-site enhancement) and the acceptance of the tightlining of the creek, with construction of a new stream bed on the south end of the property as mitigation. This was announced in a November 11 press release by the City of Olympia: "Indian Creek will have a new lease on life in the summer of 1991 as part of a cooperative stream restoration and relocation project that will mitigate for the loss of this stretch of stream habitat" (City of Olympia, 1990b).

With this surprise move, the auto dealer enhanced the value of his property and created an amenity, the City avoided potential litigation and supported local business, Trout Unlimited could satisfy its grant requirements, Fisheries could claim more habitat rather than less, and Transportation lent a helping hand. However, the portion of the stream as we knew and studied it will be dead. While it appears that the area described here will be buried in the next few months, we feel the information gathered is important to share as a description of a neglected urban stream corridor. Such information can be useful in assessment of other urban streams and in the proposed relocation of Indian Creek.

SITE CHARACTERIZATION

The site was examined by the students in January and February, 1990. This examination focused on the soil, water quality, stream substrate, and vegetation; in addition, sampling of insect larvae and other aquatic animals was carried out. Follow up work examining the stream sediment for trace metals and the water for fecal coliform was done in April and May, 1990.

Two soil types were observed on the site. The most common was a gravel and sand aggregate that was presumably fill material. This stony coarse sand had no obvious humus layer. Deposited within a zone of regular flooding was a thick accumulation of a grey to yellow-brown silty loam. These flood deposits were massive and apedal. The limitation of vegetation presence to shallow fibrous roots, the lack of faunal activity, and the absence of red-brown iron oxides all indicate frequently saturated, anaerobic soils. Soil pH had an average value of 6.53, with extremes ranging from 5.75 to 7.82.

The water had a dissolved oxygen content ranging from 9.7 to 6.7 ppm with a water temperature of 12 C. The water had a pH of 6.70-6.88, very typical of streams which arise in coniferous forests. No evidence of saline water was found at this site even after extreme high tides. The water did contain elevated levels of phosphate, ranging from 50 to 170 ug/L. These values are comparable to other urban runoff samples, but they are significantly higher than our control value of 2 ug/L obtained from relatively undeveloped Snyder Creek on the Evergreen campus (Table 2). This increase in phosphate and an elevated fecal coliform count (50-410 organisms/100 ml) observed at Indian Creek suggest that the most significant water quality problems related to site restoration lie in nutrient runoff and possible sewer and septic leaks upstream of the site.

Table 2.
PHOSPHATE COMPARISON

Body of Water	Total Phosphate (ug/L)
Snyder Creek, TESC campus, Olympia, WA	2
Lake Washington, Seattle, WA (Holt, 1991)	26
Indian Creek, Olympia, WA	52.7 - 170
Urban Runoff (Goudie, 1986)	
1) Durham, N.C.	150 - 2500
2) Morristown, N.J.	20 - 4300

The stream substrate consisted of a 5-8 cm layer of gravel interspersed with clumps of asphalt. Below this was 23-25 cm of course sand. Other than the asphalt clumps, the stream bed would make an acceptable base for the addition of spawning gravel. Under a dissecting microscope, the bottom revealed pieces of rust and paint chips. The sediment was examined for lead, mercury, cadmium, zinc, chromium, and nickel. Although the lead and zinc determinations revealed slight elevations, about 30 and 80 ppm respectively in this sediment, they were typical of many urban watersheds. These concentrations would not preclude fish reproduction and would not have to be remedied.

In the two faunal collection trips, insects representing 9 orders were collected, as well as freshwater clams and 3-17 cm long brook lamprey (*Lampetra planeri*). The most prevalent organisms were mayfly, caddisfly, and midge larvae. There is an existing food supply for fish in this stream.

Vegetation cover is continuous throughout the site. Although 24 species were observed (in the winter), 77% of the cover was reed canary grass (*Phalaris arundinacea*) and horsetail (*Equisetum arvense*). Both of these plants thrive under periodic inundation. Native vegetation was limited to a small clump of vine maple (*Acer circinatum*) and restricted but healthy samples of cattail (*Typha latifolia*) and rush (*Juncus effusus*). The stunted nature of certain plant species reflected the poor growing conditions on this site. The dominance of herbaceous species and lack of woody plants clearly limits this site, due to the lack of shading of the water.

CONCLUSION

Indian Creek is a disturbed site. Not only has it been directly altered by the filling and the limited vegetation at the site, but it has also been indirectly influenced by the "tightlining" downstream and development upstream. These changes have made this site prone to rapid fluctuations in water level and frequent inundations which have greatly limited flora and fauna.

This site is typical of many other urban watersheds in Puget Sound. Since much of our unaltered wetland has already been eliminated, future mitigation or enhancement efforts will depend on recognizing orphan streams, such as this section of Indian Creek, as opportunities for positive change. Although this stream is of uncertain history and has been severely impacted by development, it is far from sterile. We were fortunate that this enhancement opportunity was recognized; many other such hidden opportunities may exist.

However, this project also illustrates the difficulties inherent in projects involving multiple groups. Although the state and local governmental agencies, property owner, and volunteer groups began with compatible visions, their differing mandates and perspectives resulted in a compromise solution that, though acceptable to all parties, is what no one had in mind at the onset. The only loser is the original stretch of Indian Creek—no one speaks for the stream.

Finally, our main goal was the education of our students. In this regard, the project exceeded our expectations. Not only did our students learn chemistry, biology, and ecology, but they were also able to witness the struggle involved in multiple organizations attempting to reach a consensus. We hope that they will be able to use these observations in their future as citizens of a watershed.

ACKNOWLEDGEMENTS

We wish to thank Rainer Hasenstab, Member of the Faculty, and the team of Habitat students, who were fully committed to the completion of this project.

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PUGET SOUND
RESEARCH '91

STUDENT PAPERS

Sessions Chairs:

Oscar H. Soule, The Evergreen State College and
Sheri Tonn, Department of Chemistry, Pacific Lutheran University

INTRODUCTION

Oscar Soule[1] *and Sheri Tonn*[2]

Puget Sound Research '91 invited undergraduate and graduate level students to submit papers and posters. The papers were presented in a pair of special sessions, and the posters were included in the regular poster session. All students were eligible for one of three awards: best student research, best student oral presentation, and best student poster. Each award was accompanied by a $100 stipend. A total of 10 student papers were presented in the oral sessions, along with 4 student posters. Sponsored by the Society of Environmental Toxicology and Chemistry and the Marine Technological Society, the awards were presented as follows:

Best Student Research: DeeAnn Kirkpatrick, University of Washington School of Marine Studies

Best Student Presentations (a tie): Nathan Carlson (University of Washington) and Kristina Lau (University of Washington Biology Teaching Program)

Best Student Poster: Laurie Weitkamp (Fisheries Research Institute, University of Washington)

Copies of these presentations and papers and abstracts from the other students can be found below.

The sponsors of the conference can be proud of this year's student participation. It was positive in terms of quality and quantity. A look at the program shows the diversity of schools and programs within schools involved. The quality of the presentations was revealed by the size and makeup of the audiences that attended and by the lengthy question and answer periods that followed the presentations. Also, the students participated in the rest of the conference at a more active level than usual. Conferences such as this can serve as a showcase or point of contact for students ready to leave academia. These students did more than this. They attended other sessions, asked questions, and gathered new information.

The importance of the "student session" was reinforced for us by the reminiscences of several people, now well established professionally, of how they "broke in" through participation in such sessions at earlier conferences.

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TRENDS IN KILLER WHALE MOVEMENTS, VESSEL TRAFFIC, AND WHALE WATCHING IN HARO STRAIT

Richard W. Osborne[1]

INTRODUCTION

Whale watching has become an increasingly popular recreational activity throughout the world (Hoyt, 1984; Duffus, 1988). Now that the whale watching industry is approaching its second decade of operation in North America, there is growing concern about the potential negative effects of associated increases in vessel traffic around whales. In 1988 the U.S. National Marine Fisheries Service (NMFS/NOAA) and the Center for Marine Conservation sponsored a special "Workshop to Review and Evaluate Whale Watching Programs and Management Needs" (Atkins and Swartz, 1989). At the workshop how little research had been undertaken on the subject of vessel effects on whales was emphasized, but the consensus was that preliminary findings strongly indicate negative impacts from increased vessel traffic on some species and in some locations (Mayo et al., 1989). The workshop's final recommendations on research state that the "research community should direct its attention to studying the short-term and long-term effects of whale watching on individual whales, whale populations, and whale habitats. Immediate research priorities should be species, locations or situations of particular significance" (Atkins and Swartz, 1989, pg. 30). In response to that recommendation the following is an update on vessel-based killer whale (*Orcinus orca*) watching activities in Haro Strait along the U.S.-Canada border between Washington State and British Columbia (Osborne, 1988; Osborne et al., 1990).

In the international waters of Haro Strait between southern Vancouver Island and the San Juan Islands (Figure 1), a significant summer whale watching industry has developed for killer whales during the last decade (Osborne, 1988). The resident killer whale population in this region (known as the "Southern Resident Community," or "J-, K-, and L-Pods," after Bigg et al., 1987) has been the subject of intensive long term field research on various aspects of their biology and behavior (Kirkevold and Lockard, 1986; Bigg et al., 1987, 1990a; Heimlich-Boran, 1988; Ford, 1989; Olesiuk et al., 1990; Felleman et al., 1990). Most of the success of this research stems from the utility of having a complete individual photo-identification catalog of these whales that has been annually maintained from 1974 to the present (Bigg et al., 1987, 1990a).

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In combination with data from a toll-free public sighting network (Whale Hotline) that has been in place since 1976 (Boran, 1980), the published research findings on the Southern Resident killer whales provide an excellent record of the long term occurrence of these killer whales in the core whale watching area of Haro Strait. In the present study this information is considered in relation to some indicators of long term vessel traffic and the results of a questionnaire that was sent out to the local whale watching industry (Osborne, 1988). The objective was to see if there were any indications of disturbance in the recent occurrence patterns of resident killer whales in Haro Strait that might correspond with vessel traffic and/or whale watching.

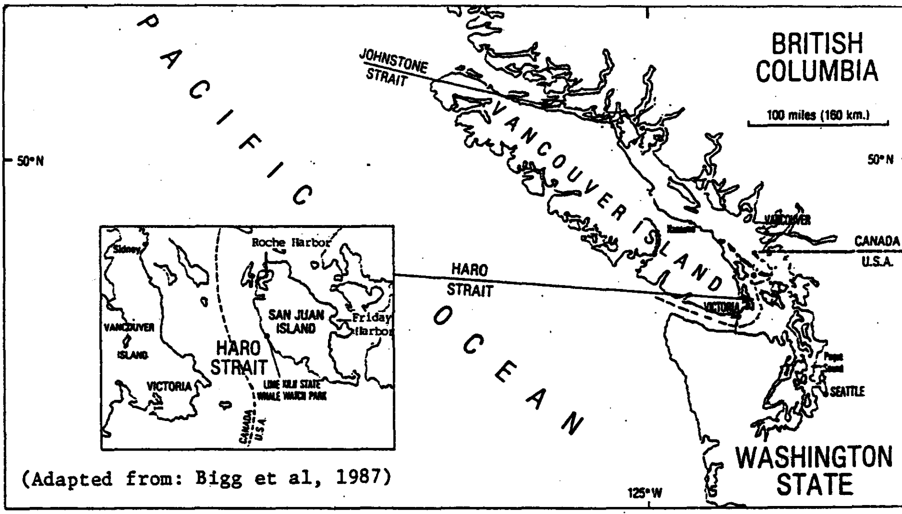

Figure 1:
MAP OF THE WEST COAST OF NORTH AMERICA FROM NORTH OF VANCOUVER ISLAND TO THE MOUTH OF THE COLUMBIA RIVER. *An enlargement shows the main study area of southern Haro Strait and San Juan Island (modified from Bigg et al., 1987).*

METHODS

The study area consists of the region of Haro Strait from Discovery Island east to Iceberg Pt., Lopez Island at the south end, and Moresby Island east to Turn Pt.on Stuart Island in the north (Figures 1 and 2). This zone will be referred to as the "core whale watching area".

Killer Whale Data

The killer whale data utilized in this study come from two sources: 1) public sightings called into the Whale Hotline, and 2) photo-identification encoun-

ters with killer whales collected by researchers working in affiliation with the Whale Museum. Both data sets go from 1976 to present, but due to initially small sample sizes (Figure 3), only 1978-1990 data are plotted. In addition, some photo-identification encounters from other researchers, particularly the Center for Whale Research, have been added to the public sighting data base when these investigators reported their observations to The Whale Museum or the Whale Hotline.

Public sighting information was collected using a collect call to the National Marine Mammal Laboratory, NMFS, NOAA in Seattle from April 1976 to August 1977 (9AM-5PM weekdays), and was switched to a toll free 24 hour number (1-800-562-8832) after that date (Boran, 1980). The toll-free number receives calls from throughout the State of Washington and has been advertised as a means for the public to report whale sightings and marine mammal strandings. In 1985 a similar toll free number was initiated for British Columbia (1-800-334-8832; Osborne, 1987).

Whale Hotline sighting information is entered into a PC data base management system (SMART). In addition to date, time, number and direction of animals, and descriptive location, entries in the data base include Washington State or Canadian fisheries reporting areas, and quadrant code (one square mile) for the inland waters of Washington and southern B.C. as developed by Whale Museum investigator James Heimlich-Boran (1988). Of the sighting information called into the Whale Hotlines, 60% are sightings of killer whales. Figure 3 shows the total number of killer whale sightings called into the Whale Hotlines from 1976-1990 (December 1990 is based on a projection from previous years). These numbers represent a crude indication of annual sighting effort, with 84% of killer whale sightings for all years representing calls phoned in between the months of May and October. This seasonal bias represents the assumptions that 1) resident killer whales spend more time in the inland waters feeding on migrating salmon in summer months (Bigg et al., 1987; Felleman et al. 1991), 2) that sighting conditions are better in summer months due to day length and weather, and 3) the bias of the summer tourist and research season which results in many more people looking for killer whales.

Photo-identification encounters include times when researchers encountered killer whales and were able to document individual identities using natural markings on the whales. This information was pooled with public sighting data.

All sighting and encounter data were sorted for the core whale watching area of Haro Strait (Figure 2). Only sightings from the summer season of May through September were analyzed. Killer whale occurrence was counted as occurrence by day. If killer whales were detected in Haro Strait, the day they

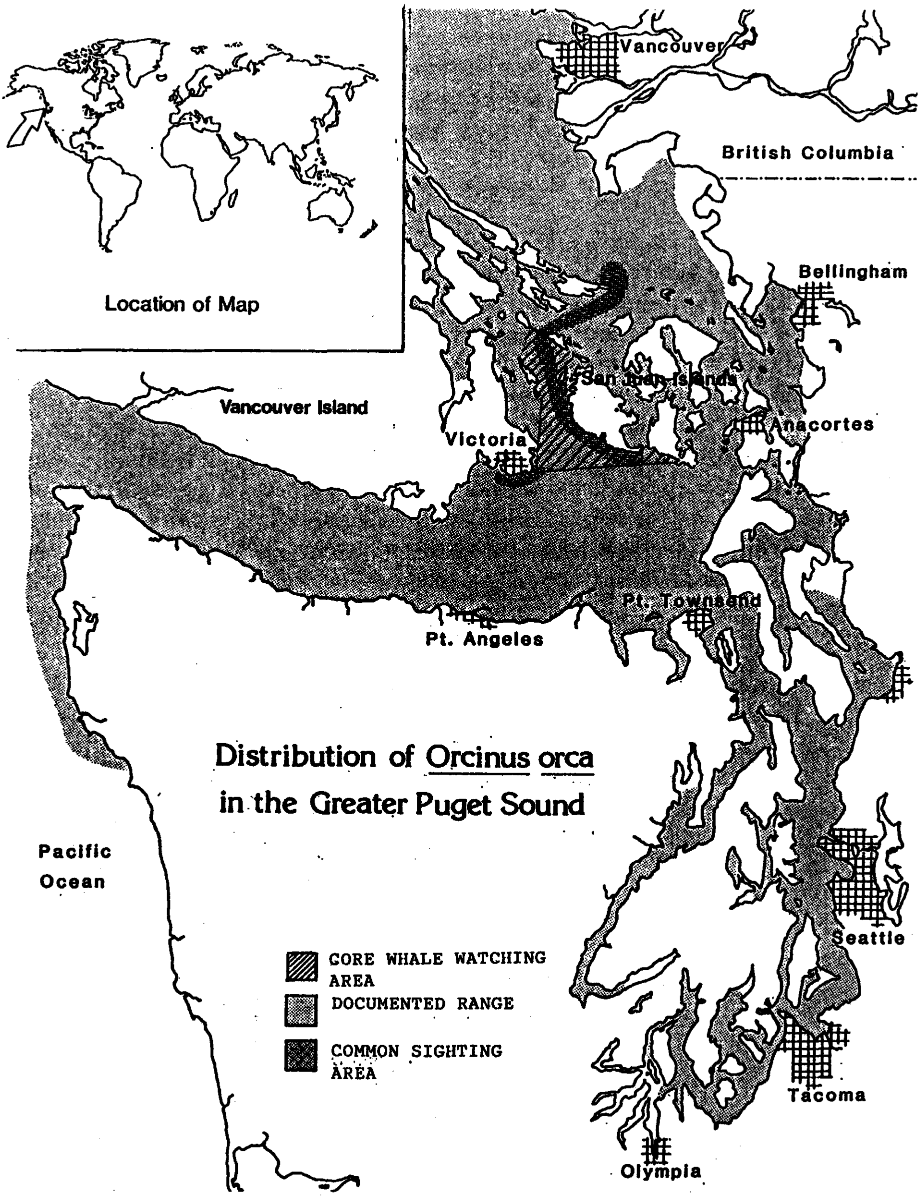

Figure 2:
***MAP OF SOUTHEASTERN VANCOUVER ISLAND AND NORTHWESTERN WASHINGTON STATE** showing the "documented range" of the Southern Resident Community of pods (J,K, and L-Pods; after M.A. Bigg). Also indicated are the "common sighting areas" for these pods and the "core whale watching area". The latter represents the formal study area for this investigation.*

were detected was given a positive score irrespective of the number of sightings that were received on that day. A negative score occurred on any day killer whales were not reported to the sighting network. This information was then plotted as an annual number of days, May through September, that killer whales used Haro Strait.

Vessel Traffic Data

Commercial shipping traffic is the only type of vessel traffic monitored by either the U.S. or Canadian Coast Guards, and Canadian data only represents port entries and exits; they do not distinguish commercial traffic routes. Therefore, U.S. Coast Guard records of commercial traffic entering the Strait of Juan de Fuca east of Port Angeles that did not proceed to any U.S. port were used to measure commercial traffic through Haro Strait. Both U.S. and Canadian Coast Guard traffic personnel indicated that virtually all traffic proceeding into or out of Canada from east of Port Angeles would go through Haro Strait. The only other route is through Rosario Strait, which is very rarely used by Canadian commercial vessels. These records include all commercial vessels such as tankers, freighters and tug-barge combinations, as well as ferries and large cruise ships. This sample does not include commercial fishing

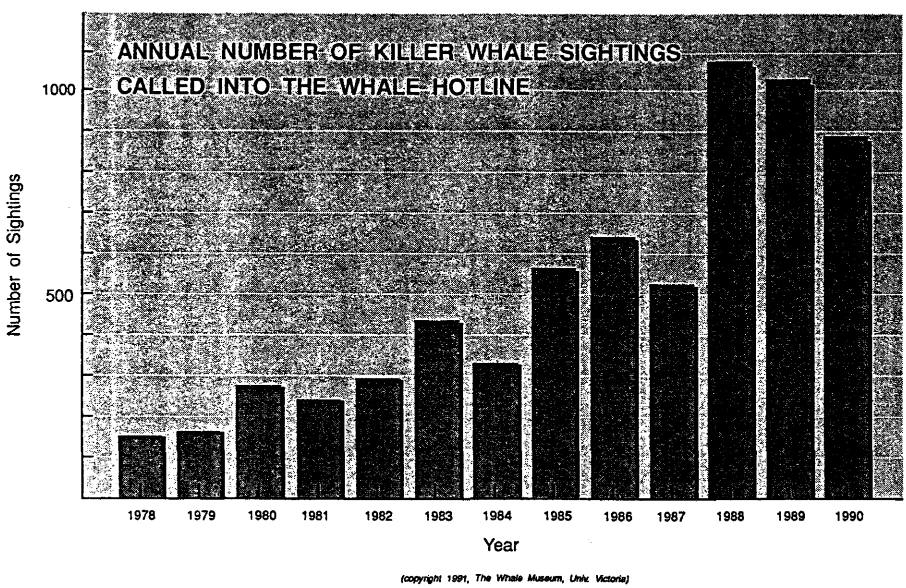

Figure 3:
***ANNUAL TOTAL NUMBERS OF KILLER WHALE SIGHTINGS** called into the Whale Hotlines from 1978-1990 as an indication of annual sighting effort.*

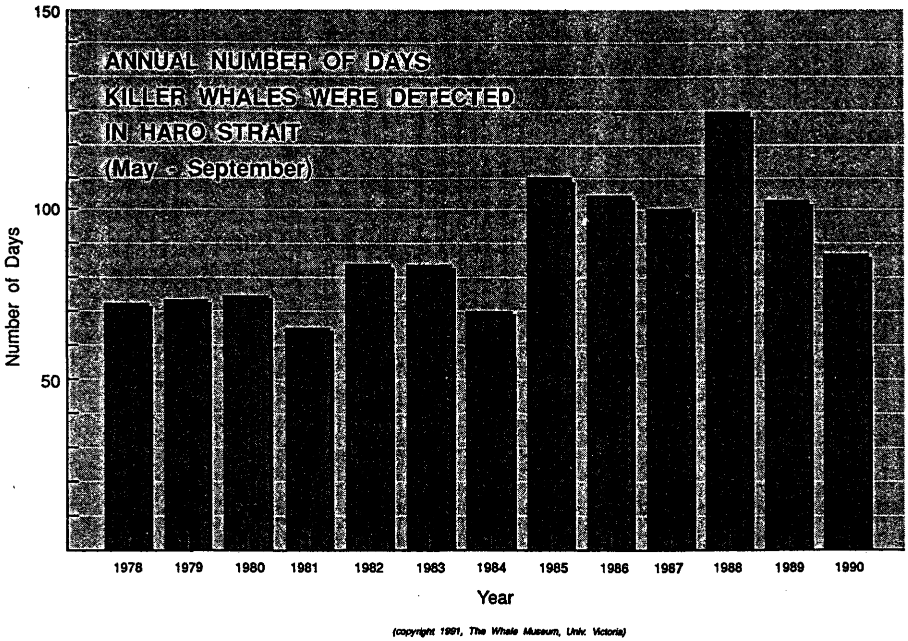

Figure 4:
***ANNUAL NUMBER OF DAYS KILLER WHALES WERE DETECTED** in the core whale watching area of Haro Strait during May through September from 1978-1990.*

vessels or recreational traffic. The data were plotted as annual number of transits from 1984 through 1989 and used as an indicator of baseline trends in commercial traffic for Haro Strait.

Records of vessel registrations for the three Washington counties immediately accessible to Haro Strait (San Juan, Whatcom and Skagit) were obtained from the Washington State Department of Licensing. This information was plotted as the annual total number of registered and non-registered vessels and was used as an index of the potential number of private boats that could be on the water watching whales. This registration program was begun in 1983, but records from the first three years of the program were not utilized, due to the fact that not all vessels were registered during the initial grace period of the program.

U.S. Customs records for the ports of Friday Harbor and Roche Harbor on San Juan Island were used as an index of recreational traffic between the core whale watching area and British Columbia. These were annual records of the number of boats processed by customs from 8AM to 5PM. The annual interval

is based on a "fiscal year" (October through September). Customs agents indicated that well over a majority of these boats are processed during the months from May through September.

Whale Watching Data

Information on the killer whale watching industry operating in Haro Strait was obtained through a questionnaire mailed out to 29 U.S. and Canadian whale watching companies and/or non-profit organizations known to be operating vessel-based whale watching operations or research in Haro Strait in 1988. There was a 96% response to the questionnaire. The questionnaire focused upon the number of boats, people, excursions, and contacts with killer whales each group had on an annual basis from 1976 to 1988.

RESULTS

Patterns of Resident Whale Occurrence

Combined sighting and encounter data for May through September, 1978 through 1990, show a fairly steady increase in the number of days the resident whales were detected in the core whale watching area of Haro Strait (Figure 4). This increase, particularly in the early years up to 1985, appears to track the gross number of sightings fairly closely (Figure 3), but the total number of sightings called in is only a partial indicator of effort and would also be expected to correlate with the number of days whales were available to be sighted. Therefore the small drops in the number of days whales were detected in Haro Strait in 1984, 1986, 1989, and 1990, are probably to some degree real drops in the occurrence of the whales in those years. 1988, when the whales were detected in the core area 85% of the days from May through September, was, by consensus of whale watchers that year (May 5th, 1989 Whale Watching Workshop, The Whale Museum, Friday Harbor WA.), considered an unusual year in terms of the high abundance of killer whales. In this context the small drops in occurrence indicated in 1989 and 1990 appear to be well within the range that would be expected from normal variation. However, until an accurate measure of sighting effort is developed, these trends in killer whale occurrence should be interpreted cautiously, and should serve as a simple index of only extreme changes in killer whale patterns. Given this caution, it appears the occurrence of killer whales in Haro Strait has remained fairly steady and is not exhibiting any signs of disturbance.

Trends in Vessel Traffic

All three of the measures of trends in relative vessel traffic (commercial vessel traffic, vessel registrations, and U.S. Customs data; Figures 5, 6, and 7) indicate a pattern of increase up to 1987-88, when there appears to have been a leveling

off. It is much too soon to know if this trend towards a plateau in vessel traffic will continue. If vessel traffic does remain near current levels, or even if it drops, it is still only a measure of ambient vessel traffic, or "potential" whale watching vessel traffic. The most critical measure in terms of impacts on killer whales is the percentage of this vessel traffic that occurs in the major habitat use areas of the whales, and the amount of this traffic that actually engages in whale watching. These measures will be the focus of future research (Otis and Osborne, 1990).

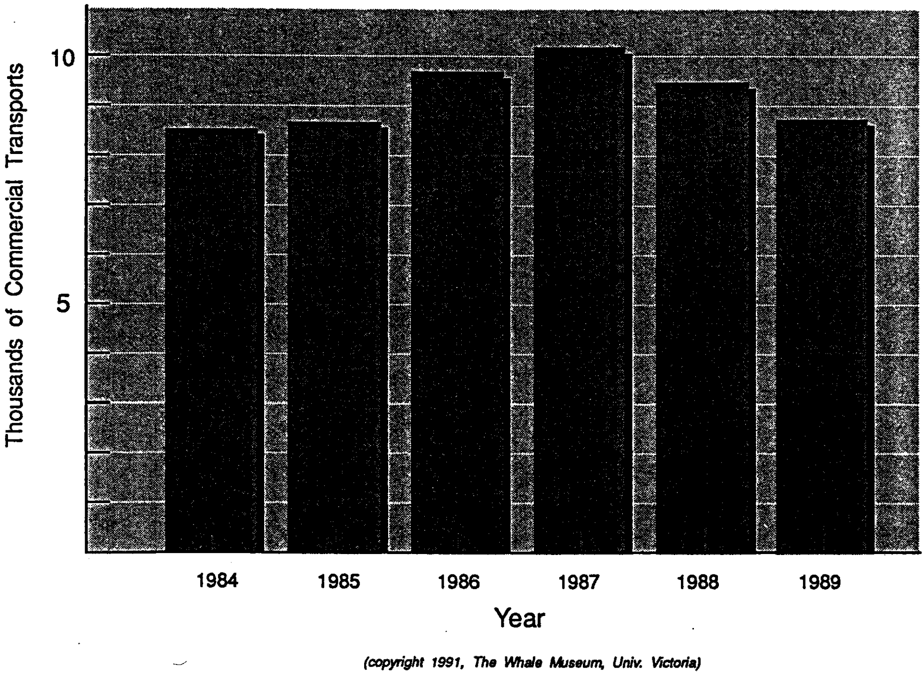

Figure 5:
ANNUAL NUMBER OF COMMERCIAL VESSEL TRANSPORTS IN HARO STRAIT *(tankers, freighters, tug-barge combinations, ferries and cruise ships) 1984-1989 (data courtesy of the U.S. Coast Guard 13th District, Seattle, WA).*

Whale Watching Trends

Virtually all whale watching and research activities take place during the May through September season, with the bulk of activity in June, July and August. The number of operations involved in commercial whale watching in Haro Strait increased steadily from 0 in 1976 to 22 in 1988 (Figure 8).

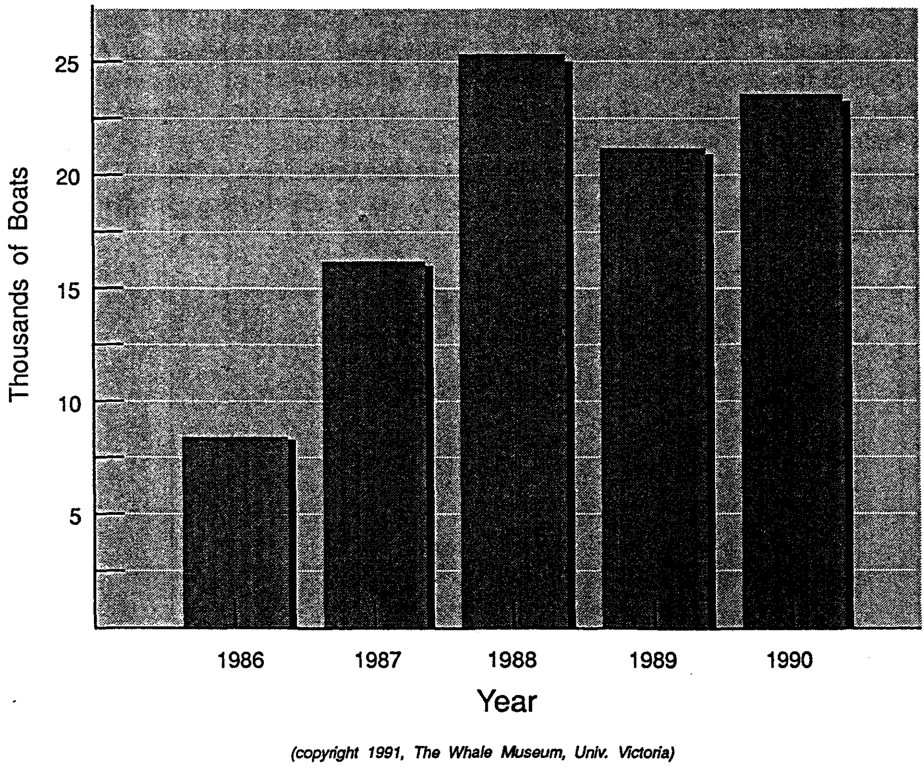

Figure 6:
***ANNUAL RECREATIONAL BOAT REGISTRATIONS IN SAN JUAN, SKAGIT, AND WHATCOM COUNTIES 1986-1990** (data courtesy of the Washington State Department of Licensing).*

The number of people actually going out on commercial vessels to whale watch went from 0 in 1976 to 16,134 in 1988 (Figure 9). The major jump in this figure occurred in 1987 when it went to 13,646 from 3,793 the year before. This increase in 1987 is probably attributable to cumulative advertising that corresponded to a shift in public interest in whale watching, and to the fact that there were enough boats and scheduled trips in place to handle the surge.

The number of research boats, commercial power boats, and kayaks involved shows some significantly different trends (Figure 10). Research boats generally range from 14-22 ft runabouts to 30-40 ft sailing vessels. Two research boats regularly encountered the whales in Haro Strait beginning in 1976. A small, gradual increase in number of research boats occurred until 1985 when it jumped from 5 to 8, and then to 9 in 1986 and 1987. In 1988 it dropped back down to 7 research boats, where it has essentially remained.

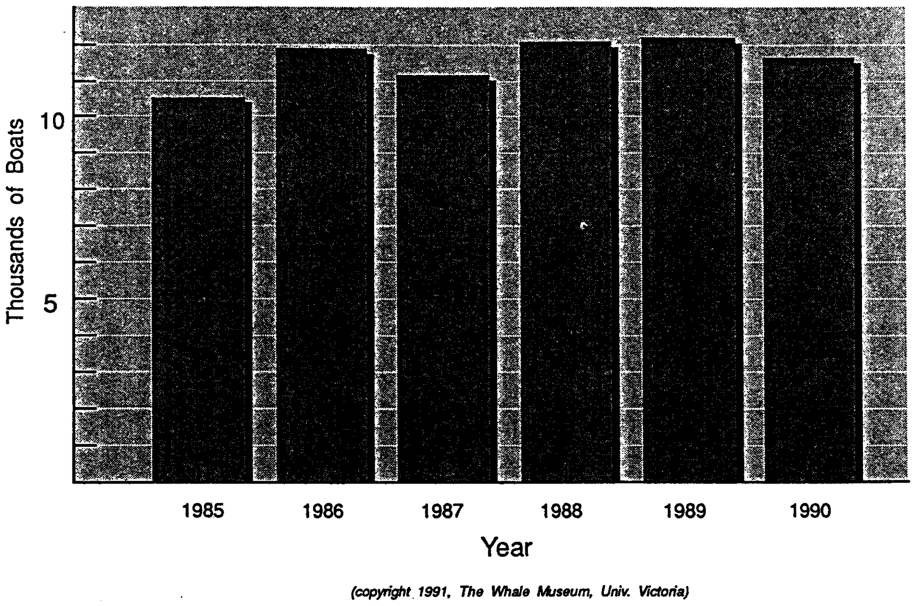

Figure 7:
***ANNUAL NUMBER OF U.S. CUSTOMS VESSEL CHECK-INS IN FRIDAY HARBOR AND ROCHE HARBOR** on San Juan Island (8 AM to 5 PM only) 1985-1990 (data courtesy of U.S. Customs, Friday Harbor).*

Only one commercial power boat (19 feet to over 50 feet) was on the scene in 1977; three boats went out only occasionally from 1979 to 1983 (Figure 10). Then in 1984 a steady annual increase in the number and size of commercial boats began, reaching a maximum of 13 boats in 1987-88.

Commercial kayak trips suddenly appeared on the scene in 1979-80 and showed a steady annual increase in the number of boats up to 1983, when they reached a 3 year plateau (Figure 10). Initially, whale watching was only a minor draw for commercial kayaks, but it has steadily increased in importance in recent years. Since 1987 there has been a steady increase in the number of commercial kayaks.

In terms of impacts on killer whales, perhaps the most relevant findings from the questionnaire come from the data on the actual annual number of encounters, or contacts, between whale watching boats and whales. In Figure 11 the contacts are divided between research boat encounters and whale watching boat encounters, including both kayak and motorized whale watching vessels. Kayak encounters represent less than 10% of the encounters and were counted not by boat but by excursion.

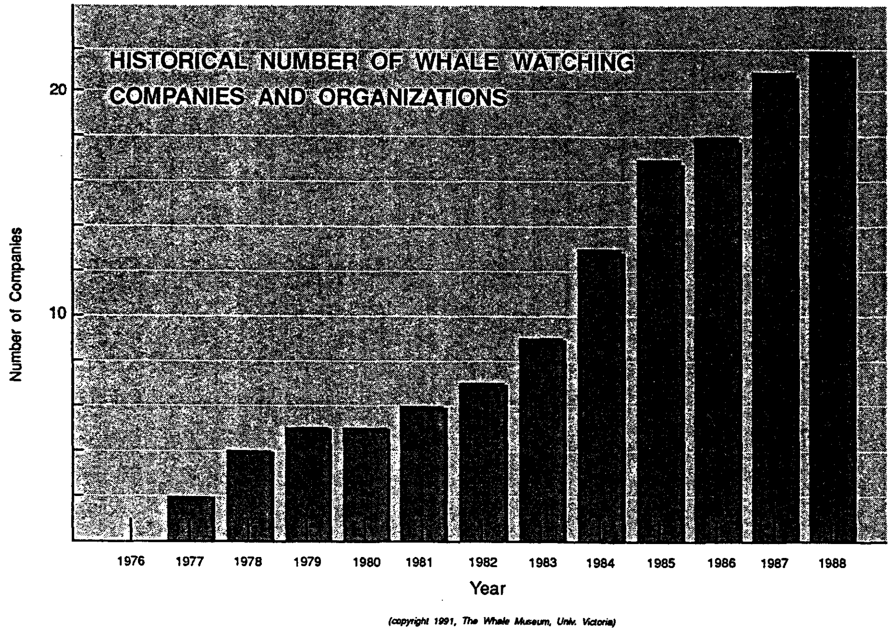

Figure 8:
HISTORICAL NUMBER OF WHALE WATCHING COMPANIES AND ORGANIZATIONS OPERATING IN THE HARO STRAIT REGION (1976-1988).

Except for 1978 (55 encounters), research boats show a fairly constant number of encounters from 1976 to 1983 (mean of 30.5). In 1984 a doubling in the annual number of research encounters began a trend that peaked in 1987 at 75 encounters. In 1988 their were only 30 encounters. Whale watching boat encounters show a steady, just under 40% increase from 1977 (6 encounters) to 1983 (28 encounters). Then over the next three years the increase was closer to 200%. Finally in 1987 the number jumped to 352 from 86 the year before, and increased to 359 in 1988. It is not expected that the exponential jump experienced between 1986 and 1987 will ever be repeated. It seems to represent the year the industry became established with the public (Figure 9), and corresponds with the peak in the number of boats (Figure 10) and an unmeasured increase in the efficiency of whale watching boats to find whales and communicate whale locations among themselves.

DISCUSSION

The impacts of whale watching and vessel traffic on cetaceans cannot be fully evaluated in the absence of a comprehensive understanding of the habitat requirements for the specific population under investigation. However, an

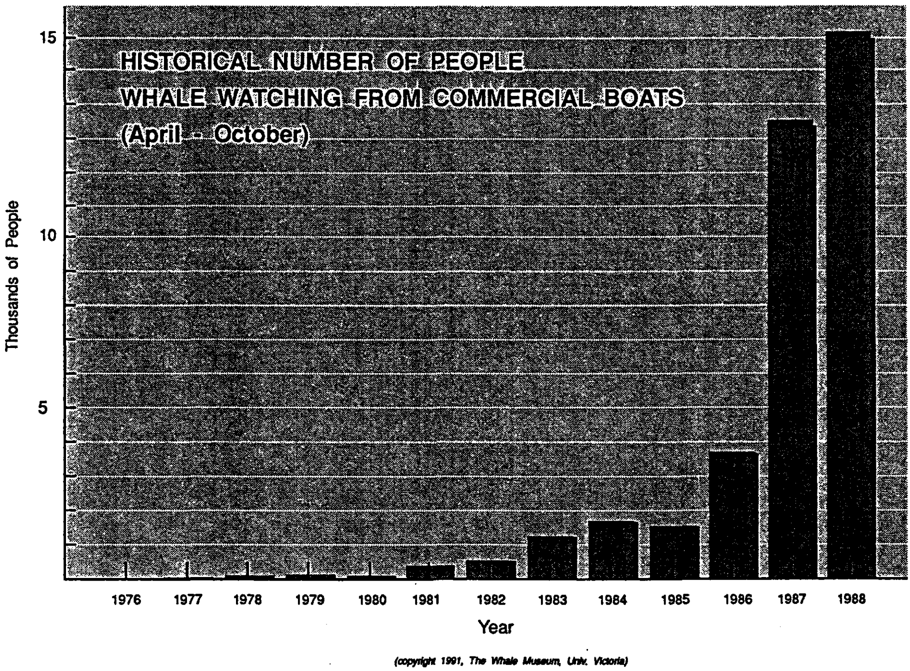

Figure 9:
HISTORICAL NUMBERS OF PEOPLE WHALE WATCHING ON COMMERCIAL BOATS IN THE HARO STRAIT REGION (1976-1988).

obvious first step is to systematically monitor new trends in human impacts that could have an affect on them, especially if the population appears to be exhibiting an obvious disturbance. In the case of the resident killer whale population that frequents Haro Strait along the southeast end of Vancouver Island, there does not appear to be any obvious change in their summertime occurrence over the last 12 years. However, if the small annual decrease in the occurrence of killer whales in the core whale watching area exhibited over the last two years continues, then there may be reason for concern about potential impacts. This remains to be seen from continued monitoring of this population and its habitat requirements.

The resident killer whale population frequenting the core whale watching area of Haro Strait has been the subject of relatively long term and fairly comprehensive studies of their summertime habitat requirements (Bigg et al., 1987; 1990a; 1990b; Heimlich-Boran, 1988; Felleman et al., 1991). However, the description of their summer habitat requirements is far from complete, especially in terms of food resources. More importantly, information is practically non-existent on their requirements in other seasons of the year, or on their

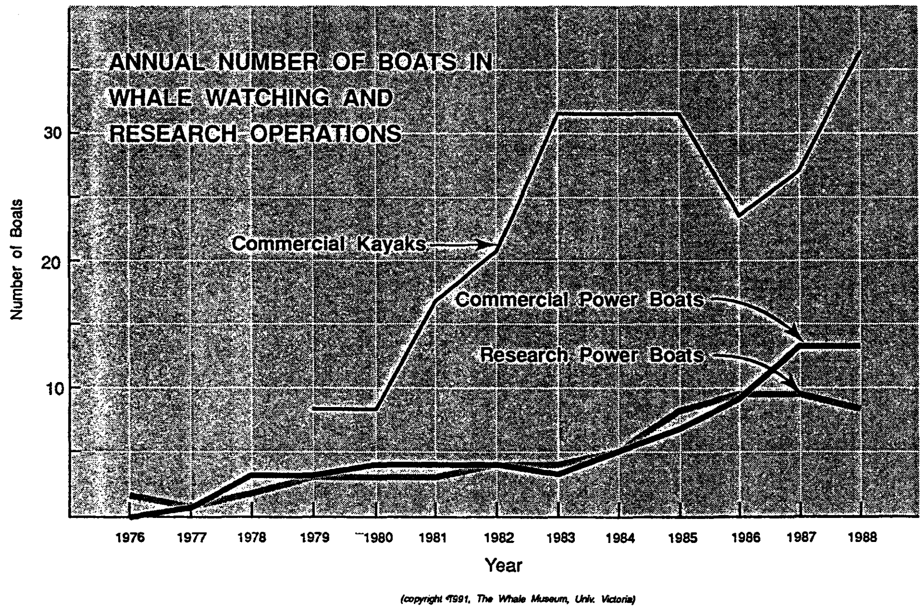

Figure 10:
HISTORICAL NUMBERS OF COMMERCIAL WHALE WATCHING BOATS, COMMERCIAL KAYAKS, AND MOTORIZED RESEARCH BOATS OPERATING IN HARO STRAIT (1976-1988).

activities outside the inland waters, where the majority of these whales appear to spend most of their time (Bigg et al., 1987; 1990a). If variables like vessel traffic, whale watching, changes in food resources, or pollution are impacting this population, such an impact has not yet manifested itself as a significant change in their summertime occurrence, but it could be affecting many other areas that this study has not addressed.

Recommendations for Further Research

The present study presents only a gross means of measuring what might be expected to occur if killer whales were exhibiting an acute habitat disturbance. It does not address potentially overriding variables such as prey abundance, or more subtle changes in variables such as activity budgets, energy budgets, or behavior and communication in the proximity of boats. A great deal more needs to be known about this population of killer whales, as well as the sympatric transient population of killer whales in this region, if a cause and effect relationship between vessel traffic and killer whale behavior is ever to be described.

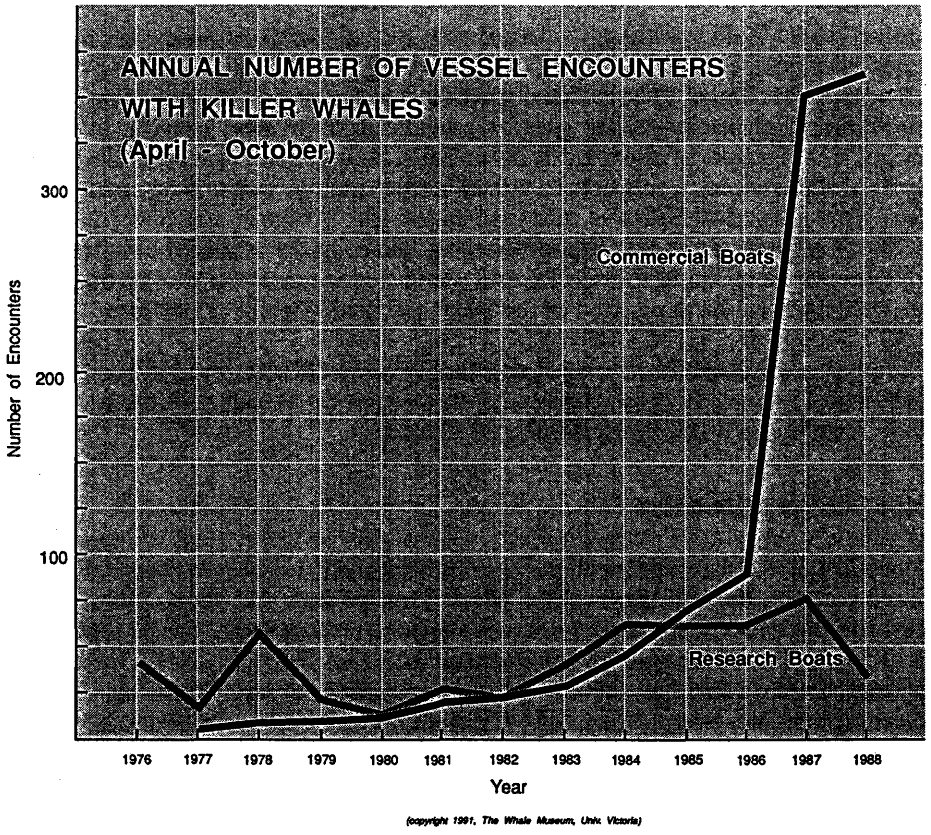

Figure 11:
ANNUAL NUMBER OF KILLER WHALE VESSEL ENCOUNTERS BY COMMERCIAL AND RESEARCH OPERATIONS IN HARO STRAIT (1976-1988).

Future research should update activity budgets for these whales (after Osborne, 1986, and Heimlich-Boran, 1988) and expand data collection to include the "off-season" and additional habitat zones where these killer whales range — the Straits of Georgia and Juan de Fuca, and along the outer coasts of Washington and Vancouver Island. More detailed information is needed on prey abundance and feeding strategies for these killer whales if changes in whale behavior due to vessel traffic are to be adequately distinguished from prey availability.

Since underwater noise generated from vessel traffic is the most likely vector of disturbance for marine mammals (Mayo et al., 1989; Myrberg, 1990), underwater acoustics of vessels and whales needs detailed investigation.

Several others have noted short term reactions to vessel traffic, underwater

noise, and whale watching in other regions of North America for several species of cetaceans (Mayo et al., 1988; Myrberg, 1990), including killer whales (Briggs, 1991; Kruse, 1991). These studies indicate a wide variety of potential reactions that are probably species specific and/or area specific in many cases. The vectors of short term behavioral changes in cetaceans that have been documented in relation to vessel traffic include swimming speed, surface time, direction changes, and respiration rate (Mayo et al., 1988; Myrberg, 1990). A pilot study to investigate these variables in the resident killer whales of Haro Strait utilizing theodolite and video documentation was undertaken in 1990 and will be expanded in the years to come (Otis and Osborne, 1990).

Finally, continued monitoring of ambient vessel traffic patterns in Haro Strait is needed as well as more detailed information on vessel traffic and whale watching in the immediate vicinity of whales.

ACKNOWLEDGEMENTS

I would like to acknowledge all the researchers and members of the public who have contributed sightings to the Whale Hotline over the years, particularly Robin Baird, Fred Felleman, Lorraine Fontaine, Mark Sears, David Seymore, Buz Shaw, Pam Stacey, and Sue Vernon, and Ken Balcomb, Kelly Balcomb-Bartok, Diane Claridge, David Ellifret, and others at the Center for Whale Research on San Juan Island, Alex Rhodes and Eric Walters of Seacoast Expeditions, Bob and Jean Van Leuvan and the naturalists with Western Prince Cruises, Cascadia Research, and Greenpeace. For accessing data acknowledgement is due to Al Smith with U.S. Customs in Friday Harbor, LCDR Sharpe with the 13th U.S. Coast Guard District in Seattle, and the Washington State Department of Licensing. For assistance with data entry thanks go to Lisa Barry, Steve Booth, Debbie Miller, and Chris Penrod. The U.S. National Marine Fisheries Service, the U.S. Marine Mammal Commission, and Moclips Cetological Society deserve mention for their contributions in the early years. The bulk of financial support for this research was provided by The Whale Museum. Preparation costs for this report were provided by The Whale Museum, Dept. of Geography, University of Victoria, and the Marine Mammal Research Group, Victoria, B.C. For editorial comments on this report I'd like to thank Robin Baird, Pam Stacy, Tim Ransom, and Linda Campbell.

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GRAY WHALES: DEATH AND DEMENTIA, THE ALUMINUM CONNECTION?

Peg Nielsen [1]

ABSTRACT

In 1984, a necropsy of an immature California grey whale recovered off the coast of Port Angeles, Washington revealed the presence of heavy metals, including aluminum oxide, pesticides and other chemical contaminants. Despite the fact that aluminum has been implicated in Alzheimer's disease and ALS in humans, in February, 1990, the EPA removed non-fibrous aluminum oxide from its list of toxic chemicals under section 313 of SARA at the recommendation of industry and industry associations.

In the spring of 1990 there were eight known beachings and deaths of grey whales in and near Puget Sound. These whales displayed uncharacteristic wandering behavior similar to that shown by the 1984 immature. There has been only limited scientific follow-through on suggestions that aluminum oxide may contribute to the apparent disorientation of these bottom-feeding marine mammals.

Several professional reports on the subject are examined, as well as data from recent necropsies, studies of the pollution in urban embayments of Puget Sound, and interviews with marine mammal researchers, a laboratory pathologist and EPA personnel. Conclusions concerning the role of aluminum in the deaths of the whales are presented.

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PATCH ECOLOGY OF *ZOSTERA MARINA*

LoAnn M. Hallum [1]

ABSTRACT

Current policies concerning land management practices are partially derived from landscape ecology. Urban development and, more commonly, park and refuge design may include the principles of matrix, corridors, patches, patch size and edge effects. Shorelines are not necessarily viewed with the same connectivity, resulting in isolated management plans. Landscape ecology may provide a framework to develop contiguous management plans for shoreline areas.

Mitigation and restoration projects on shorelines typically do not include patch morphology or connectivity within the matrix. *Zostera Marina* has often been involved in shoreline development plans and was chosen for a patch ecology study. The concept of patches and how they function due to their morphology is basic to landscape ecology. Several parameters, including above and below ground biomass, volatile solids, sediment particle analysis, and infauna, were measured along a transect which extended from the center of the patch to its edge to ascertain possible edge effects and differences among patch sizes. These measurements were also extended into the surrounding unvegetated areas. The unvegetated area, which appears to have no change with distance from the patch, is distinct from the interior of the patch. The patch size does seem to influence the internal distribution of the parameters mentioned. This information may help to refine prevailing strategies addressing the survival of target species in shoreline development projects.

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INFLUENCE OF HABITAT CHARACTERISTICS ON THE WATERFOWL USAGE OF PONDS: A CASE STUDY IN SEATTLE, WASHINGTON

Kristina G.H. Lau [1,2]

INTRODUCTION

The Union Bay Research Natural Area, located on the eastern side of the University of Washington, Seattle, encompasses the Montlake Fill, a former landfill of refuse and dirt (Fig. 1). The reclaimed wetland is now composed of diverse habitats including marshes, ponds, woodlands, grasslands and shrublands. A draft management proposal submitted to the Union Bay advisory committee in 1987 identifies research, teaching and public service as three essential uses for the research area (Hunn, 1987). Further, the proposal suggests that a potentially high species richness would enhance the ecological value of the area and thus encourage scientific, educational and community usage.

The objective of this study is to identify the physical and biological characteristics of the pond habitats which influence the diversity and abundance of waterfowl using the area. This knowledge could then be used to direct management of the ponds to maximize waterfowl diversity on the Montlake Fill to increase its value to science, teaching and community enjoyment.

STUDY AREA AND METHODS

The Montlake Fill was part of Lake Washington until 1916 when the level of the lake was lowered following its connection to Puget Sound. The lake level dropped nine feet and a marsh emerged in this area. In the early twenties, the City of Seattle began using the area for a land fill and continued to do so until 1965. By 1971, the area was filled with rubble and earth and final grading and seeding was accomplished. The Montlake Fill is under the management of the Center for Urban Horticulture, University of Washington. Of the five ponds on the Montlake Fill, two are permanent. The others are ephemeral, drying completely in the late summer and filling up in late autumn. Plant, animal, and waterbird species are present in this area despite the ephemeral conditions. This phenomena suggests diverse food resources are present.

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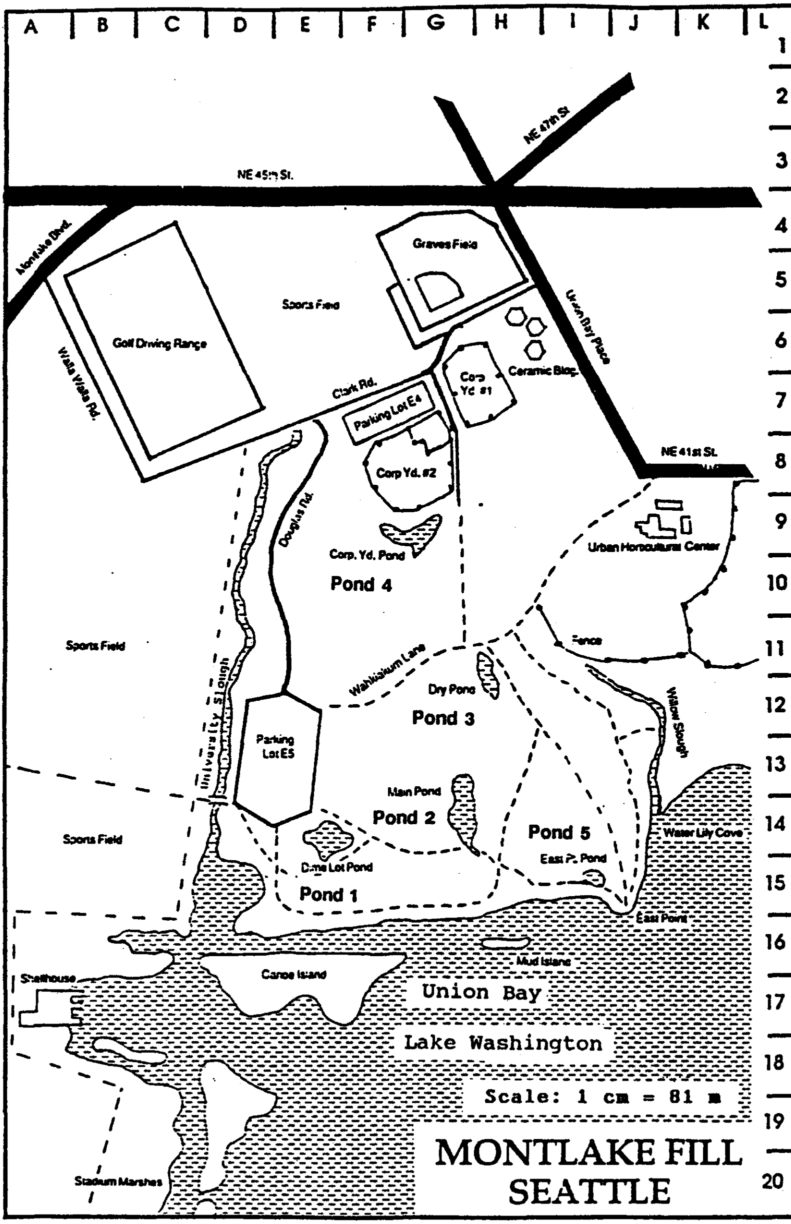

Figure 1.
***MAP OF THE FIVE PONDS ON THE MONTLAKE FILL,** part of the Union Bay Research Natural Area along the western shore of Lake Washington, Seattle (from the Washington Ornithological Society Newsletter No. 3 October, 1989).*

I censused the waterfowl on the five ponds of the Montlake Fill from 2 April to 12 May 1990 for a total of twenty-one days. The characteristics I identified and examined for the five ponds are pond perimeter, area, shoreline development, shoreline vegetation height and water chemistry. Shoreline development is the relationship between perimeter and area used to describe the irregularity of the shape of the pond: i.e., a shoreline development of 1 denotes a perfect circle with no irregularity of shape. Higher numbers reflect higher irregularity.

Percent tall vegetative cover was determined by estimating the amount of shoreline dominated (50% or more) by tall (greater than 50 cm in height) vegetative cover compared to the overall perimeter of the pond. Percent purple loosestrife (*Lythrum salicaria*) a tall, dense vegetation type, was determined by measuring the amount of shoreline dominated by purple loosestrife compared to the overall perimeter of the pond. The same method was used for determining percent woody vegetation. These two values overlap for two ponds because sections of the shoreline had equal amounts of loosestrife and woody vegetation.

Water samples which I took near the pond's surface in the early morning on 16 May 1990, were analyzed for dissolved oxygen (DO), nitrate, nitrite, total nitrogen (TN), soluble reactive phosphate (SRP), total phosphorus (TP), conductance and alkalinity according to standard methods (*Standard Methods for the Examination of Water and Wastewater*, 1985). In the field I measured pH and temperature on 11 May using a Beckman electronic pH meter and a standard thermometer.

RESULTS AND DISCUSSION

Observed Waterfowl Species

Eight different species of dabbling waterfowl and six different species of diving waterfowl were observed. I classified the Canada Goose (*Branta canadensis*) and American Coot (*Fulica americana*) as waterfowl. I also observed several species of shorebirds. The number of waterfowl species seen on a single pond on a given day ranged from zero to eleven. Over the twenty-one day period the daily average number of species of waterfowl observed on a particular pond ranged from 7.1 (Pond 2) to 1.8 (Pond 5). Paulson (1976) has indicated that this diverse list of species seen within a brief time period is unique around the Seattle area. The daily average number of waterfowl on a pond ranged from 112.2 (Pond 2) to 5.6 (Pond 5). Shorebirds were observed more often on ponds 2 and 3 which had continuous areas of open shoreline.

Pearson's simple correlation (r) was calculated between the species richness (daily average number of waterfowl species) and the habitat characteristics. I

also determined the correlation coefficient between the species density and biological and chemical characteristics of the ponds.

Physical Characteristics Of Ponds

My study shows a strong positive correlation (r = +0.89) between the species richness and the surface area (Fig. 2a). These results appear to agree with data on pond area from other researchers (Rumble & Flake, 1983; Godin & Joyner, 1981; Patterson, 1976). The larger ponds have higher species richness of waterfowl, perhaps because the larger area will allow for a greater variety of food resources. Availability of food was the most important factor in determining the pattern of distribution of the waterfowl (Courcelles & Bedard, 1979; Maitland, 1978). The larger ponds also provide security from humans and dogs. Burger (1981) observed that when ducks were disturbed by human activity they flew to the center of the pond. I had similar observations.

Shoreline development (SD) also had a strong positive correlation (r = +0.84) with waterfowl species richness (Fig. 2b). The perimeter also had a strong positive correlation (r = +0.97) with waterfowl species richness (Fig. 2c). Nilsson & Nilsson (1978) and Patterson (1976) found similar relationships. The irregularity of shoreline increases the shore length, allows for more vegetative growth, and also creates small bays and extensions of land which offer calmer, more protected habitat (Patterson, 1976). While pond size can be important, I believe that SD and increased pond perimeter are more important for waterfowl species richness because they allow for a diversity in habitat as well as in food resources. Waterfowl behaviors such as feeding, loafing, hiding and nesting require different habitats depending on the species. Therefore, if one pond were able to offer a diversity of habitats, a diversity of waterfowl would be attracted.

High SD is a good indicator of extensive shallows where waterfowl vegetative food sources could accumulate and form dense patches which would be easily accessible to the birds (Mack & Flake, 1980; Nilsson & Nilsson, 1978). This growth of submersed vegetation provides a suitable habitat for aquatic macroinvertebrates which is also an important food source for waterfowl (Murkin & Kadlec, 1986; Krapu et al., 1983; Ringelman & Longcore, 1982), especially as a protein source for young.

Since area has such a strong correlation with species diversity, it was eliminated as a primary variable when analyzing the other habitat characteristics. Instead, for further analyses, I used species density, which is the species richness per unit of pond area ($1000 m^2$).

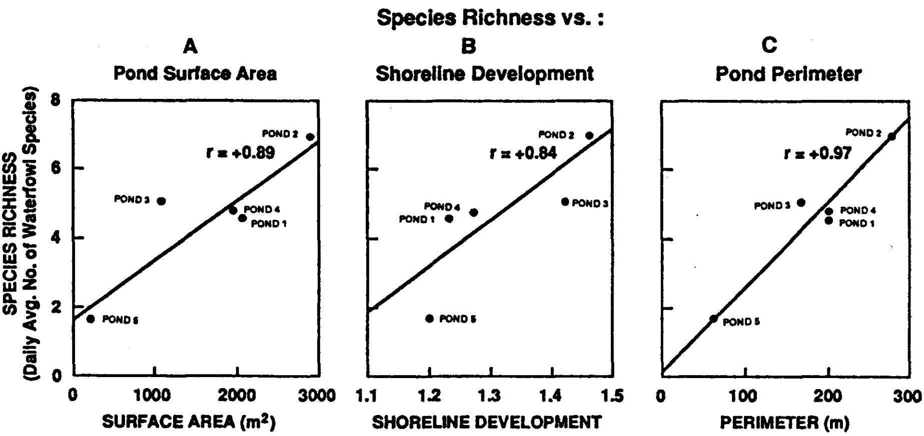

Figure 2.
RELATIONSHIP BETWEEN SPECIES RICHNESS AND PHYSICAL CHARACTERISTICS OF THE PONDS ON THE MONTLAKE FILL, SEATTLE, WASHINGTON, DURING SPRING 1990.

Vegetative Characteristics Of Ponds

The most abundant forms of pond shoreline cover on ponds 1 and 4 included dense stands of purple loosestrife (a herbaceous species) intermingled with woody vegetation, primarily willow (*Salix*) and cottonwoods (*Populus*). Pond 2 was three-quarters enclosed by tall dense stands of the exotic purple loosestrife. The sections of shoreline with no cover were a mixture of mud and low growing grasses. Ponds 3 and 5 had predominantly low vegetative cover,such as grass with small sections of tall vegetation. The vegetation on Pond 3 was the most diverse and richest in native species. It consisted of sedge (*Scirpus validus*) (a herbaceous native species), spike rush (*Eleocharis*) with a scattering of dock (*Rumex*), bitter nightshade (*Solanum dulcamara*), saltmarsh sandspurry (*Spergularia*), cudweed (*Gnaphalium*), a variety of sunflower (*Artemisia*) species and small cottonwoods. The sedge and bitter nightshade were located in two groves in the center of the pond.

A strong negative correlation exists between species density and percent tall vegetative cover (r = -0.86; Fig. 3a) and percent purple loosestrife (r = -0.86; Fig. 3b). The dominant vegetation on ponds 1, 2 and 4 was purple loosestrife. These three ponds with abundant tall shoreline plants have significantly lower species density of waterfowl than ponds 3 and 5 which have small amounts of tall vegetative cover and little to no purple loosestrife. In fact the vegetative cover on Pond 3 consisted of diverse low growing species, the native sedge and spike rush being dominant, both of which have seeds edible to waterfowl. Pond 5 has reed canarygrass; its seeds also may be a food source for waterfowl (L. Storm, personal communication).

Loosestrife's invasive nature and dense stands also prevent other vegetation, particularly nutritional vegetation, from growing. Studies in Thompson et al. (1987) suggest that loosestrife's invasive nature is partially responsible for the decline of bulrush and dwarf spikerush in areas of the United States. It is the diversity of edible vegetation which attracts waterfowl species. Gjersing (1975) and Kaminski & Prince (1984) found waterfowl preferred ponds having an abundance of emergent edible vegetation. On my research site the predominant vegetative type is purple loosestrife which is inedible by waterfowl. Therefore a limiting factor on habitat quality and, subsequently, on waterfowl species diversity on the Montlake Fill ponds, is the abundance of tightly packed purple loosestrife which dominates vegetative areas and displaces native waterfowl food plants (Thompson et al., 1987).

The structure of surrounding vegetation can influence waterfowl usage of a pond as many researchers have observed. The extreme height of the vegetation could interfere with the flight landing patterns of the birds (Probert, 1989), which might suggest that tall vegetation around ponds should be minimized. Unlike the enclosed ponds (ponds 1 and 4), the open ponds (3 and 5) provide loafing sites with an unobstructed view to spot predators, a characteristic which ducks prefer (Keith, 1961).

Pond 1 and 4 had abundant woody vegetation and had lower species density and numbers. Similar results were found by Rumble & Flake (1983) and Kaminski & Prince (1984). Trees produce leaf litter which, when decomposed by bacteria, consume oxygen which could be used by other vegetation (Kabisch & Hemmerling, 1982) and also produce ammonium salts, phosphates and other nutrients (Thompson & Coldrey, 1984) which could lead to eutrophication of the water. This creates poor conditions for aquatic vegetative growth, except for weeds such as purple loosestrife which flourish.

Water Quality Of Ponds

Eutrophication of a water source indicates that with increased productivity there is a reduction in the ability of the organisms to metabolize and adapt to changes in the system (Wetzel, 1983). Nitrogen and phosphorus are considered to be the principal limiting nutrients for primary production. All ponds were very high in TP, all over 100 ug/L. The concentration of TN and TP was highest on Pond 5, 5472 and 785 ug/L respectively. Pond 2 was second highest with almost half the concentration of TN and TP as Pond 5. Pond 4 had the lowest concentration of TN and TP, 939 and 114 ug/L respectively. Although these ponds are classified as hypereutrophic by Wetzel (1983), they still support a diversity of waterfowl. I found a positive correlation between nitrogen and phosphorus levels and species density ($r = +0.88, +0.86$), inferring that high primary productivity is associated with high species density. Nilsson & Nilsson (1978) and Murphy et al. (1984) found the same pattern.

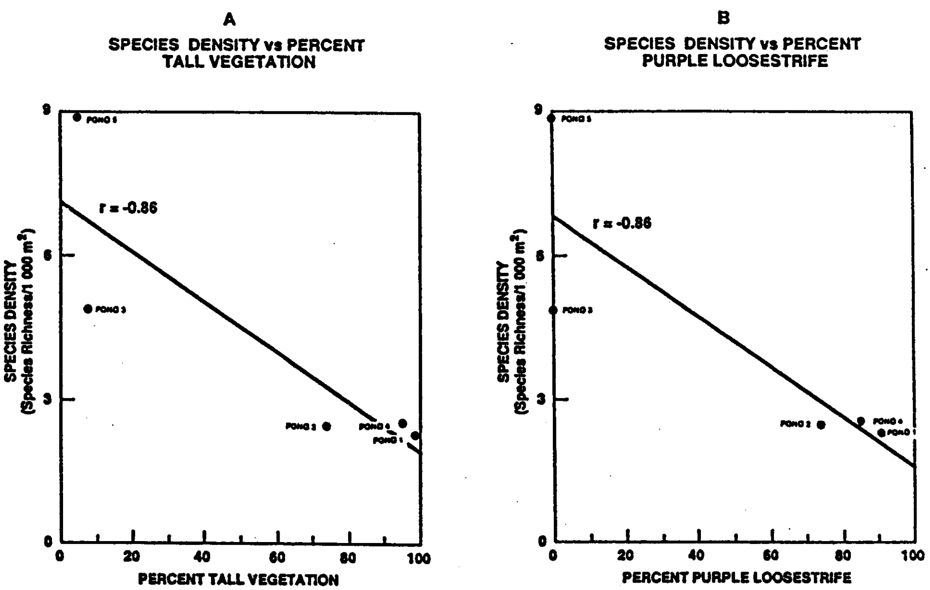

Figure 3.
RELATIONSHIP BETWEEN SPECIES DENSITY AND THE AMOUNT OF TALL VEGETATION AND PURPLE LOOSESTRIFE SURROUNDING THE PONDS OF THE MONTLAKE FILL, SEATTLE, WASHINGTON, DURING SPRING 1990.

An increase in alkalinity indicates an increase in productivity of the pond. Conductivity measures the resistance of a solution to electrical flow. The higher the salinity the lower the resistance (high conductivity), creating conditions usually intolerable to a number of waterfowl food plants. Alkalinity and conductivity had a moderate positive correlation to the species density ($r = +0.74, +0.78$). However, this was not significant enough to allow any clear conclusions, suggesting that for this study these characteristics are not appropriate indicators of species density of waterfowl.

There is no significant correlation between species density of waterfowl and the remaining water quality characteristics: nitrite, nitrate, SRP and DO. The pH and temperature were fairly constant (ranging from 6.82 to 7.77 and 11.2 to 13.0° C) between ponds, and therefore probably do not influence species richness or density of waterfowl on these ponds. I believe that water quality is probably not a reliable characteristic to use in identifying attractive waterfowl habitat on the Montlake Fill, unless the concentrations of nutrients are so high that eutrophic conditions occur.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Based on the results of this study, ponds with a large surface area or a long perimeter or high shoreline development attract a diversity of waterfowl species. Vegetation consisting of diverse and edible species also aid in attracting a diversity and increased abundance of waterfowl. Water quality characteristics, particularly total nitrogen and total phosphorus, are useful in determining the primary productivity level (of phytoplankton) of the pond. However, physical characteristics of the ponds and vegetative structure and plant types appear to be more reliable characteristics to use in identifying preferred waterfowl habitats on the Montlake Fill.

The correlations determined in my study suggest strong relationships between species richness of waterfowl and certain pond characteristics. These relationships and patterns could be used as a base for possible management strategies. Other studies (Krapu et al., 1983; Bellrose, 1979) showed that the number of ponds was positively related to species richness and numbers of waterfowl. Their results imply that no pond should be eliminated. Instead, the ponds should be altered to provide optimum attractive habitat for the waterfowl to maximize species richness. For the existing ponds, alterations could include: (1) removing the dense monospecific non-edible stands of exotic purple loosestrife to allow the development and growth of diverse native plants, including submergent and emergent waterfowl food plants (However, known methods to control purple loosestrife are complex and not always effective [Thompson et al., 1987]. Further research on control methods are needed.); and (2) the nutrient levels could be managed and monitored to maintain optimal productivity of the ponds.

If additional ponds are created, two essential characteristics appear to be desirable. Firstly, maximizing the amount of shallow water areas available for the production of submersed and emersed edible vegetation would increase production of aquatic animals which are another essential food source for waterfowl. This could be done by reshaping the ponds, i.e., altering and increasing the shoreline. Secondly, resources also could be maximized by creating large ponds which provide extra area for more shoreline vegetation to attract more waterfowl species.

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EVALUATION OF THE SCANNING ELECTRON MICROSCOPE AND X-RAY MICROANALYSIS IN THE DETECTION OF HEAVY METALS IN *MYTILUS EDULIS*

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INTRODUCTION

Fifteen years ago the Bay Mussel, *Mytilus edulis*, was proposed as a good watch species for monitoring global water quality (Goldberg, 1975). Sedentary as adults, nearly catholic in distribution, and fairly nondiscriminating as filter feeders, they effectively provide a "time-integrated value of the biologically available metals at their particular location" (Ritz, et al., 1982). Several recent studies have shown *M. edulis* absorbs some bioavailable heavy metals at nearly linear rates dependent on ambient concentrations (Young & Folsom, 1967; Schultz-Blades, 1974; Bayne, 1976; Harris, et al., 1979; Davies & Pirie, 1980; Sutherland & Major, 1981; Ritzet al., 1982; George, 1983; Elliott et al., 1985). These studies, as well as others (Graham, 1972; Thomson, 1979; Jensen et al., 1981), have used digestions of soft tissues and spectroscopic analysis to determine concentrations of heavy metals in the mussels. This method can provide reliable quantitative data, but is time consuming procedurally. Recent increases in the availability of scanning electron microscopes (SEM) equipped with multichannel x-ray detectors provide a potentially quick qualitative, if not quantitative, evaluation of heavy metal conditions, if such can be discerned from the analysis of mussel shells.

MATERIALS AND METHODS

Mytilus edulis specimens from five different locations and four different littoral levels were collected to provide a variety of potential exposures to heavy metal pollutants. The Evergreen State College (TESC) is located between Eld and Budd Inlets, (Washington State, USA), each of which experience markedly distinct pollution conditions. A municipal sewage outfall empties into Budd Inlet (Lacey, Olympia, Tumwater and Thurston County [LOTT] wastewater treatment facility). By contrast, Eld Inlet has commercial oyster beds close to the mussel collection site in this study. From the TESC beach (on Eld Inlet) individuals were collected from the highest, lowest and intermediate intertidal levels within the *Mytilus* range. In Budd Inlet collections were made from the floats of the City of Olympia, Percival Landing dock and adjacent pilings (high littoral), and three locations close to the sewage outfall near KGY Radio (AM 1240, N. Washington Street): the old Olympia Marina floats, the tideflats north of KGY, and the tideflats east of KGY and adjacent to the

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Cascade Pole site which have been designated by the Washington State Department of Ecology a toxic waste cleanup site.

These collections were regarded as eight distinct sample groups. In the lab these specimens were washed in fresh water and lightly scrubbed to remove the heaviest surface contamination. Subsequently mussels were opened by cutting the posterior abductor muscle and the kidneys were excised and placed in a solution of 2.5% glutaraldehyde and filtered seawater (Hayat, 1986). Remaining soft tissue was discarded and the shells were again washed and scrubbed in deionized water. They were then drip dried for a brief period and placed in a desiccator overnight to complete drying. Shell fragments of less than 1 cm square, including a portion of shell from the growth edge, were later glued with colloidal graphite to aluminum stages. One shell fragment was glued to a carbon stage and two of the samples were carbon coated to improve SEM imaging and provide comparative data on x-ray analysis. Other samples from the same shells were embedded in an epoxy resin in recesses drilled into the tops of aluminum stages and then ground and polished to a very smooth surface (a 0.25 micron polishing paste was used in the final step). Cross sectional slices from four of the kidney tissues (one from Eld Inlet, three from the sites closest to KGY Radio) were prepared for SEM viewing. (This involved an ethanol dehydration followed by critical point drying with CO-2 [Samdri-PVT-33], and finally coating the samples with carbon [Technics Hummer II; Argon atm, 200 millitorr, 20 milliamps, 3.5 min].) All four kidney samples were glued to the same aluminum stage to allow quick comparative evaluation.

Specimens were first imaged using an Amray 1810 scanning electron microscope at an accelerating voltage of 10 eV and low magnification (100 x) so that regions for microanalysis could be selected. Stage tops were oriented at an approximate 45 degree angle to provide an optimal backscattering coefficient. During spectra acquisition magnifications on the order of 1200x were used in conjunction with accelerating voltages of 30 eV, resulting in count rates under 1000 cps, (Reimer, 1985). A Kevex Delta Class Analyzer (model 4405) running Quantex (ver. 5.07) was used for data acquisition and analysis. This allowed spectrum samples of a uniform integral value, (integral = 500,000; i.e. total area [in points] under the spectral curve), making rough quantitative analysis possible.

RESULTS

The Quantex software allows variable sensitivity and automatic identification of principle spectral features (emission lines/escape peaks). By Gaussian analysis at a specified peak to background ratio, frequency response data are

compared to library standards. This produces a "best guess" list of quantifiable statistical certainty. Spectra files may be compared to one another by chi-square analysis.

Analysis of surface features of rough shell fragments revealed that at a peak to background ratio (P/B) of 0.75, elements which could be identified were calcium, silicon, sulfur, chlorine, sodium, potassium and phosphorous. Lowering the P/B to 0.5 allowed iron, zinc and magnesium to be identified. Chi-square comparisons of the spectra files for shells from the various sites showed no statistically significant differences between sites, though individual spectra sometimes varied widely. Polished shell fragments showed a greater consistency from sample to sample and also revealed no significant differences between samples from the various sites.

Kidney sample analysis revealed a very similar elemental mixture to that of the shell samples. The relative quantities of the elements varied (for example, the kidneys had less calcium), but there were no other elements reliably identified. Again there were no statistically significant differences between the sites.

DISCUSSION

Initially the x-ray spectra indicated an extremely high concentration of aluminum. As recent analysis of brain and liver tissue from gray whales (*Eschrichtius robustus*) grounded in Puget Sound revealed abnormally high concentrations of aluminum (Gorlick, 1990), this finding caused some excitement until it was realized that in the case of my work the high aluminum reading was an instrument artifact. An element of the microscope's focusing apparatus was misaligned, causing the machinery to detect a portion of itself. A slight adjustment corrected this problem. Unfortunately there are other less tractable artifacts generated by the process of x-ray microanalysis which ultimately limit the potential of present systems to determine trace metal concentrations. Much of this artifact generation has to do with the physics of the electron beam/specimen interaction.

Energy dispersive x-ray microanalysis uses a highly focused electron beam to bombard a small area on the surface of a specimen. Immediately beneath this limited two dimensional area, a much larger three dimensional volume of tissue (often described as "onion-shaped") interacts with the electron beam. When individual atoms have high energy electrons pass through their electron clouds, electrons normally associated with a given atom may be knocked away from that atom. If this happens to an electron of the atom's "inner shell", an electron from a higher energy, outer shell assumes the position of the lost electron. Energy in the form of an x-ray is released as a result, and the energy of this x-ray is characteristic of the particular element which lost the electron. Through the use of a multi-channel x-ray detector, an spectral

profile of the analyzed substance is generated. This may subsequently be compared to library standards to determine elemental makeup of the substance. Complicating this process, electron beam/specimen interactions are not limited to the generation of x-rays. Electrons passing close to the nucleus may be effected by its positive charge and release a *Bremsstrahlung* energy, or electrons may be scattered either elastically or inelastically and may ultimately leave the specimen as backscattered, secondary or auger electrons. These differing responses to the initial electron beam carry varying amounts of information and the most elaborate of microanalysis machines may use a combination of detectors to increase the analysis accuracy. More common today is the x-ray detector which suffers this problem: if x-rays are not generated close to the surface of the specimen, x-rays and scattered electrons may continue, albeit with less energy as a result of the initial reaction, and interact with other atoms within the specimen. This causes signal noise and artifacts which lessen the potential sensitivity of the detector (Reimer, 1985).

Much can be done in specimen preparation to mitigate problems inherent in x-ray microanalysis. To control the distance the average x-ray must travel to exit the specimen, the surface of the specimen can be polished flat. Also the sample can be sliced very thin to limit the interaction volume of the electron beam within the specimen. In the case of soft tissue samples such considerations require the specimen to be either frozen or resin embedded (Russ, 1980; Panessa-Warren, 1983).

As all electron microscopy must be performed in a vacuum, water must be removed from the specimen before examination. Osmotic fixatives such as the glutaraldehyde used in this study may cause leaching of certain elements from the tissue. Also stains which may be required to identify specific organelles may well disrupt the chemistry of the specimen. Tissue smears followed by air drying of the sample have been used successfully (Morgan,1984) but may not be suitable in many cases due to the ion translocation which occurs during slow drying (Morgan, 1985).

With careful specimen preparation and spectral analysis, energy dispersive x-ray microanalysis may be able to detect trace metals in concentrations as low as 100 ppm (Morgan, 1985). Heavy metals have been observed to be concentrated in tertiary lysosomes of the kidney (Sutherland & Major, 1980; George, 1983; Chassard-Bouchaud & Hallegot, 1984). In *Mytilus edulis* these storage organelles occupy some 20% of the kidney cell volume (George, 1983) and may have concentrations of metals several times higher than elsewhere in the organism (Sutherland & Major, 1980). Therefore x-ray microanalysis is sufficient to determine the presence of iron and zinc, as these naturally occur in concentrations somewhat higher than 100 ppm. However other heavy metals may be considered to be present in elevated amounts at levels of less than 1 ppm (Davies & Pirie, 1980), so that energy dispersive x-ray microanalysis is not

suitable for detecting pollution problems which may in fact be causing changes in *Mytilus edulis* tissues. Another type of x-ray detector, the wavelength dispersive analyzer, has detection limits 10-50 times lower than the energy dispersive variety (Morgan, 1985), though this increase in sensitivity is insufficient for the proposed application.

Advances in technology of energy dispersive x-ray microanalysis equipment may one day be sufficient to allow meaningful detection of trace amounts of heavy metals, though today the mechanism does not exist. Practical considerations of specimen preparation also present prohibitive hurdles.

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EFFECTIVE NONPOINT SOURCE PUBLIC EDUCATION AND OUTREACH: A REVIEW AND EVALUATION OF SELECTED PROGRAMS

Clare Ryan [1]

ABSTRACT

Nonpoint source (NPS) pollution has been identified as the principal remaining cause of water quality problems throughout the United States. Regulation and control of NPS pollution is difficult because of the diffuse nature of the problem. As a result, public education is recognized as an essential element of an effective NPS control program.

Several successful NPS related public education and outreach programs are being planned and implemented in EPA Region 10 (Alaska, Idaho, Oregon and Washington). The objectives of this research are to document and review selected programs in Region 10, and to provide a reference document for state and local governments and other groups regarding the development and implementation of successful NPS public education and outreach programs. Specific Puget Sound area initiatives evaluated include programs underway in the Johnson Creek and Clearwater River areas, the Burley-Minter Clean Water Project, and the Puget Sound FARM Project and the Associated General Contractors Project, both Puget Sound Water Quality Authority Public Involvement in Education Fund projects.

Documentation was accomplished through review of existing literature, phone interviews and personal visits to project areas. Program evaluations were conducted, consisting of a subjective assessment of the effectiveness of the program in general as well as the specific educational techniques employed. The study concludes with a recommended framework for evaluation of NPS public education and outreach programs.

Many of the educational techniques identified as effective are common to several of the programs, regardless of the target audience or type of NPS pollution. These techniques have been identified as "keys" to success and represent what educators see as the most crucial elements of success for their particular educational efforts. Several of the more common successful techniques include strategic framing of the problem, provision of complete information and adequate technical assistance, frequent personal contacts, financial incentives, peer education, interagency coordination, timing considerations, local and individual autonomy, and participatory events.

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The recommended framework for evaluation of programs includes examining program elements such as goals, objectives and criteria, program scope, voluntary versus mandatory, funding, monitoring, educational strategy, timing, and other socioeconomic impacts.

PUGET SOUND NONPOINT POLLUTION MANAGEMENT AS A PROBLEM IN WATER QUALITY GOVERNANCE

Eric Shott[1]

Puget Sound faces nonpoint threats from agriculture and forest practices, failed on-site sewage disposal systems, urban runoff, domestic and wild animal wastes, and marinas and recreational boating (Puget Sound Water Quality Authority [PSWQA], 1986a). Numerous efforts have been made to address nonpoint source problems in Puget Sound over the years. For example, the first such planning effort was outlined by the Washington Department of Ecology (DOE) in 1981 under the state's Section 208 nonpoint source management program (DOE, 1981).

This paper analyzes the evolution of rural nonpoint source pollution management in Puget Sound from 1980-1990 using an assessment strategy developed by Leschine et al. (1991, this volume). The biogeophysical nature of nonpoint source pollution indicates that effective nonpoint source management requires the cooperation of a large number of individual land owners, each of whom is contributing a small amount to the total pollution problem. The necessity for group action to achieve management goals gives nonpoint source management the characteristics of a public good. Consideration of the institutional arrangements that determined the management of this public good problem leads to important inferences as to how and why programs evolved. Moreover, the effectiveness of the different decision making and management structures that have addressed various aspects of the problem at different institutional levels can be assessed.

The entities involved at the "constitutional", "collective choice," and "operational" institutional levels can be evaluated in terms of decision making structure, geographic scope, functional scope, and size (Leschine et al., 1991, this volume). Different types of decision making strategies (computational, collegial judgement, and bargaining) can be used, depending upon what is known about the causes of a problem and the level of agreement on decision outcomes. For various reasons, management entities may choose decision strategies that do not "fit" the problem they are addressing. Setbacks or ineffective approaches may result.

If the geographic scope of the agency (or interagency arrangement) is much larger or smaller than the size of the nonpoint problem area, inattention to the problem may occur. Also, if a source of nonpoint pollution cannot be addressed, the functional scope is incomplete and results will be limited. Finally, the size of agencies or arrangements may affect access to decision makers, data collection, and internal management (Bish et al., 1975).

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Federal, state, and local agencies in Puget Sound have made and are making many attempts to address the nonpoint source pollution problem there. These efforts involve changes at all three levels of institutional arrangements noted above. New decision making structures, geographic and functional scopes, and sizes have emerged. Many of these changes are the result of feedback between, and internal to, the institutional levels (Leschine et al., 1991, this volume).

THE EARLY 1980s

In the early 1980s the governance structure in Puget Sound was just beginning to address rural nonpoint source problems. Although the basics of this type of pollution were well understood, the institutional arrangements in place had evolved to deal with other issues, such as point sources and preventing the loss of good crop growing soils. The focus was on state-wide programs to address various sources of nonpoint source pollution. The state Department of Ecology took the lead for Clean Water Act section 208 efforts. But federal 208 funding was terminated in 1981 (PSWQA, 1986a).

The DOE first addressed nonpoint source problems and Puget Sound as a region in 1981 when it proposed a water quality plan, the Puget Sound Sensitive Area Study (PSSAS). Sensitive areas would be identified by available data and a management plan would be written. The PSSAS was never fully implemented, due mainly to the aforementioned lack of federal funds after 1981.

Statewide, DOE's work on rural nonpoint sources used a decision making strategy already familiar: the internal computation that resulted in National Pollution Discharge and Elimination System (NPDES) permits. The Dairy Waste Management Plan mandated that dairies with over 200 mature animals without "Best Management Practices" (BMPs) would need to obtain a NPDES permit from DOE (DOE, 1981). According to a 1986 PSWQA evaluation, the plan, while well conceived, suffered in implementation from lack of adequate staffing (PSWQA, 1986a). DOE also provided its technical expertise to the Forest Practice Board's water quality efforts, and urban stormwater runoff was eventually put under a NPDES system as well (DOE, 1981).

In dryland agriculture, DOE recognized that a NPDES type management system would not work. In bargaining among DOE, the Washington Conservation Commission, and water quality committees composed mainly of farmers, it was determined that conservation districts would act as management agencies for dryland agricultural operations. The state was relying on an almost completely voluntary BMP program in this area with little state-wide oversight. DOE provided regulatory investigations and enforcement only at

the request of a conservation district (DOE, 1981). Some agricultural sources, such as noncommercial farms, were not included in the regulatory effort. Again, the cut off of federal Section 208 funding in 1981 further hindered these nonpoint source programs (PSWQA, 1986a).

Notwithstanding the DOE state-wide NPDES and supporting technical study efforts (many of which were desperately needed), the Shorelands program at DOE began developing a different approach to handle nonpoint source problems. The closure of six Puget Sound commercial shellfish beds had alerted DOE to nonpoint problems (PSWQA, 1986a). Shorelands developed a pilot basin planning approach to address bacterial problems at commercial shellfish beds that focussed on on-site sewage systems and agriculture. The first pilot project would take place in the Burley Minter watershed. DOE expected to expand the program after evaluation of the first effort (Shigenaka, 1987).

Residential on-site systems in the early 1980s were mainly under the jurisdiction of local health departments who follow state Board of Health Regulations. The Washington Department of Health (DOH, part of the Department of Social and Health Services [DSHS] until the late 1980s) provided oversight. But updates to state regulations in 1983 exempted most systems installed before 1979, resulting in a gap in regulatory coverage. Moreover, there was no state wide maintenance plan for single family dwellings in the early 1980s (PSWQA, 1986a).

In the early 1980s the Puget Sound Water Quality Authority (PSWQA) acted in the role of assessor and commentator only. In its 1984 report the Authority outlined the nonpoint source problem and noted the lack of a systematic approach focusing on water quality. PSWQA also recommended that regulations be applied more strongly against toxic pollutants, that Shorelands' basin planning program be applied more expansively and extensively, and that more technical assistance to localities be provided (PSWQA, 1984).

THE MID 1980s

In the mid 1980s, Puget Sound became the special focus of many water quality programs. In the nonpoint source area, DOE Shorelands' basin planning effort had resulted in problems in the decision making processes used. The counties and DOE relied on a technical advisory committee and a consultant to put together a management plan (Hansen, 1989). The resulting draft of sample ordinances had the support of the counties and DOE. When watershed residents learned of the proposed regulations to on-site systems and agriculture, a "firestorm" of citizen protest occurred (Shigenaka, 1987). What followed was the creation of a citizens review committee that involved the public much more directly and early in the decision making process (Shigenaka, 1987).

Meanwhile, the state legislature responded to the Shellfish Protection Strategy by funding more Shorelands basin planning and creating the Shellfish Protection Program (McKamey, 1987). The new law left it up to localities to decide upon the creation of "Shellfish protection districts" and to find funding to facilitate nonpoint source planning (Chapter 90.72 RCW). No districts were established. With more funding, Shorelands had received 11 applications and funded seven shellfish basin planning projects by 1986. Similar to the above, DOE let the localities decide if they needed the program (PSWQA, 1986a). DOE and local governments had learned from the Burley Minter experience, and local citizens became much more involved in these basin planning efforts (PSWQA, 1986a). However, Shorelands was addressing only bacterial contamination of commercial beds. EPA and DSHS moved to expand the coverage of the shellfish policy by investigating the chemical contamination of shellfish beds in 1986 (PSWQA, 1986a).

In the mid 1980s public concern and environmental activists had pushed the legislature to act on Puget Sound water quality problems. PSWQA was granted planning power (although the exact extent of its authority remained unclear). The Authority began preliminary efforts at overall water quality planning, including nonpoint source pollution. PSWQA recognized the value and limitations of DOE Shorelands' basin planning and expanded upon it. A more comprehensive approach was outlined. All localities in Puget Sound were to prepare nonpoint source management plans under the same management program with state oversight. The Burley Minter experience had also affected the Authority's approach (Hansen, 1989). Watershed planning would involve all concerned and affected citizens.

However, funding for the nonpoint effort remained uncertain. PSWQA noted that the amount of funding available would affect deadlines outlined in the plan (PSWQA, 1986b). Money was sought from the Centennial Clean Water Fund (Cigarette tax), and local government general funds (PSWQA, 1986b).

THE LATE 1980s

In cooperation with DOE, DOH, and DOA, PSWQA began to fill in the details of the nonpoint source management effort. Basically, PSWQA adopted an approach that can be described as a mix between collegial judgement and bargaining. The process involved substantial comment from affected parties, but did not directly involve them in decision making. This approach ran into problems when it tried to write specific regulations without direct participation from those to be regulated. Mandatory stream fencing and animal density controls were suggested (Hansen, 1989). The agricultural community complained both to PSWQA and the state legislature. Several state legislators wrote letters to the Authority in support of the old voluntary 208 program

(Rayburn to PSWQA, 1987; Hanson to PSWQA, 1987). PSWQA held several meetings with agricultural interests, and backed off of mandatory stream fencing (Hansen, 1989). Section 208 farm plans would satisfy in most cases (WAC 400-12).

The result of the planning effort was WAC 400-12 (Local Planning and Management of Nonpoint Source Pollution), a new and innovative approach to nonpoint source management that was more consistent with the precepts of good institutional design implied by public choice theory than previous efforts. Each level of government is asked to do what it does best. Localities use data familiar to them (time and place information) to prioritize watersheds and identify the most serious nonpoint sources. Locals then develop management plans for the problem sources in high priority watersheds. DOE coordinates all aspects of the program Sound-wide and provides its technical expertise to localities to help with data collection and interpretation. Other agencies provide their technical expertise as well, in the form of a technical support team headed by DOE. Watershed management committees involving all those affected by nonpoint source planning are created to write the management plans (PSWQA, 1990).

Thus, the approach is Sound-wide and the geographic scope matches the size of the problem. The decision making process that will result in management plans is not one dominated by internal computation (the way DOE's attempt to use the NPDES permit system was), but more one of bargaining and negotiation that involves critical participants in Watershed Action Committees (that construct the management plans). Because all possible nonpoint sources must be investigated, the focus is on providing complete functional coverage. This is furthered by requiring statements of concurrence between the watershed management committee and any governmental agencies that will be asked to participate in a management plan (WAC 400-12). It has also been recognized that the watershed plans must be coordinated with other programs such as the Timber, Fish and Wildlife agreement (T/F/W) and DOE's ground water program, and with new on-site regulations that may be enacted by the State Board of Health (PSWQA, 1990).

Under WAC 400-12, watershed ranking has taken place. Also, 12 early action watershed plans begun before the completion of WAC 400-12 are complete, or almost so. These plans do not need to follow the letter of the rule, but its intent (PSWQA, 1990). Funding for implementation of these and later plans is in question. Most of the money being used is from the Centennial Clean Water Fund, but it will not be sufficient to provide all the funding needed (PSWQA, 1990). The Authority is encouraging watershed lead agencies to apply for other types of state and federal funding that are available. Both PSWQA and DOE are in the process of looking for ways to secure federal funding for the plans (PSWQA, 1990).

CONCLUSIONS

What began mainly as a single agency, computational decision making structure in the early 1980s evolved into a multi-agency negotiated bargaining arrangement better able to address the problem by the late 1980s. In many instances, feedback as to the shortcomings of old programs resulted in new institutional arrangements to address nonpoint pollution.

Initial efforts, led mainly by DOE, established a pattern of computational decision making or collegial judgement, as evidenced by the Dairy Waste Management Plan and early Shellfish Protection Strategy planning. Later efforts, led mainly by PSWQA, show a reliance on collegial judgement and negotiated bargaining among affected parties. Hansen notes that the "wisdom" of the technical committee and technical expertise of the consultant did not produce a workable solution in the Burley Minter case, while the PSWQA approach has been much more acceptable to affected parties (Hansen, 1989).

Moreover, in the early 1980s the nonpoint source management approach had problems in its geographic and functional scope. The size of the lead agency played a role as well. Geographic scope problems could be seen in numerous efforts. The program for dryland agriculture and shellfish initiatives left the decision to plan up to localities. There were many local efforts more independent of DOE as well. The problem with these approaches is the lack of a Sound-wide focus, given the information available on Sound-wide nonpoint problems. Small local entities have neither the ability to collect and analyze this type of information nor the "need" to respond to other localities outside their jurisdictions that may be affected by pollution they generate (Bish et al., 1975).

Unlike localities, DOE does have the size and technical expertise necessary to collect Sound-wide data and coordinate management efforts (such as watershed ranking). However, its large size implies that interest groups may have better communication with the agency than individuals (Bish et al., 1975). Also, with a geographic scope larger than Puget Sound, other problems will compete for scant time and resources.

Functional scope problems included the partial and complete gaps in nonpoint sources addressed. In the early 1980s, noncommercial farms and on-site systems built before 1979 suffered from lack of attention. By the late 1980s it was clear that redressing the functional scope issue would require cooperation among PSWQA, DOE, DOH, and DOA to write the WAC, and numerous other agencies to concur with local management plans.

The constitutional level decision to create PSWQA established an agency that was better able to address Puget Sound problems than the DOE as it then existed, because its geographic scope excluded other problem areas. Other

characteristics, such as its functional scope (planning only) and size (small, implying better access for citizens) enabled the Authority, in concert with other state and local agencies, to create a more comprehensive nonpoint source program.

The complexity of nonpoint source problems results in situations where different agencies and decision strategies will be more or less appropriate, given the nature of the specific problem being addressed. Attempting to broadly apply one type of decision process can result in snags such as occurred at Burley Minter or with stream fencing. Leaving localities to "go it alone" emphasizes the weaknesses of localities implied by collective choice theory, while ignoring the strengths of larger agencies, given the same analysis. At the other extreme, complete program control by a single state agency can ignore local strengths and emphasize the weaknesses of a larger agency.

Finally, funding is a problem that has not been adequately addressed by the current nonpoint source planning effort. While funding is controlled at various institutional levels, the highest levels administer the largest amounts. Funding requests for watershed plans compete with many other interests at all levels. Proposals to generate new revenue specific to the watershed management effort may become simply another tax increase that individuals reject locally or state wide. These funding problems must be resolved for successful implementation.

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THE EFFECTIVENESS OF STORMWATER MANAGEMENT POLICIES IN PROTECTING STREAMS

DeeAnn Kirkpatrick[1,2]

INTRODUCTION

Unmanaged stormwater runoff entering streams can have a number of adverse effects on stream systems. Local governments in Washington State are responsible for managing stormwater runoff within their jurisdictions, resulting in a wide variety of stormwater management policies and programs. Whether these policies and programs are effective, particularly in protecting natural fish communities and fish habitat, is the focus of this paper.

The stormwater programs of five local government jurisdictions, two state programs (one presently being drafted and one recently adopted), and a recently adopted federal program were examined. Experts in the stormwater management and fisheries fields provided information on the necessary elements of effective stormwater policy and effective methods of addressing these elements. This information was used to judge the overall effectiveness of the eight case-study programs in addressing the full range of stream protection concerns.

STORMWATER IMPACTS ON STREAMS

Impacts of unmanaged stormwater runoff that affect stream quality include: increased flooding, channel erosion and alteration of the streambed particle size composition; reduced base flow, alteration of the character and volume of energy inputs to the stream; increased entry of toxic substances such as heavy metals, pesticides, oil, detergents, and other pollutants to the stream; elevated nutrient inputs to the stream; and alteration of the natural stream temperature regime (Klein, 1979). These changes can degrade instream physical habitat as the number of pools decrease, riparian vegetation and large woody debris are removed by increased stream flows and volumes, and large volumes of sediment degrade spawning gravels. The cumulative impact of these changes is a decrease in the number and diversity of fish (Scott, 1982; Ragan and Dietemann, 1975) and aquatic invertebrates (Pedersen, 1981; Richey, 1982).

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STORMWATER MANAGEMENT

To maintain healthy stream ecosystems, stormwater programs must manage the causes of these impacts. The scientific literature (Schueler, 1987, and others) suggests six elements that must be managed to prevent or diminish these impacts: peak discharge, stormflow volume, groundwater recharge, streambank erosion, water quality, and instream and riparian habitat.

Peak discharge and storm volume must be controlled to prevent flooding, erosion, water quality and habitat damage. Groundwater recharge must be provided to maintain summer stream flows. Managing streambank erosion, limiting pollutant inputs, and maintaining habitat are also important.

DELPHI TECHNIQUE METHODS AND RESULTS

While the scientific literature provides some information on management elements needed to maintain streams, the literature does not provide information on the best methods for addressing each of these elements. To collect further information, the Delphi Technique (Delbecq, 1975) was used as a means of aggregating judgements of individuals to reach consensus on these stormwater management issues. Through the use of two carefully designed sequential questionnaires, a systematic solicitation and collaboration of judgements of fifteen panel members was accomplished. The panel members included experts from either the stormwater management and/or fisheries fields from throughout the Puget Sound area. Their responses were reviewed and statistically summarized, forming the basis for determining important stormwater management elements and effective methods of addressing these elements in order to protect fish and fish habitat.

The panel listed the following elements, in order of priority, as necessary for inclusion in an effective stormwater management program:

1. Habitat protection
2. Peak discharge control
3. Development-related erosion control
4. Base flow protection
5. Riparian zone protection
6. Pollution source controls
7. Streambank erosion control
8. Flow volume control

In addition, the panel chose stormwater management methods that effectively address the elements listed above. They chose requiring riparian buffers

that are based on the physical and biological factors of the site, as well as requiring maintenance of instream habitat, as the most effective methods of providing habitat protection. For controlling peak discharge, they chose requiring duplication of pre-development infiltration. Requiring infiltration where site conditions are favorable was chosen as the most effective method for providing groundwater recharge (or base flow protection). For managing streambank erosion, requiring preservation of wetlands and other natural drainage features and requiring maintenance of pre-development peak flows and durations were considered the most effective methods. And for maintaining water quality, requiring wet ponds, swales and erosion control were chosen as the most effective methods.

PROGRAM EVALUATION

To examine stormwater policies, program evaluation was conducted using a multiple-case study approach (Yin, 1981). Policy inputs, or in other words, the standards, regulations, guidelines, or ordinances that the programs utilized to implement stormwater management, were examined. The following eight programs were chosen as case studies for this research:

- U.S. Environmental Protection Agency (EPA) (National Pollutant Discharge Elimination System Permit)
- Puget Sound Water Quality Authority (PSWQA) Stormwater Plan to be implemented by the Washington State Department of Ecology (DOE)
- Washington State Department of Fisheries (WDF) Stormwater Guidelines
- King County
- Snohomish County
- City of Bellevue
- City of Mountlake Terrace
- City of Lynnwood

The three agency programs (EPA, PSWQA/DOE, and WDF) were chosen for study because they set guidelines for local governments. King, Snohomish, Bellevue, and Mountlake Terrace were chosen because they are among the most well-developed and comprehensive programs in the Puget Sound area. As a contrast, the city of Lynnwood, a relatively new program, was also examined.

Table 1 summarizes whether the eight programs addressed the most important stormwater management elements by using the methods considered to be the most effective by the Delphi Panel experts. Under the program heading on the right, the first number represents how many programs required the use of this specific method.

Table 1.
OVERALL PROGRAM EVALUATION

Element	Effective Methods	Program
Habitat	• maintain riparian buffers	3 of 8
	• base buffers on site factors	0 of 8
	• maintain instream habitat	0 of 8
Peak Flows	• duplicate pre-development infiltration	0 of 8
Groundwater	• infiltration where possible	1 of 8
Streambank Erosion	• preserve wetlands	4 of 8
	• maintain pre-development flows	0 of 8
Pollutant Removal	• wet ponds and swales	1 of 8
	• erosion control	5 of 8

The table shows that the eight programs overall did not do very well in addressing the most important stormwater management elements with the most effective stormwater management methods. Only three of the five local government programs required riparian buffers. None of the three agency programs required buffers, although DOE and WDF may require buffers on a case-by case basis, largely depending on the current regulations of the local government. None of the programs required a buffer that was determined by the physical and biological factors of the site, which the Delphi Panel overwhelmingly chose as the best method for determining effective buffers.

Maintaining in-stream habitat is the primary focus of WDF's Habitat Program, although no state-wide regulations exist which provide for this requirement. Maintenance of in-stream habitat under WDF's authority is determined on a case-by-case basis. None of the other programs require maintenance of in-stream habitat, although three local programs have set guidelines for stream rehabilitation.

To manage peak discharge, most programs required controlling discharge of one or two specific design storms, or controlling discharge to a specific pre-development level. No programs required duplicating pre-development infiltration.

To promote groundwater recharge, only one state program required the use of infiltration, although infiltration is encouraged by two local government programs and one state program. Infiltration is discouraged by one local government and not mentioned as a part of three other programs.

Controlling streambank erosion by preserving wetlands is required by four local governments. The two state programs encouraged preservation of wetlands, but do not have the authority to require it, except in the case where

other state, federal or local regulations for preserving wetlands apply to a specific site. Controlling streambank erosion by maintaining pre-development flows and durations was not required by any of the programs.

To limit pollutants, five programs had specific requirements for erosion control, and one program had specific requirements for wet ponds and swales. The other programs encouraged the use of general Best Management Practices (BMP's) to protect water quality.

According to the Delphi Panel results, none of the eight programs will be very effective in protecting and maintaining streams in a manner that sustains fish habitat and fish resources (Kirkpatrick, 1990). This is somewhat surprising since at least some of these programs are widely considered to be the most well-developed and comprehensive programs in the Puget Sound area.

RECOMMENDATIONS AND CONCLUSIONS

Until better information on effective stormwater management is available, the consensus professional judgements of the Delphi Panel experts should guide stormwater managers in designing and implementing stormwater management programs that protect fish and fish habitat. Incorporating the methods listed in Table 1 into new or existing stormwater programs is recommended wherever and whenever possible.

An appropriate conclusion for this paper is to paraphrase what one panel member wrote when asked about the elements most lacking in stormwater programs:

> All stormwater programs start out with a rainfall event and end up downstream. To protect fish and fish habitat you need to start in streams and work upslope. This is completely opposite of how drainage engineers analyze stormwater problems. Fish and fish habitat are probably the most sensitive components to protect with a stormwater program. The key is to protect the hydrologic processes which form fish habitat and apply BMP's to maintain water quality. How this is done is the question. Fish habitat needs to be a priority in stormwater management, not a result.

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SEWAGE SLUDGE, VALUABLE RESOURCE OR COMMUNITY PROBLEM?

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INTRODUCTION

Between six and seven million tons of dry sewage sludge are generated each year in the U.S. This sludge is rich in nitrogen (N), phosphorous (P) and potassium (K). However, concern that nitrates and contaminants in the sludge could leach into groundwater or enter food chains has limited its use.

In 1985 the Municipality of Metropolitan Seattle (Metro) generated 65,000 tons of dewatered sludge. Metro's sludge is sold for fertilizing Christmas tree farms and timber plantations, as a soil conditioner, and for mixing with sawdust to make compost. Metro has purchased land in southeast King County near Cumberland to provide an additional opportunity for profitable sludge use. The Concerned Citizens of Cumberland (CCC) have raised a number of issues that have forced Metro to prepare a site-specific Draft Environmental Impact Statement (DEIS) for its proposed sludge operation.

In this paper I will address technical and nontechnical factors that bear on Metro's plans and recommend an approach that minimizes the impact on Cumberland of sludge application. The principal technical factors relate to sludge's effectiveness as a fertilizer, and to possible hazards from contamination of ground water and forest food chains and from accidental spillage. I will also respond to the most significant issues raised by the CCC, including the perceived burdening of the rural community with urban waste.

BACKGROUND

According to Burd (1986), "Sludge disposal has been an issue in the Western world since at least 1857, when sanitation authorities in England first proposed sewage treatment." He goes on to report that as early as 1909, sewage sludge was used to fertilize vegetable farms around Baltimore, Maryland. "The odors in the vicinity of the sewage lagoons are very offensive but as far as is known they have not had an unfavorable affect on the health of those living on the farms. However the nuisance from the flies was considerable." That may have been an effective use of sludge but it is hardly one that would be acceptable today.

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Fradkin et al. (1988) note that approximately 6.2 million dry metric tons of wastewater sludge are generated each year, or 26 kilograms (kg) per person. Scarpino et al. (1988) estimate it was "almost seven million metric tons dry weight in 1982. By the year 2000, production is expected to nearly double."

Bastian (1986) estimated that "total reuse of the nutrients in the organic wastes from 150 million Americans on central sewage disposal systems, another 50 million on septic tanks, and 87,000 industrial plants could provide 1.4 million tons N, 0.3 million tons P and 0.6 million tons K or about $950 million worth of nutrients currently supplied by commercial fertilizer sources."

There are a variety of reasons why sludge is not used more, but one of the most important is concern about pathogens, heavy metals, hazardous organic compounds and nitrates that are present. These substances contaminate the site where sludge is deposited and can enter surface and ground water or food chains through uptake by primary producers.

Metro generates dewatered sludge at its West Point treatment plant (WPTP) and Renton treatment plant (RTP) from processing residential and industrial sewage and stormwater in the greater Seattle area, including much of east and southeast King County. Metro also provides for disposal of septic tank solids and leachate from the Cedar Hills and Hobart land fills. Sludge will be trucked to the site near Cumberland where it is mixed with water and sprayed on the trees from a spray vehicle. The sprayed sludge cakes when it dries, but washes to the ground at the first rain.

TECHNICAL CONSIDERATIONS

General Effects on Flora and Fauna

"Current studies in the Pacific Northwest with Douglas-fir indicate that the growth response from sludge is at least twice as great and lasts twice as long as when this species is fertilized with urea..." (Cole and Henry, 1986). The exact response depends on the tree species, its age, and the sludge source. Table 1 shows that the response of the Douglas-fir to municipal sewage sludge is extremely favorable. Tree mortality, while higher than the control stand, is relatively low (Table 2).

Growth of understory vegetation is greatly accelerated, and grass and understory herbaceous species have higher protein levels, causing preferential grazing by large herbivores. For Italian rye grass, the crude protein level increased between 160 and 176%. Elevated N levels were also found in seven understory plants found in Douglas-fir forests. The level of P was also increased. Another factor, in vitro digestibility, was found to increase in some species in low quality sites (Cole and Henry, 1986).

Table 1.
***FIRST YEAR DIAMETER/HEIGHT RESPONSE TO SLUDGE AMENDMENTS** (% growth compared with control) (after Cole and Henry, 1986).*

	Treatments			
Species	Tacoma Muni Sludge	* CZ Pri Sludge	# BC Pri Sludge	CZ Sec Sludge
Hybrid cottonwood	17/14	-17/-18	3/-2	87/45
Douglas-fir	116/42	-11/14	6/16	300/100
Noble fir	66/77	-54/-9	-35/15	91/58
White pine	5/86	-40/14	-16/-21	26/59
Average	51/55	-31/0	-11/2	126/66

** Crown Zellerbach; # Boise Cascade*

Table 2.
***PERCENT MORTALITY OF 4 SPECIES OF TREES TREATED WITH SLUDGE** (after Cole and Henry, 1986)*

	Treatments				
Species	Control (Sand)	Tacoma Muni Sludge	CZ Pri Sludge	BC Pri Sludge	CZ Sec Sludge
Hybrid cottonwood	6	16	0	3	34
Douglas-fir	3	9	3	0	16
Noble fir	25	16	3	3	28
White pine	3	9	0	0	19

Anderson (1985) found that does foraging on sludge amended areas recruited to the six month age class more fawns than a control group of does foraging on non sludge amended vegetation (Table 3). The increased fawn recruitment was believed primarily due to the increased protein level of Italian rye grass and also to the browse available to the experimental does. The crude protein consumption was estimated to be 219 g/day for the experimental does and 113 g/day for the control does during the forb/shrub dominant season.

Sludge application to forest areas can affect soil fauna. Nutrients and heavy metals are concentrated in the foliage of trees and recycled when the leaves drop, thereby increasing the concentration of these substances in the organic ped. Several species of mesofauna (size range from 100 mm to 1 cm) were investigated by comparing a control area to areas exposed to three different sludge applications (MacConnell et al., 1986). The investigators found that the response varied between species, sludge types, sludge application rates, and season of the year when the sample was taken (Table 4). In almost all cases the

total number of mesofauna increased, but in several cases the number of mites was reduced by almost one half.

Table 3.
***FAWN RECRUITMENT IN EXPERIMENTAL AND CONTROL AREAS** (after Anderson, 1985).*

Years	Group	No. of Does	Fawns/Doe (Avg.)
1979-80	Experimental	7	2.0
	Control	5	1.4
1980-81	Experimental	4	1.75
	Control	4	0.75

Table 4.
***MESOFAUNA RESPONSE TO FOUR SLUDGE TREATMENTS** (after MacConnell et al., 1986).*

	Treatment			
	Control	Augusta 400kgN/ha	Augusta 800kgN/ha	Aiken 630kgN/ha
Sample 1 (April 20, 1982)				
Mites	100%	80%	50%	145%
Collumbria	100%	95%	70%	210%
Total mesofauna	100%	95%	115%	180%
Sample 2 (Nov. 4, 1982)				
Mites	100%	55%	40%	145%
Collumbria	100%	90%	60%	130%
Total mesofauna	100%	120%	110%	130%
Sample 3 (May 19, 1983)				
Mites	100%	100%	65%	220%
Collumbria	100%	120%	140%	180%
Total mesofauna	100%	135%	150%	200%

Fate of Contaminants

Even an incomplete listing of sewage contaminants is daunting. Fortunately, many are in relatively low concentration, are reduced in the sludge treatment process, or are reduced in a relatively short time by normal biological or physical processes once the sludge has been spread. However, ground water can be contaminated, forest vegetation can take up contaminants, and children who eat dirt can ingest contaminants directly.

The principal threats to groundwater are leached nitrates and heavy metals like cadmium (Cd), and sludge borne pathogens. Vegetative uptakes of Cd, polyaromatic hydrocarbons (PAH)s and poly-chlorinated bipheynls (PCB)s are the main concerns.

Sludge contains 30,000-50,000 milligrams per kilogram (mg/kg) of N; the EPA guideline for the maximum level of nitrates in drinking water is 10 mg/kg. Nitrates formed over time from N in the sludge limit the rate at which sludge can be applied. To limit leaching, it is necessary that volitization, denitrification, soil storage and plant uptake be equivalent to the application rate. The N uptake by forests is dependent upon a number of factors, including the forest species, the age of the trees, and the region of the country (Table 5). In the Pacific Northwest, when N addition with sludge application in forests is limited to 400 kgN/hectare-year, significant leaching of nitrate below the rooting zone can be avoided (Brockway et al., 1986). It is significant to note that the total N content of the RTP sludge (6.64%) is almost twice that of the West Point treatment plant (WPTP) sludge (3.71%) (Florentino, 1989), thus reducing by about one half the maximum allowable application rate.

Table 5.
***NITROGEN UPTAKE RATES OF VARIOUS FORESTS RECEIVING SLUDGE APPLICATIONS** (after Brockway et al., 1986).*

Species	Age (years)	Uptake Rate (kg/ha-yr)	Reference
Douglas-fir	young stands	up to 225	Cole and Henry, 1983
Douglas-fir	55	90	ibid.

The survival times of pathogens in sludge amended soil is a function of many factors including temperature, pH, sunlight, organic matter, and antagonistic soil microflora. The half-life (in hours) of fecal coliforms, salmonella and viruses varies from a few hours to a few hundred hours (Table 6) (Sorber and Moore, 1986). Once pathogens reach ground water, their inactivation rate is reduced; however, groundwater travel is quite slow, ranging from 1.5 meters per year (m/yr) to 150 m/yr, so significant additional die-off of organisms will occur. This points out the criticalness of the distance to surface discharge or well location from the area where sludge is spread, and the necessity of buffer zones of 15 to 60 m from stream locations (Cole and Henry, 1986).

Table 6.
***HALF-LIFE FOR SELECTED MICROORGANISMS IN SOIL SYSTEMS** (after Reddy et al., 1981)*

	Half-life (hours)			Number of
Microorganism	Minimum	Average	Maximum	Observations
Fecal coliform	1.8	20.9	237.6	46
Salmonella sp.	2.4	37.1	184.8	16
Shigella sp.	22.5	24.5	26.8	3
Viruses	4.5	11.5	415.9	11

In comparison to the WPTP sludge, the number of pathogens in the RPT sludge was down from a factor of three to a factor of ten (Florentino, 1989). This reflects the increased effectiveness of secondary treatment and the desirability of using RTP sludge at Cumberland instead of WPTP sludge.

For Cd, one of the heavy metals of most concern, the range in sludge is 1-3,400 mg/kg, with 10 mg/kg an average in the absence of heavy industrial contamination; the EPA guideline for drinking water is 0.01 mg/kg (Zasoski and Edmonds, 1986).

Leaching of Cd and other metals does not appear to be a problem at sludge application rates that do not exceed nitrate leaching limits. "Even though Cd and other metals can be leached through forest soils treated with sludge and wastewater, concentrations in leachates are very low and often similar or below native levels at other sites. These levels are typically 1/2 to 1/3 of the EPA guideline of 0.01 mg/l for drinking water" (Zasoski and Edmonds, 1986).

Investigating Cd bioaccumulation by browsers, Anderson (1983) reported that as of 1981, when the sludge amendment experiment had been under way for four years, no significant heavy metal accumulations had been found in deer repository organs. Serologic and hematologic levels were all within normal ranges also.

Haufler and West (1986) investigated the same problem by performing bioassays on small mammals. There was an increase in the level of Cd, especially in insectivores where kidney levels to 200 ppm were noted. No kidney, liver or testis lesions were noted in these animals, however, and there were no observable effects on populations from these metal accumulations.

Human Health Risks

In 1988 Cd levels in Metro sludge were below the guideline of 25 mg/kg dry for "high quality sludge" suitable for use on food chain crops per USEPA, USFDA and USDA regulations. The average for the WPTP sludge was 22.32 mg/kg and for RTP 11.84 mg/kg (Florentino, 1989).

Munger (1986) performed a risk analysis to determine the conditions under which forest sludge application could increase life-time cancer risk by 1/100,000 from PCBs. The increased intake required to reach this risk level was 204 nanograms per day (ng/day) for a 70 kg person. This equates to consumption of 1000 g per day of blackberries or other edible forest plants. Intake of deer fat should be held to 20 g/day and children who eat dirt should be limited to 10 g/day.

Munger's estimates were based on a total PCB concentration in the sludge of slightly over 1 mg/kg. The Metro (1988) data are limited to WPTP, where the

concentration was about 1.15 mg/kg. Therefore the estimated consumption should be reduced about 15% to maintain the same risk level.

Utilizing the same risk criterion, Munger's (1986) study of benzo(a)pyrene (BaP), a common carcinogenic PAH, would limit intake to 61 ng/day. Intake of sludge grown blackberries should be limited to 100 g/day for 6 to 12 months following sludge application. Children who eat more than 60 g/day of dirt would exceed the 1/100,000 risk threshold.

The BaP concentration in sludge for the above risk estimate by Munger was 2.6 mg/kg, almost an order of magnitude higher than the WPTP level of 0.29 mg/kg. BaP was not detected in the RTP sludge (Florentino, 1989).

To control the input of potentially hazardous substances, Metro has a permitting process that imposes effluent limits and monitoring requirements. These permits are required not only by industrial firms that discharge wastewater into the Metro system but also by other governmental bodies. The King County Solid Waste Division, for example, requires a permit for the discharge of leachate from the Cedar Hills and Hobart landfills.

Another issue raised by the CCC is whether or not sludge is hazardous waste. "What would be the consequences of an accident that spilled sludge on the roadway where children wait for the school bus?" they asked. Metro contends that its waste is not hazardous. Metro has

> "analyzed its sludge according to the Washington State Department of Ecology and federal Resource Conservation and Recovery Act's Extraction Procedures (EP) Toxicity and the Toxicity Characteristics Leaching Procedures (TCLP) being developed by the United States Environmental Protection Agency (USEPA). Analysis of the WPTP and RTP extracts using these procedures reveals that Metro's sludge is well below the hazardous waste criteria and is thus not considered a hazardous waste." (Florentino, 1989)

NONTECHNICAL CONSIDERATIONS

Alternate Disposal Options, and Equity

A variety of disposal methods for sewage sludge other than use as a fertilizer have been employed, including ocean disposal, incineration, and deposition in landfills. Ocean disposal, a low cost approach, was widely used until the seventies when Federal Regulations limited it in the interest of conserving resources and protecting the environment. A 1977 Amendment (PL 95-153) to The Marine Protection, Research and Sanctuaries Act "effectively established

December 31, 1981, as the deadline for terminating ocean dumping of 'sewage sludges'" (Bastian, 1986).

Little benefit is gained from the nutrients in sludge if it is placed in landfills or incinerated. In the latter case capture by stack scrubbers and eventual landfill disposal of heavy metals in fly and bottom ash would be required. Also, careful maintenance of combustion temperature at not less than 1450 degrees K. is required to insure that PCBs don't form dibenzofurans or dibenzodioxins, extremely toxic carcinogens (Nelson et al., 1988).

The equity issue raised by the CCC is interesting, for it shows the failure to recognize the dependence of even Cumberland residents on Metro. Item #33 on their list asked, "Why do country people who have septic tanks get the Seattle Sewage dumped on them? Why not leave Seattle Sewage in Seattle?" The originator of the question apparently does not know that when his or her septic tank is pumped, the solids from the tank must be safely disposed of; they are probably taken to Metro's RTP.

CONCLUSIONS AND RECOMMENDATIONS

It appears that the answer to the question posed in the title of this paper as to whether sewage sludge is a valuable resource or a community problem is that it is both. It clearly is a valuable resource and it can be a community problem unless the program is carefully managed.

Sewage sludge can be safely applied without jeopardizing groundwater quality or introducing dangerous amounts of hazardous substances into forest food chains, as long as adequate precautions are taken to control the rate and time of deposition. Also, access to the site must be restricted for a year after sludge application, particularly to children who might eat dirt. Limits on deer fat intake should also be provided to hunters.

As a further safeguard, Metro should only use RTP sludge at Cumberland until secondary treatment is added to the WPTP. The higher N of the RTP sludge will reduce the application rate by about 50%, since nitrate leaching into the ground is the limiting factor. This reduced application rate will in turn reduce the loading of heavy metals, pathogens, and organic compounds, already generally low compared to levels used in the risk analysis and low in RTP sludge compared to WPTP sludge. Metro's control of contaminant input should allow this favorable condition to continue.

There are substantial uncertainties remaining, however, particularly with regard to groundwater contamination. Because of this uncertainty Metro should manage the sludge application process as an experiment and be prepared for surprises. The Adaptive Management process advocated by Lee

and Lawrence (1986) is well suited for projects where significant uncertainty is present and where there is the opportunity to learn and improve as an operation proceeds.

Test wells to monitor ground water and detect any contamination movement would be essential, along with a backup plan to provide safe water should contamination occur. Until data are available, it is recommended that the criteria from the Washington Department of Ecology's (WDOE) Proposed Dangerous Waste Management Facilities Siting Regulations be applied. These criteria include siting "one-fourth mile from surface water, dwellings and wells" (WDOE, 1990). Finally, regular meetings with the community can build confidence and allow Metro to pursue its sludge project with minimum resistance from the community.

A good model for community confidence building is the Cedar Hills Citizens Review Committee (CRC). CRC was set up by court order in response to legal action by a neighborhood coalition. It consists of three members of the Solid Waste Division, three citizens and an appointed chair, Dr. Jerry Ongerth of the University of Washington Department of Environmental Health. It has been so effective in defusing community concerns about the Cedar Hills landfill that meetings, originally held monthly, are now semimonthly.

A group of this sort would allow CCC members to meet regularly with Metro personnel to defuse emotions, build confidence and investigate concerns. During the initial stages of the sewage sludge disposal program, this process would be especially useful in resolving the questions that will arise and would assist Metro in responding to them in a timely way.

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MANNED AIRCRAFT SAMPLING: ANIONS IN THE PUGET SOUND ATMOSPHERE DURING COMMUTE HOURS

Nathan D. Carlson[1,2], *Louis A. Figueroa*[2] *and William H. Zoller*[2]

SUMMARY

For several hours each day, aircraft patrol the Puget Sound region's highly-traveled expressways informing listeners of the traffic conditions (Mark Carlson, Metro Traffic Control, pers. comm.). This arrangement affords a unique, inexpensive method to assess integrated, urban air quality. In this work, sampling packs were attached to a traffic-watch airplane to access air quality in the Puget Sound Region. Analysis for trace metals by instrumental neutron activation has yet to be completed, but anions from both the gas and particulate phases are reported.

INTRODUCTION

Past research has shown that regional pollution aerosols have characteristic signatures which can be tracked to remote regions as far as several thousand kilometers down wind (Rahn and Lowenthal, 1984). Thus, if chemical signatures of urban areas can be characterized, the accuracy of pollution source studies may increase. For example, to assess whether the Puget Sound region affects the air chemistry on the coast, as measured by University of Washington researchers at a remote sampling site on the Olympic Peninsula (Cheeka Peak)[3], it would be useful to be able to characterize Seattle's chemical signature—the ratios of common elements and pollutants in its air. Aircraft sampling is the ideal method to determine a region's integrated chemical signature, but is very expensive.

However, major metropolitan districts are often serviced by airborne traffic reporters who survey and report on the condition of our roadways during commute hours. Thus, an opportunity exists for inexpensive, daily air quality monitoring and chemistry assessment. In the study reported here, sampling packs were attached to a traffic-watch airplane which traveled along Seattle's most heavily used freeways. Gas and particulate phase anion data and preliminary trace metal data are reported.

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[1] Co-winner of the award for Best Student Presentation at *Puget Sound Research '91.*

[2] Department of Chemistry, University of Washington, Seattle, WA 98195

[3] Current research undertaken by Professor William H. Zoller and others in the Department of Chemistry, Oceanography, and Atmospheric Sciences.

Project Advantages And Disadvantages

The advantages of this project design are many. First, the average hourly rental of a small aircraft with pilot is $80 per hour. Arrangements may be made to split the cost with the traffic-watch company or the time may be donated, as it was in this work. The route of the plane covers a large area of Interstate 5, I-90, 405, and 520, and extends from Tacoma to the south, to Everett to the north and Bellevue to the east. The average altitude is 1500 ft (457.2 m), close enough to the ground to be affected by fresh pollution. Aircraft samples integrate the entire area.

The disadvantages of this method include the fact that one must receive FAA approval. A custom clamp had to be designed to hold the filter packs on the plane. In addition, weather limits flights. The cloud ceiling must be greater than 2000 ft before the plane will fly for traffic watch. On average during the rainy Seattle winter, the plane flies three times weekly (Mark Carlson, Metro Traffic Control, pers. comm.).

The purpose of this project is to see if this type of sampling in the Seattle area is effective for ambient air chemical characterization.

METHODOLOGY

Isokinetic Sampling

A five-filter cartridge using 47mm Whatman treated filters and a teflon particle filter pack is combined with a custom designed cone to assure isokinetic sampling at the average aircraft velocity (Figure 1). Biases toward large or small particles are eliminated by pumping the air in just as fast as it is encountered by the tip of the cone. The cone opening's size is based on average airspeed and pump flow. Airspeeds tend to average 110 mph but can go as low as 90 mph and as high as 120 during the sampling flight. Our pump, on a fully charged battery, draws 1.86 ft/min.

Filter cartridges are labeled A-E, where A is a teflon particle filter, and B-E are LiOH treated filters to collect acidic species in the gas phase. Filter A is closest to the incoming air.

Loading And Unloading Procedures

For each sampling flight, two identical filter packs are loaded on a clean bench at the University of Washington. All loading and unloading implements and all surfaces are cleaned with 95% EtOH to assure cleanliness upon loading and to eliminate cross- contamination upon unloading. Filter packs that have

been loaded and then immediately unloaded and analyzed show integrity of the clean bench procedures. Previous studies back up this claim.[1]

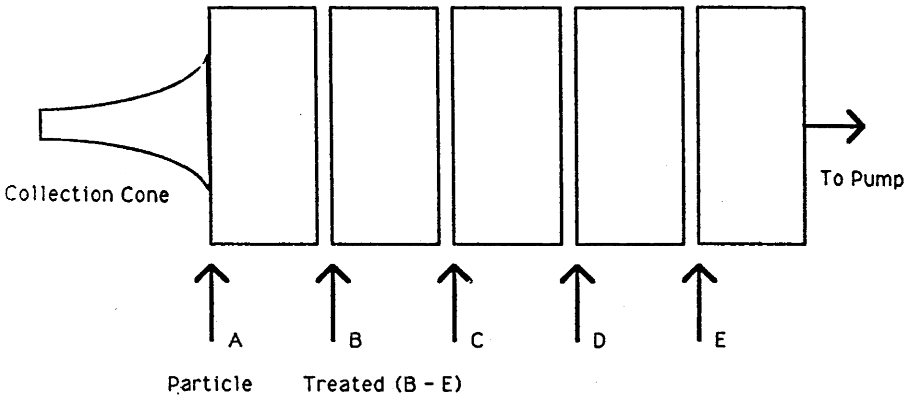

Figure 1.
47MM FILTER PACK.

Filter Pack Transportation

Loaded treated filter packs are transported in double poly- ethylene zip-lock bags. Blank studies show that treatment and loading in a clean bench are not significant sources of contamination. A "trip blank" where the pack is loaded and put into a bag, brought along on the trip and returned unopened assures that transport is not a major source of handler contamination (Table 1).

Field Blank Technique

Once the bagged filter packs have been transported to the airplane, one pack is taken out of the bag, hooked up to a hose connected to the diaphragm pump and left for approximately 1 minute. It is then removed from the strut and replaced in the bag. This is the "field blank" which is subtracted from the actual sample, assuming handling contamination remains constant between the filter packs (Table 1).

Preparation For Sampling

First, the filter holder is clamped to the strut and the hose is either clamped or taped along the length of the strut. The pump end of the hose is fed through the window and placed into the back seat. It is taped securely to the door in at

[1] Numerous undergraduates and graduate students have conducted blank studies on our clean bench procedure. These are on file with Professor William H. Zoller, Department of Chemistry, University of Washington.

Table 1:
BLANK VALUES, ALL PHASES (PPB)

Blank Name	$[Cl^-]$	[NOx]	[SOx]
LiOH Treatment	—	9 + 0.3	—
Clean Bench	91.00 + 0.65	226.00 + 0.11	67.00 + 0.90
Trip Blank	—	342.0 + 1.6	43.00 + 0.10
Field Blanks:			
6/21/90 M	103	122	615
6/26/90 P	206	148	101
6/28/90 M	558	126	1965
6/29/90 P	383	515	1617
7/10/90 P&M	443	235	170
7/20/90 P&M	183	316	73
MEAN:	312	243	756

"—" denotes none detected
M indicates morning flight
P indicates afternoon flight
P&M denotes same filter pack used on both afternoon and morning flights

least three places with duct tape. Then the inner handle of the window is tied to the handle of the door with light-weave rope or string. One must tape the remaining crack inside and outside the window. The pump is placed next to a 24 amp, 12 volt rechargeable, gel-sealed battery on the back seat of the plane. Both pump and battery are secured with duct tape and the seat belt.

Complete recharging of the battery is possible with a commercially available charger. Six hours at 6 amps or overnight at 2 amps is adequate to fully recharge the cells. There is plenty of time between morning and afternoon flights to recharge the battery.

The final step, attaching the filter pack to the hose and clamping it in the holder, occurs just as the reporter is walking out from the terminal to the plane. At this point, preparation is complete.

Sampling Protocol

The pump is left off until the plane reaches 1000 ft regardless of location. At 1000 ft, the pump is turned on, the time, direction of flight, location, airspeed, and altitude are recorded. Additional entries are made whenever changes in direction of flight or of altitude, or any event which may influence the data (clouds, plumes, etc) occur. When landing, the pump is turned off at 1000 ft. After taxiing to the terminal, the filter pack is quickly returned to the double

polyethylene bags and the apparatus swiftly removed from the airplane. The morning flights last about 2.5 hours, while the afternoon flights are close to 1.5 hours long. See Table 2 for a list of volumes for each flight in this study.

RESULTS

Analysis For Acidic Anions

Acidic species—sulfate, nitrate, and chloride—are analyzed on a Dionex Ion Chromatography Column using prepared standards. Half particle and whole treated filter papers are extracted with 5-10 mL of de-ionized water, ultrasonicated for 30 min, and centrifuged for 10 min. New, sterile injection syringes are used for each sample.

Figure 2a shows a distribution of anion over the filters B-D. That we get a true decrease across the pack assures that this method is quantitative for gas phase species. Occasionally different distributions over the pack are found (see Figure 2b). In this case, air has been forced from the back of the filter pack in the reverse direction, perhaps because of a rapid pressure change when the pump is turned off and on. If there is a 2a-type distribution, filters B-D are integrated. This distribution of species on the filters shows that this method is quantitative for the species in question (see figure 2b and 2c for additional possibilities). In each case, filters D and E, respectively, are ignored in the calculation. In all cases, blank values for the appropriate filters are subtracted from the sample filters.

The breakdown of the analyte by phase is shown in Table 2. Note that the amount of aerosol phase material is generally small compared to the gas phase. Note also that on 6/28/90 there is an extremely high pulse of gaseous SOx, and on 6/29/90, we find a pulse of aerosol SOx.

See Table 2 and Figures 3 and 4 for graphic information pertaining to concentrations and phases of anions detected, and weather at the time of sampling.

Preliminary Trace Metal Data

Three test filters were irradiated with thermal neutrons at the Los Alamos National Laboratory in Los Alamos, New Mexico. Instrumental neutron activation analysis of these filters shows Na, W, Br, Al, Mn, Sb, and As. Once gamma spectroscopy of standard reference materials is completed, the concentrations of these elements can be found.

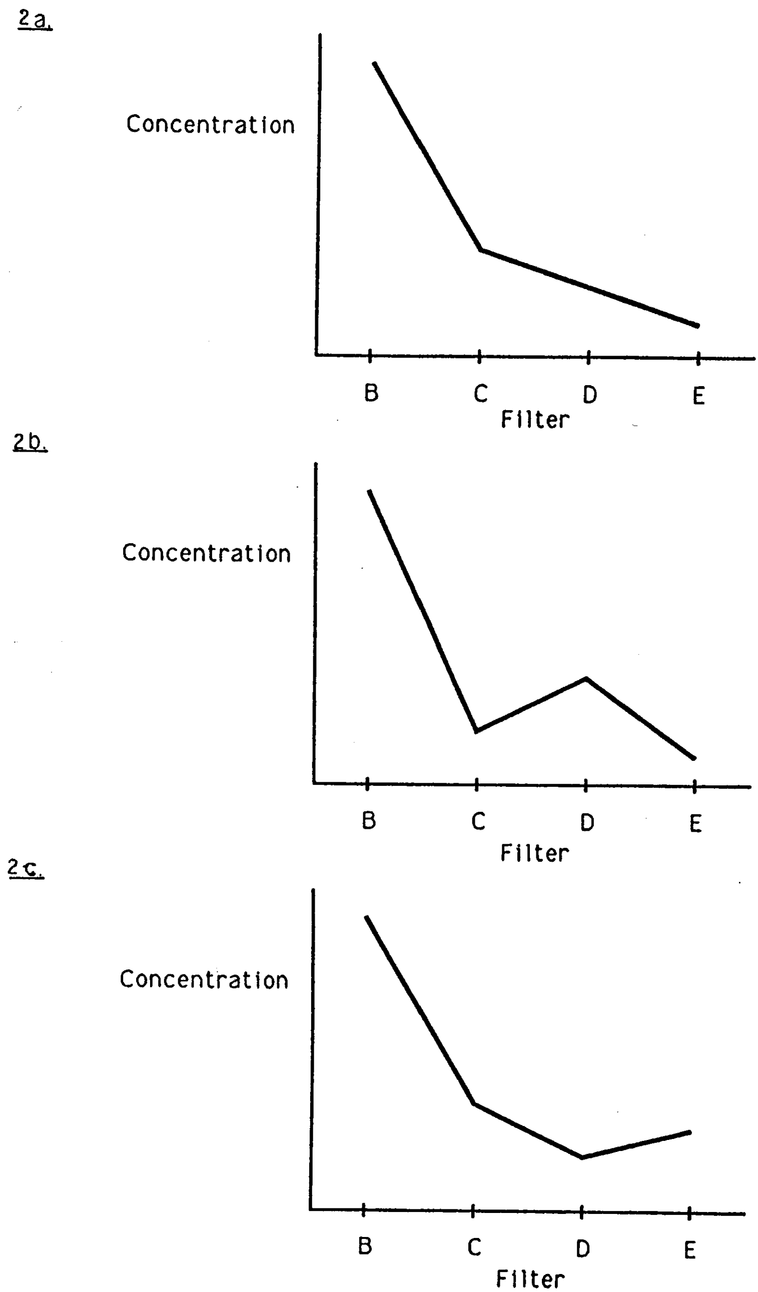

Figure 2.
POSSIBLE ANION DISTRIBUTIONS.

Table 2:
ANION CONCENTRATION BY PHASE

All concentrations in $ng/m^3 \pm 1\ \sigma$

Sample	Volume (m^3)	[Cl^-] Aerosol	[Cl^-] Gas	[NO_x] Aerosol	[NO_x] Gas	[SO_x] Aerosol	[SO_x] Gas
6/21/90 M	5.50	45.92±.32	710.5±4.9	171.6±1.2	1559±11	409.0±1.6	429.2±1.7
% Aerosol		6.07%		9.9%		48%	
6/26/90 P	3.69	----	916.0±6.9	108.8±1.2	3211±37	346.5±3.0	2320±20
% Aerosol		0%		3.3%		13%	
6/28/90 M	5.66	1018±13	972±13	133.0±1.7	464.9±5.9	581.6±9.5	13920±240
% Aerosol		51%		22%		4.0%	
6/29/90 P	8.02	----	----	165.7±6.6	2570±100	1508.0±9.3	5815±365
% Aerosol		0%		6.1%		20.6%	
7/10/90 P & M	17.13	23.78±.11	212.61±.95	44.19±.233	106.24±.56	424.7±1.6	3404±13
% Aerosol		10%		29%		11%	
7/20/90 P & M	11.06	706.6±1.9	350.00±.95	660.0±6.0	192.0±2.1	366.60±.98	2283.0±8.7
% Aerosol		67%		77%		14%	

"----" indicates none detected.

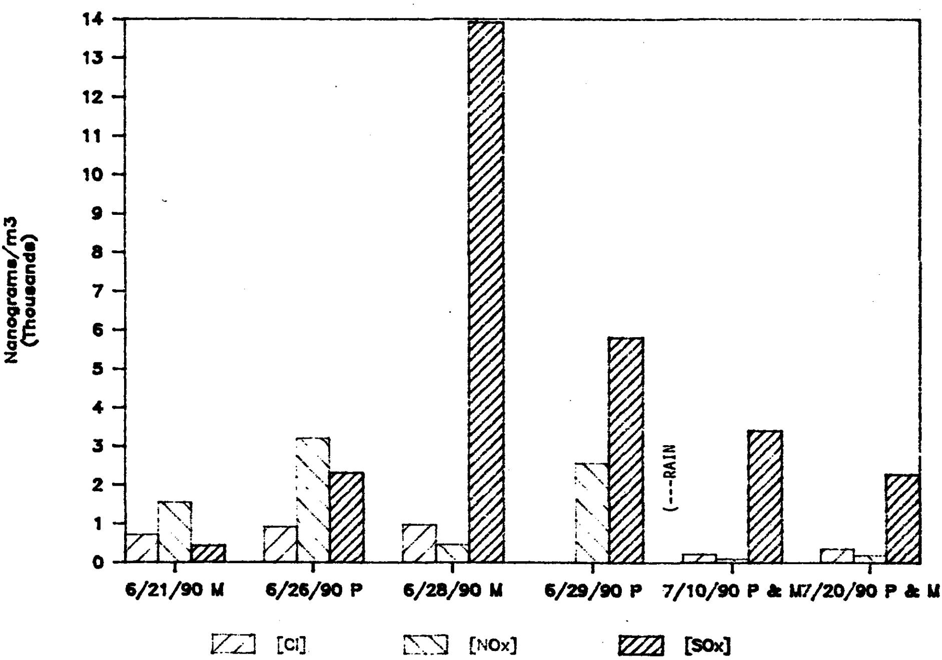

Figure 3.
SEATTLE AIR CHEMISTRY: GAS PHASE CONCENTRATIONS.

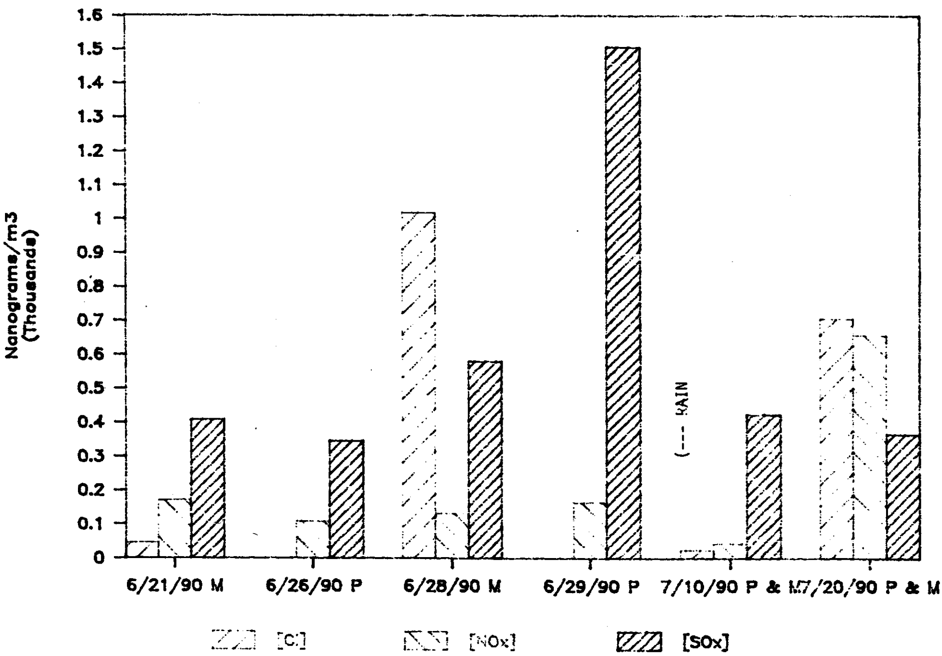

Figure 4.
SEATTLE AIR CHEMISTRY: AEROSOL PHASE CONCENTRATIONS.

CONCLUSIONS AND DISCUSSION

First, from the limited amount of data it appears that concentrations of acidic species vary from day to day and from morning to afternoon. From the meteorological data recorded, rain seems to wash out the acidic gases and the particles (Figs. 3 and 4). Also, in at least one case, there is a pulse of particulate SOx following an increase in gas phase SOx. It is expected that over time gas phase pollution will react with a salt or some other material to form an insoluble particle. Thus, this study suggests that this is occurring. More data are necessary to characterize the particular mechanisms of particle formation that are illustrated in this data set.

The study shows that this method of aircraft sampling may be a very effective way to monitor and characterize pollution in the ambient air in a metropolitan area. More research is needed,including comparisons with ground stations, to assess the usefulness of this method. Since cost-containment is such an important aspect of environmental monitoring, effective use of existing resources is a key. Investigators in other parts must establish contacts with the traffic reporting community to take advantage of this unique opportunity for air quality monitoring.

ACKNOWLEDGMENTS

We thank Xin Ying Cai and Kevin Ghomashchi for their work in preparing the data.

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PUGET SOUND

RESEARCH '91

PUGET SOUND CURRICULUM EXCHANGE

Session Coordinators:

Paula Cullenberg, Washington Sea Grant

Ann Butler, Mason County Cooperative Extension

Laurie Usher, Washington State University Cooperative Extension

INTRODUCTION

Paula Cullenberg[1], Ann Butler[2] and Laurie Usher[3]

The Puget Sound Curriculum Exchange was a session for teachers and environmental educators at *Puget Sound Research '91.* The purpose of the exchange was to give teachers the opportunity to share curricula, course activity ideas, and resources related to water quality monitoring, marine science, watershed ecology, oceanography, environmental decision-making, fish and shellfish. Teachers were also encouraged to attend the entire conference and to interact with scientists studying Puget Sound.

The Curriculum Exchange was a valuable opportunity for teachers to share innovative class projects with fellow educators as well as to obtain curricula and activity ideas from state agencies and environmental organizations.

Environmental education has become a professional and personal priority for teachers. The Curriculum Exchange addressed the need for educators to network for project ideas and resources and illustrated the importance of including educators in the overall effort to protect Puget Sound.

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[2] Mason County Cooperative Extension, 9 Federal Building, Shelton, WA 98584

[3] WSU Cooperative Extension, Room 216, 921 Lakeridge Dr. SW, Olympia, Wa 98502

TEACHER PRESENTATIONS

Alonda Schutzmann

Steilacoom High School
54 Sentinal
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(206) 588-1885

Alonda's biology classes at Steilacoom High School participate in water quality civic projects in cooperation with the city council and its "Clean Water Community". The project was originally funded by a PIE grant in 1987 and is now sponsored by the City of Steilacoom. Students in 9-12th grade participate in the school/community partnership of testing surface and well water, providing useful data to the city.

The program includes study of water resources in Steilacoom. Students take field trips in the local watershed to explore where water comes from and impacts on water quality. In class speakers present information to the students on how water quality can be preserved and improved, and on the natural cycle of water.

Karen Lippy

North Mason High School
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Belfair, WA 98528
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North Mason School District recently inherited a 70-acre parcel of land including a salt marsh, an alder creek swamp, and fresh water ponds. Funded by a state 21st Century grant, teachers are integrating the wetlands and environmental issues across the K-12 curriculum.

Funds have been used to purchase materials to establish a wetlands and environmental curriculum library, materials for the school district's libraries, field equipment, and to create a master plan for developing the wetlands into a nature center open to the public. Inservices have been offered to teachers in wetlands and freshwater ecology.

Teachers have begun to use the wetlands as teaching tools in subjects such as English, art, and science, as well as in development of appreciation of the environment. Middle school students are publishing "The Watchful Eye", a newspaper focusing on environmental issues. High school biology students travel to the wetlands monthly for plant and ecological studies. A

team of high school students is performing water quality tests and macroinvertebrate bioassessment on the fresh water areas in and leading to the site.

Darrell Hanberg

Tenino Middle School
Tenino, WA 98589
(206) 264-2663

Darrell's middle school science classes have been networking water quality monitoring data internationally via computer through Project Green at the University of Michigan. Project Green is a computer bulletin board linking water quality data from 25 countries. Science students at Tenino Middle School participate in periodic sampling of water quality on the Chehalis River. Students are trained in sampling techniques, water quality parameters, and analysis of their results.

Currently nine schools are sampling water as part of the education phase of the Chehalis River Plan. Students, sampling water quality on the Chehalis River, are able to call up comparative data from such places as the Rhine River in Germany. Hanberg's ultimate goal is to establish a local Puget Sound bulletin board of student-collected data from all over the Sound.

Paul Larson

Garfield High School
400 23rd Avenue
Seattle, WA 98122
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Garfield High School students are working with elementary students to monitor water quality in coordination with the Drainage and Wastewater Utility of the City of Seattle. High school students teach elementary students to sample stream waters, then analyze the data themselves.

Harlan Kredit

Lynden Christian High School
Lynden, WA 98264
(206) 354-3221

The advanced biology class at Lynden Christian High School operates a coho salmon hatchery. Kredit's students participate in all phases of the hatchery process—hatching eggs, feeding and maintaining the fish and

water quality of their environment, and releasing the salmon in nearby creeks.

Students also work on habitat protection projects including stream clean-ups and restoration, stream sampling, water quality testing and habitat surveys. Competed projects included construction of a pond, tree planting, and stenciling 400 storm drains. The hatchery has been in operation for nine years, releasing over one hundred thousand coho smolts each year into Fishtrap Creek and the Nooksack River. The hatchery is currently funded by local service clubs and the Washington Department of Fisheries.

CURRICULUM INSERVICE PRESENTATIONS

Puget Sound Project

Jim Kolb and Tom Armentrout
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(206) 799-5549

The Puget Sound Project is an integrated curriculum focusing on the science and social issues which will determine the future of Puget Sound. Designed to foster a "Puget Sound Ethic", the curriculum provides the information base and decision making skills necessary for developing a personal commitment to Puget Sound.

Through the Puget Sound Project curriculum, students analyze environmental problems, from industrial discharges and nonpoint pollution to shellfish protection and household hazardous waste. They examine the pro and con arguments of interest groups and explore possible side effects of solutions to environmental problems. Finally, they learn to make long-term life style decisions which maintain a proper balance between the natural system and the human system functions of Puget Sound. Program elements are problem-focused and oriented to decision-making.

Active involvement with the marine environment at a local level, coupled with general knowledge of the dynamics of Puget Sound as a whole, results in the changes in attitude and behavior necessary to develop a personal commitment that leads to the protection of Puget Sound as a unique treasure.

Multi-disciplinary Puget Sound curricula are available at the elementary, middle-junior, and high school levels. Stressing the relationships between the ecology, economy, and society of Puget Sound, the materials provide teachers with a readily useable, activity-oriented approach to teaching about the Sound.

Stream Scene: Watersheds, Wildlife and People

Bill Hastie
Oregon Department of Fish and Wildlife, Office of Public Affairs
Box 59
Portland, OR 97207
(503) 229-5400

This curriculum was produced by the Watershed Education Project, a part of the Oregon Department of Fish and Wildlife's Aquatic Education Program. The Stream Scene is a comprehensive curriculum package designed to bring watershed awareness into schools and communities. The book's format will guide the user from awareness to action as the study of watersheds progresses.

The Stream Scene is written primarily for use with grades 6-12, but most activities can be adapted for younger students. Its active learning style is valuable in earth science, biology, geology, chemistry, physical science, forestry, agriculture, outdoor school, social studies, and other classes. The focus is on an overall view of watersheds, leading the reader from the broad spectrum of watershed systems, riparian areas, and their component parts to the specific nature of streams and the aquatic life they support.

This 300-page guide is divided into several units related to watershed management. Each unit contains background information for the teacher, activities for use with students, a bibliography, and a list of related extensions. The book is complete with a five-part appendices of useful information, including a glossary of bold terms found throughout the guide.

CURRICULUM FAIR

The following presented materials on additional curricula:

Padilla Bay National Estuarine Research Reserve

(Alex Alexander; 1043 Bayview-Edison Road, Mt. Vernon, WA 98273)

Display of various research and education programs; Level 1&2 Estuary Curricula - K-8

Snake Lake Nature Center

(Tom Weathers; 1919 S. Tyler, Tacoma, WA 98405; (206) 591-6437)

Self-contained 3rd and 4th grade wetlands curriculum; 19 in-school programs; outdoor adventures; interpretive center; 54-acre wetlands park

Seattle Aquarium

(Belinda Chin; 1483 Alaskan Way, Pier 59, Seattle, WA 98101; (206) 591-6437)

Curriculum on a variety of marine topics: Pre-school through high school; Get Wet Kit sample (rental)

Washington State Office of Environmental Education

(Rikka Cecil; 17011 Meridian Avenue N., Seattle, WA 98123; (206) 542-7671)

Catalog of environmental education materials; posters, curriculum

Northwest Association of Marine Educators, (NAME)

(Doug Emery, Issaquah Middle School, Issaquah, WA 98027; (206) 392-0830)

Information on NAME, their summer conference, and bi-monthly publication: Clearing

Metro-Water Resources

(Chuck Dolan; MS-81, 821 2nd Avenue, Seattle, WA 98104-1598; (206) 684-2065)

Grant program information; volunteer and school projects in water quality improvement

Pure Sound Society

(Brad Wetmore; P.O. Box 526, Vashon Island, WA 98070; (206) 463-5607)

Marine science workshops and classroom afloat

Water and Vashon's Ecosystem, (WAVE)

(Susie Kalhorn and Lisa Jones; Vashon Island School District, 20424 Vashon Highway S.W., Vashon, WA 98070; (206) 463-2121)

Examples of curriculum materials: Salmon, aquatic birds, waste water disposal, drinking water/groundwater

Adopt-a-Stream

(Kate O'Laughlin, Box 5558, Everett, WA 98201; (206 388-3313, ext. 2587)

Information and map of workshops throughout the state; salmon costumes; Adopt-a-Stream/wetland curriculum

Earth Corps, Metrocenter YMCA

(Nan Little; 909 4th Avenue, Seattle, WA 98104; (206) 382-5013)

Earth Corps manual; Adopt-a-Tree; Coast Week Fun Book; Volunteer Resources guide; t-shirts

Project Learning Tree

(Barb McGregor; 711 Capital Way, Suite 608, Olympia, WA 98501; (206) 352-1500)

Representative samples of the 9 curricula/workshops, including the new "Indians and Environment"

Department of Ecology

(Rhonda Hunter; PV-11, Olympia, WA 98504-8711; (206) 459-6147)

Away with Waste & Discover Wetlands curriculum; posters; Ecology materials directory; wetlands video

Poulsbo Marine Science Center

(Jim Kolb and Tom Armentrout; 17771 Fjord Avenue, Poulsbo, WA 98370; (206) 779-5549)

Display examples of three guides for Puget Sound Project curriculum

Marine Science Afloat

(Tom Schaeffer; 4707 9th Street N.E., Seattle, WA 98105; (206) 779-5549)

Marine science afloat with students; video of boat trips

Pacific Science Center

(Barb Williams; 200 2nd Avenue N., Seattle, WA 98109; (206) 443-2899)

Orca curriculum materials; salmon kits, water tape

Hatfield Marine Science Center

(Vicki Osis; 2030 S. Marine Science Drive, Newport, OR 97365-5296; (503) 867-0100)

Information and display on the Oregon State University's Masters Degree Program with emphasis in marine studies

PUGET SOUND

RESEARCH '91

POSTER ABSTRACTS

REMEDIAL ACTION IN PUGET SOUND WATESHEDS: NONPOINT POLLUTION AND CONTAMINATION OF SHELLFISH BEDS

Timothy A. Determan[1]

Puget Sound presently produces about 16 million pounds of bivalve shellfish, including oysters, clams and mussels, for recreational and commercial use. This bountiful harvest is threatened by nonpoint source pollution from rapidly developing Puget Sound watersheds. Since 1984, the Department of Ecology has awarded grants to local governments to address nonpoint sources through remedial action and watershed planning. Rural watersheds undergoing high rates of urbanization were targeted. Failed on-site waste disposal systems were located and repaired. Rural residents were encouraged to develop and use best management practices to control the export of nonpoint pollutants from their lands. A review of these activities shows that success fell well below original expectations. Reasons for this outcome are given and ways of improving effectiveness are suggested.

[1] Shorelands Program, Washington State Department of Ecology, PV-11, Olympia, WA 98504

A REVIEW OF RISKS AND REGULATION OF PERSISTENT CONTAMINANTS IN THE AQUATIC ECOSYSTEM

David H. Monroe[1]

The aquatic bioaccumulation of persistent hazardous chemicals has been a major human health and ecological problem for many decades. Government regulations restricting the production and discharge of persistent chemicals have yet to solve this complex problem. Although the insecticide DDT was banned from use in 1973, and PCB production was banned in 1976, these compounds continue to threaten wildlife populations and human health in the Pacific Northwest. Chlorinated dibenzo-dioxins and furans, primarily from pulp mill effluents, have been found to accumulate to significant levels in bottom sediments, fish, and wildlife from the Columbia River to Prince Rupert. Due to the low water solubility of these compounds, aquatic sediments serve as the major sink and a persistent source of the chemicals. The impacts of extensive persistent chemical contamination in the Northwest have been noted in declining reproductive success in bald eagle and blue heron populations, chronic effects in bottom fish, and significant human health risks from the consumption of contaminated seafood.

Improvements in the regulation of contaminant discharges and the management of contaminated sediments in the aquatic environment are needed to address these problems. Current regulation of pollutant discharge and contaminated sediments focuses on acute toxicity, virtually ignoring the environmental and human health risks of persistent chemicals. Continuation of this trend is likely to result in a further decline in the quality of marine and freshwater ecosystems.

This report will review pertinent literature, data, and current regulations. Included is a discussion of current research needs for determining the relationships between discharges into the aquatic environment, sediment contaminant levels, and bioaccumulation in the food chain, and related ecologic/ human health risks. Such research can serve as a foundation on which to design more appropriate discharge limits, acceptable sediment contaminant levels, and seafood quality guidelines.

[1] Monroe Toxicology Professionals, 1254 W. Pioneer Way, Suite 142, Oak Harbor, WA 98277

A NUMERICAL MODEL FOR THE DISTRIBUTION OF TIDAL CURRENTS IN PUGET SOUND IN TWO HORIZONTAL DIMENSIONS

Cynthia Cudaback and J. William Lavelle[1]

Knowing how tidal currents in Puget Sound vary laterally on small spatial scales and at any time is of value to those involved in navigation and pollution transport studies. A model that provides this information should be inexpensive to run, allow superimposition of several tidal components, and should recreate measured tidal velocities and heights.

A linearized, one-dimensional channel model, well calibrated with measurements in Puget Sound, was the precursor to the model introduced here. This two-dimensional model uses linearized hydrodynamic equations with bottom friction and Coriolis force to predict vertically averaged tidal currents and tidal heights. The shape of the basin is determined from real bathymetric data on a 457 x 309 meter grid. The model was run both at the resolution of the bathymetric data and at half that resolution. Boundary transport conditions are obtained from the earlier one-dimensional model.

Calculations of the distribution of tidal currents have been made for a region between Point Wells and The Narrows and compared to measurements in that area. Plots of the model results provide a visual perspective on the tidal patterns in the main basin and allow closer examination of areas of special interest such as channel branches, headlands and urban embayments.

[1] NOAA/Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115

WSU BEACH WATCHER VOLUNTEER TRAINING PROGRAM

Donald B. Meehan [1]

There are many ways to change the way people act and think regarding Puget Sound waters. One technique which is being tested in Island County, Washington, is the WSU Beach Watchers Program. Volunteers are selected based on their record of public service and interest in protecting Puget Sound waters. They are then extensively trained by qualified, non-biased instructors. Prior to being accepted into the program, volunteers must agree to participate in public education activities for a minimum of 50 hours during the first year following training and to adopt and monitor a section of beach of their choosing.

The WSU Beach Watcher program has reached more than 10,000 people, provides data to the Marine Debris Survey, PSP program, Low Tide Survey and Marine Beached Bird Survey, and has developed procedures for volunteer monitoring of beaches for changes in quality. Participants in the program have developed a radio show called Beach Talk, and are reaching out to schools to be included as a part of the curriculum. The cost effectiveness of this type of program is over 3 dollars for every one invested.

[1] WSU Cooperative Extension, P.O. Box 500, Coupeville, WA 98239

NOXIOUS PHYTOPLANKTON AND SALMON AQUACULTURE IN PUGET SOUND

James R. Postel[1], Karl Banse[1], Rita Horner[1], Frieda B. Taub[2] and John E. Rensel[2]

Worldwide, the occurrence of noxious and toxic blooms of phytoplankton is increasing. Blooms of toxic dinoflagellates that cause paralytic shellfish poisoning have long been a problem in Puget Sound, but algal blooms that kill pen-reared salmonids have been known for only 20 years.

In countries where marine fish farms are common (e.g., Japan, Norway, and Scotland), flagellates and dinoflagellates are the main phytoplankton groups that are reported to cause fish kills. In Puget Sound, however, fish distress or death has often been the first indication of the presence of the diatom *Chaetoceros convolutus*, or a closely related species, *C. concavicornis*, that do not have to be present in high numbers (blooms) to kill fish. Our original proposal was directed toward their effects on pen-reared Atlantic salmon.

However, in Puget Sound in the last year alone, *Heterosigma akashiwo*, a flagellate which has been a major problem in British Columbia and in most marine fish farming countries in the past, has caused more than $6 million in fish losses . As a result, our investigations have expanded to include this organism.

The ecological conditions that lead to noxious blooms and the physiological mechanisms by which they kill fish are unknown and need to be studied in the field and laboratory. Fish growers need to know how to anticipate these events and what mitigating measures they might use to alleviate their effects. Little research leading to timely prediction has been done anywhere to answer these questions.

[1] University of Washington, School of Oceanography, WB-10, Seattle, WA 98195
[2] University of Washington, School of Fisheries, Seattle, WA 98195

CIRCULATION IN ADMIRALTY INLET AND THE MAIN BASIN: NUMERICAL MODEL RESULTS

J. William Lavelle and E.D. Cokelet[1]

A hydrodynamical model has been used to study the circulation of water within Puget Sound. The model allows the computation of changes in subtidal currents and salinities with changes in distance into the estuary, depth, and time. Model results were compared to measurements taken in the Sound from December 1983 to March 1984. The comparison shows that the model incorporates the important circulation features of this estuary.

Circulation, the movement of water after tidal motions have been set aside, determines the renewal time of water in the estuary and has an important influence on the pathways of contaminants. In Puget Sound, circulation depends on a number of factors, including salinity variations at the entrance to the Sound near Port Townsend, vertical mixing of water in Admiralty Inlet, fresh water runoff from the rivers, and the strength and direction of winds. Density intrusions are one important process which episodically influences main basin circulation - under certain conditions, denser, more oceanic water makes its way along the bottom of Admiralty Inlet and passes into the interior basin. These conditions include a density difference across the length of the Inlet exceeding ~1.3 o/oo, and little in the way of fresh water discharge that could be mixed downward in the Inlet to dilute the salinity of the intruding water. A synthesis of model results on circulation during the study period takes the form of an animation.

[1] NOAA/Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115

PROTECTING WATER QUALITY THROUGH COMMUNITY EDUCATION: THE EXTENSION MODEL

L. Katherine Baril[1], Kate Benkert[1], Jim Bolger[2] and Paula Cullenberg[2]

Public education and technical assistance have been identified by planners, legislators and the Puget Sound Water Quality Authority as essential to the protection of Puget Sound from nonpoint source pollution. A resource team of four water quality specialists from Washington State University Cooperative Extension and the University of Washington Sea Grant Program are developing a model extension education program in Jefferson, Kitsap and Mason counties. This team makes up the regional field agent model identified in the education and public involvement action plan of the 1991 Puget Sound Water Quality Management Plan. The field agent model increases public awareness and involvement in water quality issues by linking research universities to local government and citizen's groups. The future expansion and placement of the water quality field agents in other Puget Sound counties is contingent upon the success of this model program.

Programs, workshops and informational materials are developed and coordinated by the resource team to encompass a variety of water quality topics. Wetlands, non-point source pollution, shoreline development, groundwater and the importance of clean water for commercial and recreational shellfish harvesting are some of the topics addressed. Field agents work with local governments, tribal planners, watershed management committees, boaters, shellfish users, school systems and the general public. The problems encountered in defining and addressing the regional education needs of a large and diverse constituency are presented, as are recommendations for facilitating future program development by water quality field agents in other regions. Examples of demonstrated successes and future program activities are highlighted.

[1] WSU Cooperative Extension for Mason County, 9 Federal Building, Shelton, WA 98584

[2] Washington Sea Grant Program, University of Washington, Seattle, WA 98195

A SUCCESSFUL APPROACH TO POINT AND NONPOINT WATER POLLUTION CONTROL: THE URBAN BAY ACTION PROGRAM

Debbie Munt[1]

The U.S. Environmental Protection Agency and the Washington Department of Ecology identified chemical contamination of Puget Sound as a high priority problem in 1983. This set the foundation for the urban bay action program, a unique, cross-programmatic approach to controlling contamination of urban bays around Puget Sound. Urban bays typically are receiving waters for various wastes related to human activities in and near coastal cities. Sources of urban bay contamination can include industrial facilities, stormwater runoff, combined sewer overflows, boats, marinas, and landfills.

Currently there are seven urban bay action teams (UBATs) in Puget Sound at various stages of implementation: Commencement Bay, Elliott Bay, Everett Harbor, Lake Union, Bellingham Bay, Sinclair and Dyes Inlets, and Budd Inlet. The objectives of each of these teams are to identify historical and ongoing sources of contamination, and to identify and prioritize problem areas and sources for corrective action. This basic information is used to generate an action plan which guides the activities of the action teams. Citizen advisory committees and industries also guide development of the action plans. The action teams are comprised of staff from various federal, state and local agencies and tribes that share common shoreline, sediment and water quality concerns. This coordination provides a common forum for public agencies, private industries and informed citizens to address pollution problems. UBATs create an efficient regulatory and management network and enhance the effectiveness of existing regulatory programs.

The poster provides a more in-depth look at the program objectives and accomplishments in each urban bay.

Prepared by the Washington State Urban Bay Action Team Coordinators: Dan Cargill, Kevin Godbout, Fran Solomon, Deborah Munt, Martha Turvey, Barbara Trejo, Dave Nazy, Lucy Pebles and Melanie Vorass.

[1] Department of Ecology, NW Regional Office, 4350 150th Avenue NE, Redmond, WA 98502

STILLAGUAMISH RIVER VOLUNTEER WATER QUALITY MONITORING PROJECT

Kathy Thornburgh and Kit Paulsen[1]

In June of 1989, the Tulalip Tribes began a two-year project to monitor water quality in the lower Stillaguamish River and Port Susan. The project was contracted through the Department of Ecology using Centennial Clean Water Funds. The objectives of the monitoring program include:

1) Establish a baseline water quality monitoring program for selected mainstem and tributary sites to evaluate water quality effects from rural housing, hobby farms, and commercial agricultural land uses.
2) Monitor baseline levels of water quality variables on selected marine sites over time to assess riverine bacterial contributions to northern Port Susan.
3) Provide public education on water quality problems and solutions by presenting educational programs and training volunteers to assist in sample collection and laboratory analysis.
4) Institute a set of quality control guidelines and procedures which meet established laboratory and field protocols. Determine if significant differences exist between laboratory tests conducted by staff and trained volunteers.

The poster presentation includes information on the sampling design of the study which consists of a factorial, randomized block design that allows comparisons between locations, years, seasons, and land use impacts. The poster includes pictorial information on land use impacts and volunteer involvement. Quality control assessments and analysis of storm sampling data are presented graphically.

[1] Tulalip Fisheries Department, 10610 Waterworks Road, Marysville, WA 98270

LANDER SEPARATION PROJECT INDUSTRIAL INVENTORY AND SOURCE CONTROL

Christie J. True[1]

The Lander Separation Project is part of Metro's Combined Sewer Overflow (CSO) Plan to reduce the amount of CSOs by 75 percent, systemwide, by the year 2005. By separating stormwater from sanitary sewers, this project will create a new stormwater discharge to the Duwamish River from an industrial/commercial area. As part of Metro's stormwater mitigation program, Metro's Industrial Waste Section conducted a one year source control project in the Lander drainage basin to determine the sources of specific contaminants entering the new stormwater discharge.

Metro identified and inspected a total of 152 businesses that were potential sources of pollutants. Metro staff located illegal connections and connections of industrial wastes to storm sewers. A combination of educational programs, on site inspections, and compliance schedules induced more than 50 businesses to change their waste disposal practices.

Metro was able to significantly reduce pollutant loadings to both the storm and sanitary sewers in the Lander drainage basin, thus reducing the potential water quality effects that the new stormwater discharge could have on the Duwamish River and Elliott Bay.

This project's success demonstrates that source control is an effective means of mitigating stormwater impacts on receiving waters and of reducing pollutant loadings to the sanitary sewer by having businesses control and treat their wastes.

[1] METRO Comprehensive Planning Division, 322 West Ewing, Seattle, WA 98119

MONITORING THE EFFECTS OF NONPOINT SOURCE POLLUTION ON BOG ECOSYSTEMS

Sarah S. Cooke[1] *and Michele Stevens*[2]

The Puget Sound lowlands in Washington State are predominantly glacial in origin. Coupled with a glacial terrain, the wet climate has produced an ideal environment for the development of wetlands. The area is also marked by intense urban growth. Of the many wetland types common to this area, *Sphagnum/Ledum* bogs are the most sensitive to any form of disturbance, especially that resulting from construction activity and urban stormwater runoff. It is important, therefore, to document the occurrence and significance of changes in some of the bogs that are currently being affected by urbanization, so that future disturbances to other bog systems can be minimized.

One large bog and one small bog, both very old and both affected by urban development, were chosen for study. Monitoring began two years ago, and is expected to continue for another five years. The monitoring study consists of surveys of the vegetation's species composition, percent cover, and distribution, the spread of invasive species such as *Typha* and *Potentilla*, hydrology, water quality, soils, and animal inhabitants. It is apparent that some immediate changes in vegetation species composition and percent cover are occurring as a result of urban stormwater inputs into some of wetland habitats. The effects of these inputs on bog degradation will be discussed.

[1] University of Washington, College of Forest Resources, AR-10, Seattle, WA 98195
[2] Washington State Department of Ecology, Olympia, WA 98504

CYTOCHROME P-450 AS A BIOINDICATOR OF CONTAMINANT EXPOSURE AND EFFECTS IN THREE SPECIES OF FLATFISH FROM PUGET SOUND

S. Denise Connor, Tracy K. Collier, Bich-Thuy Le Eberhart, and Usha Varanasi [1]

Puget Sound is a large marine and estuarine ecosystem, comprising a variety of habitats having different levels of environmental contamination. For this reason it provides scientists with a good 'field laboratory' for testing and validation of bioindicators of contaminant exposure and effects in fish. The cytochrome P-450 system is one of the earliest and most sensitive indicators of contaminant exposure and effects. This system responds to a variety of different types of contaminants, including aromatic hydrocarbons, polychlorinated biphenyls, and dioxins, all compounds of interest in the Puget Sound Basin and environs.

We have tested the ability of the cytochrome P-450 system to discriminate different levels of exposure in flatfish from Puget Sound. Three species (English sole, rock sole, and starry flounder) were sampled from several sites, and at several times of the year. Cytochrome P-450 was measured by three different methods in subcellular liver fractions from these fish. Our results show that this system is very useful in assessing exposure of these species at all times of the year.

These results validate the use of the cytochrome P-450 system in monitoring studies of the effects of pollution on marine fish. However, the results also showed that a single measure such as this should not be relied upon exclusively to assess exposure and effects, and that a combination of analyses should be employed.

[1] Environmental Conservation Division, Northwest Fisheries Center, NOAA/NMFS, 2725 Montlake Blvd East, Seattle, WA 98112

EFFECTS OF CONTAMINANT EXPOSURE ON REPRODUCTION IN PUGET SOUND FLATFISH: RESEARCH IN PROGRESS

Lyndal L. Johnson, Sean Sol, Greg Nelson, Edmundo Casillas, and Usha Varanasi[1]

Since 1987, the Environmental Conservation Division of NOAA/NMFS has been evaluating the reproductive success of selected teleost fish in Puget Sound, Washington. Results of our previous studies show reduced reproductive success in the English sole (*Parophrys vetulus*) from contaminated areas of Puget Sound. Among the effects observed are inhibition of oocyte development, inhibition of spawning, and depressed plasma estradiol level.

We have now expanded our research program to look at other species that may be at risk, and to evaluate additional elements of the reproductive process that could be affected by contaminants. Several studies have been initiated: 1) effects of contaminant exposure on ovarian development and spawning success in rock sole (*Lepidopsetta bilineata*), 2) contaminant-related effects on fecundity and egg size in English sole, and 3) development of an *in vitro* bioassay system to examine effects of contaminant exposure on estradiol production by ovaries.

Preliminary results from studies with rock sole show no clear differences between fish from Yukon Harbor (reference site) and Eagle Harbor (contaminated site) in gonadosomatic indices, proportion of maturing females, or plasma estradiol levels. However, in a laboratory spawning experiment, rock sole from Eagle Harbor took significantly longer to spawn than fish from Sinclair Inlet, Yukon Harbor or University Point, and had lower fertilization success and smaller eggs. Egg weight appears to be lower in English sole from contaminated sites as well. Results of the bioassay system are promising; *in vitro* estradiol production by ovarian tissue fragments from English sole captured at contaminated sites is lower than ovarian estradiol production in sole from uncontaminated sites. These findings suggest that reduced plasma estradiol levels in fish exposed to contaminants may be due at least in part to decreased ovarian estradiol production.

[1] Environmental Conservation Division, Northwest Fisheries Center, NOAA/NMFS, 2725 Montlake Blvd East, Seattle, WA 98112

AN ANALYSIS OF THE RELATIONSHIP BETWEEN A SAND-DOLLAR EMBRYO ELUTRIATE ASSAY AND SEDIMENT CONTAMINANTS FROM STATIONS IN AN URBAN EMBAYMENT OF PUGET SOUND, WASHINGTON

James P. Meador[1], Brian D. Ross[2], Paul A. Dinnel[3], and Susan J. Picquelle[4]

A sand-dollar embryo test was used to assess the toxicity of contaminants in sediment elutriate samples from Puget Sound, Washington. A synoptic chemical data set of priority pollutants was reduced and subjected to combinatorial clustering which grouped stations by the amount of chemicals present. Clustering was done for metals and organic compounds together and separately. Analysis of variance revealed that the embryo test was able to predict the group of stations considered least contaminated by organic chemicals but not for metals, although copper and lead could not be excluded due to confounding effects. The results generally support the additivity hypothesis of toxicity, in that as total contamination increased, toxicity increased. Due to a possible change in redox conditions or the release of bio-organically bound metals, it was concluded that the elutriate test may not be appropriate for assessment of metal contaminants associated with sediment. A concentration-response relationship between embryo abnormality and the degree of elutriate dilution was observed which demonstrates that serial dilutions of an elutriate should be tested to properly characterize a sediment's toxicity.

[1] Environmental Conservation Division, Northwest Fisheries Center, NOAA/NMFS, 2725 Montlake Blvd East, Seattle, WA 98112

[2] U.S. Environmental Protection Agency, Seattle, WA 98101

[3] University of Washington Fisheries Research Institute, Seattle, WA 98195

[4] NOAA/National Marine Fisheries Service RACE Division, 7600 Sand Point Way NE, Seattle, WA 98115

TOXICOPATHIC HEPATIC LESIONS IN JUVENILES OF THREE SPECIES OF FLATFISH FROM PUGET SOUND: RELATIONSHIPS WITH INDICES OF CONTAMINANT EXPOSURE

Mark.S. Myers, O.Paul Olson, Lyndal L. Johnson, Carla.S. Stehr, Ken.R. Carrasco, and Tom Hom[1]

Liver neoplasms are rarely detected in young wild fish; consequently, other liver lesions that occur prior to neoplasms must be considered as potential biomarkers of contaminant exposure effects in monitoring studies where target fish specimens are juveniles or subadults. Also, some investigators have argued that effects of contaminant exposure are more reliably assessed and interpreted in juvenile fish that have not yet migrated extensively.

We have addressed these issues by histologically examining juveniles/subadults of English sole, rock sole, and starry flounder captured from eight sites in Puget Sound, and by measuring fluorescent aromatic compounds (FACs) in bile, as well as other chemical and biochemical indices of contaminant exposure. Neoplastic and preneoplastic focal lesions were detected at very low prevalences, whereas much higher prevalences of several types of degenerative lesions were detected in all three species. High prevalences of a unique lesion type characterized by severe hydropic degeneration of hepatocytes and biliary epithelial cells were detected in rock sole and starry flounder from contaminated sites. These lesion types have been experimentally induced in fish by exposure to various toxicants, and/or have been associated with contaminant exposure and the process of liver neoplasia in adult fish.

Prevalences of these earlier biomarkers were significantly higher at the more contaminated sites compared to the less contaminated sites. Moreover, prevalences of most lesion types in all three species were significantly correlated with mean bile FACs levels at the sites, in agreement with the results of previous studies utilizing adults. These findings further support the utility of certain liver lesions other than neoplasms as early indicators of biological damage in juvenile as well as adult fish exposed to xenobiotics in the marine environment.

[1] NOAA/National Marine Fisheries Service RACE Division, 7600 Sand Point Way NE, Seattle, WA 98115

THE METABOLISM OF XENOBIOTICS BY ISOLATED HEPATOCYTES OF ENGLISH SOLE (*PAROPHRYS VETULUS*)

Marc Nishimoto, John E. Stein, Gladys K. Yanagida, and Usha Varanasi[1]

English sole from polluted sites within Puget Sound are susceptible to hepatocarcinogenesis which is associated with exposure to polycyclic aromatic hydrocarbon, as demonstrated by extensive field and laboratory studies. Isolated hepatocytes of fish have been used to study processes believed to be involved in xenobiotic-induced hepatocarcinogenesis, because the cells are biochemically similar to the intact liver. Therefore, we evaluated isolated hepatocytes from English sole as a useful surrogate for the *in vivo* metabolism of xenobiotics as an aid in identifying mechanism(s) of toxic effects in liver due to xenobiotic exposure.

Hepatocytes were isolated from English sole after perfusion of liver with collagenase and hyaluronidase in Ca+2-free buffer. Viable cells were incubated with 3H-BaP under an O_2:CO_2 atmosphere at either 10 or 17°C for 24 hrs in Waymouth MB 752/1 medium supplemented with sodium bicarbonate. The BaP metabolites present in the medium were analyzed by reversed-phase HPLC and ion-pair liquid chromatography, whereas the cells were analyzed for the formation of BaP-DNA adducts. The major organic solvent-soluble metabolite formed by English sole hepatocytes was the unconjugated BaP-9,10-dihydrodiol. The major metabolites released by b-glucuronidase and arylsulfatase hydrolysis of the remaining aqueous phase were BaP-7,8-dihydrodiol, 3-hydroxyBaP and 1-hydroxyBaP. Analysis of the BaP-DNA adducts by 32P-postlabeling revealed that a major adduct arising from the metabolism of BaP is derived from the 7,8-dihydrodiol-9,10-epoxideBaP.

The results of these initial studies show that isolated English sole hepatocytes biotransform BaP to metabolites similar to those identified in English sole exposed to BaP *in vivo*. Thus a system is established for studying in detail the early steps in the toxicity and carcinogenicity of chemical contaminants in benthic fish from Puget Sound.

[1] NOAA/National Marine Fisheries Service RACE Division, 7600 Sand Point Way NE, Seattle, WA 98115

DNA-XENOBIOTIC ADDUCTS AS A BIOINDICATOR OF EXPOSURE TO GENOTOXIC COMPOUNDS IN FISH SPECIES FROM PUGET SOUND

William L. Reichert, John E. Stein, Gladys K. Yanagida, Usha Varanasi[1]

The binding of a chemical carcinogen to DNA is believed to be an essential early step in the process of chemical carcinogenesis. Thus DNA-xenobiotic adducts have received considerable attention as potential bioindicators of exposure to genotoxic compounds. In contaminated environments organisms are exposed to complex mixtures of genotoxic compounds, some of which have not been identified. The 32P-postlabeling assay shows particular promise for measuring DNA-xenobiotic adducts in feral fish because it can detect with high sensitivity a wide range of xenobiotics bound to DNA. We have used this assay for assessing DNA damage by bulky aromatic compounds, such as polycyclic aromatic hydrocarbons, in three Puget Sound benthic fish species from sites ranging from highly contaminated to minimally contaminated. We also have conducted laboratory studies on the persistence of DNA-xenobiotic adducts in English sole.

Overall, the results of these studies using the 32P-postlabeling assay have shown that: 1) bulky hydrophobic aromatic compounds of human origin appear to be the major adducts present in DNA of fish from contaminated sites of Puget Sound, whereas these adducts are generally not present in DNA of fish from reference sites; 2) the levels of DNA adducts generally reflected contaminant levels at a site; and 3) DNA-xenobiotic adducts are persistent and not readily removed from hepatic DNA of English sole. Thus, the results of these studies show that the measurement of DNA-xenobiotic adducts using the 32P-postlabeling assay provides information on the long-term exposure history of benthic fish in Puget Sound to genotoxic compounds, and demonstrate the usefulness of the 32P-postlabeling assay as a tool in studies monitoring the effects of chemical contaminants on fish of Puget Sound.

[1] NOAA/National Marine Fisheries Service RACE Division, 7600 Sand Point Way NE, Seattle, WA 98115

SEVERE HYDROPIC DEGENERATION IN THE LIVER OF ROCK SOLE AND STARRY FLOUNDER FROM CONTAMINATED AREAS OF PUGET SOUND

Carla Stehr, Lyndal Johnson, and Mark Myers [1]

A non-neoplastic, vacuolated liver condition described here as severe hydropic degeneration (SHD) of hepatic parenchymal cells, has been observed in rock sole and starry flounder living in contaminated areas of Puget Sound. This lesion is of interest because a similar contaminant-related, vacuolar liver condition occurs in winter flounder from the east coast of the U. S. With light microscopy, SHD in rock sole and starry flounder is evident as large, intracellular vacuoles that do not contain either lipid or glycogen. Vacuolated cells are scattered throughout the liver, either individually or in aggregates sometimes resembling tubules. Pyknotic nuclei are often apparent against one edge of the vacuole. Electron microscopy reveals that the vacuoles occur in both hepatocytes and biliary epithelial cells. The nuclear cisternae is greatly dilated and the resulting vacuole is bordered by the RER of the outer nuclear membrane. The vacuole often fills the entire cell leaving only a thin rim of cytoplasm. In less severely affected cells, other portions of the RER cisternae may be dilated as well.

This lesion is noteworthy because: 1) membrane damage is apparent in both hepatocytes and biliary epithelial cells; 2) as in winter flounder, SHD seems to be an indicator of contaminant exposure in rock sole and starry flounder; 3) SHD does not occur in English sole, which to date is the species showing the highest prevalence of contaminate-associated liver lesions in Puget Sound.

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LIPID ANALYSIS CONSIDERATIONS FOR BIOACCUMULATION MODELING

Robert C. Randall[1], Henry Lee II[1], Robert J. Ozretich[1] and Judy Pelletier[2]

Current pollutant bioaccumulation models use total lipid concentrations to normalize organism tissue residues. Review of the lipid data base, however, reveals wide variations in reported lipid concentrations for the same organism, resulting in equally wide variations in bioaccumulation model predictions. The large lipid deviations appear to be caused, for the most part, by the use of different lipid extraction methods.

It is a common mistake to believe that total lipid analyses are easy and not particularly solvent dependent. In fact, "total lipid" residues are combinations of perhaps hundreds of specific lipid or lipid-like compounds whose solubilities are dependent on the choice of extraction solvent. Analysis problems are not only limited to choice of solvent, however. Decomposition of solvents may change their lipid extraction capabilities. Lipids can also oxidize, break down at elevated temperatures, and decompose from exposure to light and pH shifts. Finally, preliminary results show that the analyses might be dependent on sample size.

Considering the multitude of problems involved in lipid analyses, we submit that standardization to a specific method of analysis is essential for comparing normalized bioaccumulation data. We recommend a modified Bligh-Dyer technique as an interim standard. This standard would require modelers to provide the factor/factors needed to convert their method results to Bligh-Dyer results, but would not require modelers to change over to the Bligh-Dyer method. We further recommend that lipid results be reported such that conversion is possible between wet and dry bases.

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SPARTINA IN WASHINGTON: A THREAT TO THE ESTUARINE ECOSYSTEM

Barbara Aberle[1] and Thomas F. Mumford, Jr[2]

Intertidal areas of Washington, Oregon, California and British Columbia are currently being invaded by three exotic species of cordgrass: *Spartina alterniflora, S.patens,* and *S.townsendii/anglica.* These plants form dense, monotypic stands that colonize tideflats and displace high intertidal salt marsh. If left uncontrolled, these areas will ultimately consist of broad marsh flats cut by narrow, deep channels. The result is massive habitat alteration, with ramifications for wildlife, fisheries, geology, and hydrology.

The objectives of the research were to determine the extent of *Spartina* infestation in Washington, the ramifications of its spread if left unchecked, what control methods have been employed elsewhere, and courses of action to recommend for its control. Aerial photographs of Willapa Bay from 1963, 1970 and 1988 were photo-interpreted and the resulting *Spartina* coverage entered into a GIS. An extensive literature review and worldwide interviews of *Spartina* experts and researchers were made.

The photo-interpretation indicates that the *Spartina* areas that could be seen expanded from 4.7 ha in 1963, to 30 ha in 1970, to 444 ha in 1988. Field observation show that *S. anglica* is widespread in Port Susan, Skagit Bay and the west and south sides of Whidbey Islands. As a result of the literature review and interviews, we recommend that a regional *Spartina* Coordinating Committee and a State *Spartina* Task Force be established, and that a state-level coordinator and staff be hired to set up long-term and short-term *Spartina* research and control programs. Educational programs and intensive research on *Spartina* biology and ecology in Washington should be begun, and an inventory and mapping program designed.

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[2] Washington Department of Natural Resources, Division of Aquatic Lands, Olympia, WA 98504

A HABITAT CLASSIFICATION SYSTEM FOR WASHINGTON WATERS: THE SEARCH FOR A COMMON LANGUAGE

Megan N. Dethier [1]

Marine and estuarine scientists, resource managers, planners, and others in Washington State have had no common language for discussing and studying saltwater habitat types. Some agencies have used the wetland classification scheme of Cowardin et al., but a lack of ecological realism in this scheme and a tendency for each group to modify it has reduced its usefulness.

The Washington Natural Heritage Program (DNR) funded the creation of a new habitat classification scheme, based on Cowardin to maximize compatibility, as a first step in an attempt to establish marine and estuarine preserves in the state. Data on abundances and quality of different habitat types are needed before decisions can be made on the types and locations of preserves needed. The new scheme is based on substrate type (rock, gravel, etc.), energy (waves and currents), depth, and salinities. Different combinations of these physical parameters define habitat types that are characterized by distinct suites of plants and animals. A first attempt at listing these diagnostic species is presented. These habitat definitions should prove of use not only to preserve designers but to agencies (e.g., in habitat mapping), consulting firms, academic scientists, county planners, and others who need to discuss the presence of, or impacts on, different marine and estuarine habitats on our shoreline.

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KELP INVENTORY FOR THE STRAITS OF JUAN DE FUCA AND THE OUTER COAST OF WASHINGTON, 1989-90

Thomas F. Mumford, Jr[1] *and Bob Van Wagenen*[2]

Floating kelp beds consisting of *Macrocystis integrifolia* (giant kelp) and *Nereocystis luetkeana* (bull kelp) stretch along 313 kilometers (about 12%) of the coast of Puget Sound and the Strait of Juan de Fuca. These multi-canopied beds are made up of rich, diverse communities and provide critical habitat for many important commercial and sport fish and invertebrate species, including juvenile and adult salmon, rockfish, herring, lingcod, and abalone and crab. All floating kelp beds are located on state-owned aquatic lands. The beds of *N. luetkeana* and *M. integrifolia* in Washington have been poorly mapped. The only complete statewide mapping was done in 1912-15 by Rigg and Cameron, with updates done in 1977 by Albright (DoE Coastal Zone Atlas). These maps do not include the outer coast.

This study's purpose was to map the floating kelp beds of the Straits of Juan de Fuca and outer coast of Washington using photo-interpretation of color infrared aerial photographs. Photography was obtained on October 14-15, 1989. Images were photo-interpreted and kelp beds mapped on 1:12,000 base maps derived from USGS 7.5' quads. The extent of the beds was digitized and incorporated into a GIS data base using ARC/INFO software.

The results have produced the most comprehensive inventory of kelp beds in these areas since 1915. The inventory will allow better management and protection of these resources and the fisheries and marine mammals that depend upon them. It will also serve as a baseline for determining future changes in distribution and abundance.

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A GEOGRAPHIC INFORMATION SYSTEM FOR THE DIVISION OF AQUATIC LANDS, DEPARTMENT OF NATURAL RESOURCES

Daniel Saul, Thomas F. Mumford, Jr., and Elizabeth Calvert[1]

The Division of Aquatic Lands of the Department of Natural Resources (DNR) manages the underwater lands deeded to Washington State by the federal government at statehood. Hand-drawn maps created at the time of statehood are currently the only record of public aquatic land ownership. These maps are difficult to use and update and are vulnerable to damage or destruction. All data entry and retrieval must be done by hand. More importantly, the maps can only be used to track ownership use authorizations — they are difficult to use in conjunction with other environmental, land use, or improvement information. This severely hinders their use in making land management decisions regarding the state-owned aquatic land base.

In order to improve the information base for making land management decisions, the division is undertaking a project to prototype a Geographic Information System (GIS) for aquatic land management. Test sites at Port Townsend, Willapa Bay, and Moses Lake were selected for prototype development. For each test site, the original public ownership maps are being digitized and attributed with tabular ownership data. Another layer will record current and historic uses, such as leases, right of ways, and resource extractions. Data layers on such themes as aquatic resources, shorelines, land uses, bathymetry, and aquatic pollution are being developed for use in conjunction with the aquatic ownership data. The data layers under development will be designed to be compatible with existing and planned data within the upland DNR GIS.

The goals of the project are to determine what products the GIS needs to produce, to design the data layers, and to estimate the resources necessary for implementation.

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A LESSON PLAN FOR THE HEALTH RISK IN AQUATIC RECREATION OF PUGET SOUND BEACHES: HISTORICAL PERSPECTIVES TO DEVELOP AESTHETICS

Bonnie Orme[1]

Objective: For today's and tomorrow's choices, are the state's economic trade benefits in harmony with the human health risks in Puget Sound recreation?

Aesthetics, our philosophy that deals with beauty and the beautiful, is really why we have sensed a stewardship for Puget Sound. It can't be weighed or measured by science. It can't be legislated or litigated, but it is the public's preference, and is priceless. Our water and sediment laws and criteria have tried to find a balance for economic benefits, and environmental ethics. Historically Puget Sound has relieved the stress and depression aquatic recreationalists suffered in their economic pursuits. What is the value of joy, and play? We elect those who govern for public safety with "negligible risk".

Unfortunately, prior Puget Sound Protocols are so mired in data deficiencies and definitional discrepancies that it's impossible to predict accurately what would happen to folks and fish. "Risk management" is a political ball game. While policymakers, advised by biased administrators, engage in verbal exercises worthy of medieval scholastics, the public is left trying to understand the big picture, often without the basic tool to do so. Exposure criteria must assess concerns for not only consumption of chemically contaminated seafood, but sunbathers' dermal exposure to contaminated sediments, swimmers', boaters', and fishermen's exposure to contaminated water, and residents' to contaminated fumes from improper hazardous waste treatment, and transport. Using a matrix of health-based selection criteria, I will present a simple lesson plan to guide tomorrow's decision makers to avoid historical flaws.

[1] 1949 Perkins Lane West, Seattle, WA 98199

INCREMEMENTAL MODELING FOR EVALUATING TRANSPORT PATHS OF EAGLE HARBOR SEDIMENTS

Bradley K. Paulson and Steven L. Da Costa[1]

Understanding the physical processes within Puget Sound estuarine systems is important in evaluating the fate and transport of natural substances and man-made contaminants in sediments and the overlying water column. An incremental or phased modeling approach was used to evaluate the transport paths of sediment within and on the boundaries of Eagle Harbor, a small, semi-enclosed embayment located on the eastern side of Bainbridge Island in central Puget Sound. Because of the number of driving forces and the degree of spatial and temporal variability involved, a set of models was selected to describe the long-term, net behavior of this complex system. An incremental modeling approach is one in which a set of models is used and the results are then superimposed on each other.

Our approach involved the application of models which predict spatial and temporal variability of local current velocity fields generated in response to tidal, surface wind stress, and vessel propeller action. Models were also developed to predict along-the-shore transport, seiches, and influences from riverine sources. A set of criteria that evaluates the potential for sediment transport and deposition was developed and integrated into the overall design of the study.

Once developed, the models simulating transport dynamics in Eagle Harbor were used in two complementary ways. First, model results were compared with hypothesized transport paths, sources, and sinks of contaminated material derived from sources other than the models. Second, conclusions were drawn from the model results about the transport paths, sources and sinks, and were compared with indications from other sources of information. Thus, the set of models was used both to investigate existing indications about the fate and transport of contaminants, and to provide new insight and information about these processes.

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HUMAN DISTURBANCES OF HARBOR SEALS AT HAUL-OUT SITES IN PUGET SOUND

John Calambokidis, Joseph R. Evenson, Gretchen H. Steiger, Yousef Farhoum, and Molly Knox[1]

Harbor seals generally rest, give birth, and nurse young at haul-out areas. The potential impact of increasing disturbances from human activities on harbor seals has been a concern in a number of areas. Seal disturbance at sites were monitored in Puget Sound, Hood Canal, and northern Washington inland waters, with the major effort focused on Henderson Inlet in Puget Sound. Disturbances were caused primarily by the close approach of small boats at most sites.

The highest rates of disturbance were seen at Henderson Inlet, a log-boom haul-out site where a majority of boaters came to the site to observe the seals. The number of seals disturbed varied by haul-out habitat and the cause of disturbance. Disturbance rates at Henderson Inlet varied by season, year, time of day, and day of week, reflecting the factors that influence boating activity.

The impacts of disturbance may include: interruption of rest, resulting in lower fitness and health, interference with nursing of young and a concomitant reduction in their health, separation of mother and pups, resulting in starvation and death of pups, and abandonment of haul-out areas. Higher rates of disturbances in July of 1990 at Henderson Inlet prompted the initiation of a program consisting of sign posting, publishing a newspaper article, placing a float-line around the perimeter of the site, and enforcement of the Marine Mammal Protection Act. A dramatic decrease in disturbance occurred as a result of these actions.

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A CULTURAL PRESERVATION MOVEMENT, THE CARVING AND VOYAGING OF NATIVE AMERICAN CANOES FOR THE 1989 WASHINGTON STATE CENTENNIAL

Leslie Lincoln [1]

This presentation of the Centennial "Native Canoe Project" combines a historic perspective gathered from explorers' journals, ethnographic descriptions, artifacts and photo archives with a contemporary Native perspective gathered from oral history and participant fieldwork. Transcribed testimonies communicate Native American understandings.

The Coast Salish Natives of Puget Sound continue to express an attitude of stewardship for our coastal region. Their desire to bring back canoeing traditions which were disrupted during the last century relates to water quality preservation and coastal management efforts. Reclaiming access to landing beaches and forest resources are important issues.

Leaders from the Centennial Commission, National Forests and Tribal Councils cooperated to renew carving, voyaging and racing skills. Seventeen Western Washington tribes participated in the culminating Centennial event, the "Paddle to Seattle." Fleets of canoes from the Pacific Coast and Canada and thousands of support crew and spectators gathered at more than twenty encampments held on traditional landing beach sites.

Widespread enthusiasm for the return of the canoes reflect their vital role in Indian life; in fact, they carry important values for the wider public. Individuals were radiant with pride to have overcome a century of obstacles, to have crafted paddles and launched and traveled in new canoes, to have gathered cedar bark and learned to weave, and to have instilled an interest in youth to participate in their own heritage. Many regained a positive ethnic identity. Racing and voyaging are effective, culturally relevant alternatives to drug and alcohol abuse. Community support revived ancient ways and where necessary created appropriate new institutions to replace those that had been lost. The graceful cedar dugout is a symbol of revitalized Native American culture and is of significance to marine-oriented Puget Sound research.

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BENEFICIAL USE OF DREDGED MATERIAL FOR SALT MARSH DEVELOPMENT AT JETTY ISLAND, EVERETT, WASHINGTON

Hiram Arden [1] *and Justine Smith* [2]

The Jetty Island project in Everett, Washington, is the first project by the Seattle District Corps of Engineers and the Port of Everett which has used clean, dredged sand for habitat development. The western shore of Jetty Island is a dynamic environment subject to wave erosion. In conjunction with 1989 river depth maintenance, a plan was proposed to construct along the west shore of the island a protective berm that would shelter about 19 acres of mudflat.

Following interagency coordination and baseline studies, 323,000 cubic yards of material were used to construct a 1,800 foot long protective berm. Pilot plots of a number of species of salt marsh plants were planted in spring 1990 in the protected embayment, and based on recently obtained results, final planting is scheduled for spring 1991.

[1] U.S. Army Corps of Engineers, Seattle District, P.O. Box C-3755, Seattle, WA 98125-2255

[2] U.S. Environmental Protection Agency, Region 10, 1200 Sixth Avenue, Seattle, WA 98101

PUGET SOUND NEARSHORE HABITAT INVENTORY PROTOCOL

Thomas F.Mumford, Jr., J. Anne Shaffer, Daniel Saul, Allison Bailey, and Elizabeth Calvert[1]

Nearshore wetland habitats serve a number of ecological, economic and research functions, including nesting, breeding or refuge areas for wildlife, fisheries, food web support, sediment trapping, and nutrient cycling. Information regarding the distribution, type, and functions of wetland habitats is critical for making good management decisions. Local, state and federal regulatory and proprietary agencies require this information in planning, zoning, leasing permitting and preservation activities.

Estuarine and marine habitats have been poorly or incompletely inventoried. Existing inventories of Washington shorelines include the Department of Ecology's Coastal Zone Atlas, PSWQA's Puget Sound Atlas, and the US Fish & Wildlife Service's National Wetland Inventory maps. All suffer from outdated information, inadequate resolution, or inaccurate information, especially in subtidal regions.

EPA's Region 10 Estuary Program and Environmental Monitoring Systems Lab and the Washington State Department of Natural Resources have jointly funded a research program to determine the most cost- and program-effective methods of inventorying marine and estuarine habitats of Puget Sound, and to routinely monitor the distribution and types of marine and estuarine habitats of Puget Sound. New remote sensing data of nearshore habitats at six test sites in Puget Sound were acquired at a tidal level of 1 ft. or less during July/August using both color infrared photography at three scales (1:6,000, 1:12,000, 1:24,000) and an aircraft-based, multispectral scanner at a minimum resolution of 5 m. We compared spatial and classification accuracy of these two methods, developed ground truthing protocols, verified remote sensing data with simultaneous ground truthing, and analyzed the design, feasibility and costs of using a GIS system to store, analyze, and display information.

Our recommendations for best methods of data acquisition, analysis, and classification are provided.

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NATIONAL MARINE SANCTUARIES: A FEDERAL PROGRAM TO PREVENT HABITAT DEGRADATION AND TO PROMOTE RESEARCH

Fred Felleman[1]

The National Marine Sanctuary Program came into existence in 1972 as a result of the passage of the federal Marine Protection, Research, and Sanctuaries Act (MPRSA), but it has remained a small and poorly understood division of the National Oceanic and Atmospheric Administration (NOAA) ever since. Until 1988 only seven examples of the United States' diverse marine habitats had been afforded the enhanced protection associated with Sanctuary status. These few sites also have benefitted from the resulting coordination of the various agencies responsible for their management, from federally funded research aimed at improving management practices, and from enhanced public awareness of the need to abide by current laws. Moreover, new regulations have been imposed which the public identified as needed to fill gaps in the existing regulatory system. Because each sanctuary is created to fit the needs of a specific region, however, there is still much confusion concerning what the designation of a new sanctuary will mean.

During the last reauthorization of the MPRSA, Congress for the first time directed NOAA to designate new sanctuaries, including the Olympic Coast of Washington State (by June 1990), and to review the possibility of designating the waters of Juan de Fuca Strait and surrounding the San Juan Islands as a sanctuary by March 1991. In addition, NOAA was directed to give priority to funding research in sanctuaries and to assure that funds recovered from damages to a sanctuary be directed to restoring sanctuary resources.

The purpose of this presentation is to clarify the mandate and evaluate the accomplishments of the Sanctuary Program with specific examples from management plans and research programs of existing sanctuaries. In addition, the process and issues being addressed in the review of the Olympic Coast and Northern Puget Sound proposals, including research, management, and enforcement, will be discussed.

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EFFECTIVENESS OF VARIOUS SURFACE WATER MANAGEMENT TOOLS IN A RAPIDLY URBANIZING DRAINAGE BASIN

Bruce Barker, Margaret Moorehead, Derek B. Booth, Robert Fuerstenberg, and Richard E. Thomas[1]

A basin management program is recommended for the Soos Creek basin, a rapidly urbanizing watershed with diverse salmonid habitat. Using a continuous hydrologic model, field studies, and empirical data, the effectiveness of various management tools is predicted with greater certainty than previously possible. The recommended program will substantially reduce, but not eliminate, development-related flow increases.

Maintaining stable stream channels and high-quality habitat through control of development-related flow increases is an objective of the management program. Potential flow control measures include regional detention ponds, onsite detention requirements, floodplain development limits, clearing limits, and land-use controls. The effectiveness of these measures varies. For example, regional detention ponds provide only localized flow control. Of thirteen regional ponds evaluated, only six ponds reduce flows downstream by more than nine percent. Because most of the Soos Creek basin has not yet been urbanized, controls on new development are the most effective ways to control flow increases. Sub-basin, specific on-site detention standards limit peak flow increases to 12 percent in less sensitive reaches and maintain flow peaks and long-term durations in erosion- and habitat-sensitive reaches. Under recommended floodplain development limits, peak flows in a sample reach are about 30 percent lower than under federal floodplain standards. When clearing is limited to 80 percent or less of the site in low density areas, peak flows can be reduced by 26 percent.

Lowering of zoned land-use densities provides substantial flow benefits. On a sample commercial site, stream flows with a two-year return frequency are predicted to be more than three times higher than from a medium-density (1 to 3 units/acre) residential subdivision. Even relatively small density differences can significantly affect flows. Erosion-causing 2-year flows occur between 30 and 1000 percent more often at densities of one unit per 2.5 acres, compared to densities of one unit per five acres.

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THE PUGET SOUND WETLANDS AND STORMWATER MANAGEMENT RESEARCH PROGRAM: RESULTS TO DATE AND THEIR IMPLICATIONS

Richard R. Horner[1], Klaus O. Richter[1], Amanda L. Azous[1], Eric C. Stockdale[1], Sarah S. Cooke[2], and Lorin E. Reinelt[3]

In 1986 the Puget Sound Wetlands and Stormwater Management Research Program began to perform research on the short- and long-term impacts of urban stormwater on the region's freshwater wetlands and on the transport and fate of pollutants discharged to those wetlands. The goal of the program is to improve the management of both urban wetlands and the storm runoff that affects them either incidentally or through drainage management actions. The program has completed an initial survey and the first three years of a long-term investigation of wetland ecological change, and the implications of any such change, as urbanization proceeds.

The research primarily involves comparisons of hydrology, water quality, soils, and plant and animal communities before and after urbanization, as well as between wetlands affected (treatment sites) and unaffected (control sites) by urbanization. While results are available only through the first stages of urbanization around treatment wetlands, key findings from our studies include: (1) regional wetlands exhibit one of four characteristic hydrologic patterns that, if changed, will affect the resident plant and animal communities; (2) water quality characteristics are generally quite variable, but means and ranges identified under different conditions provide a basis for indicating deterioration and setting criteria to prevent it; (3) heavy metals have rarely exceeded accepted water quality limits, but accumulation in soils and, to a lesser extent, in plant tissue is determined by their relative concentrations in water; (4) one year after urbanization began, treatment sites overall exhibited greater shifts in plant species presence and cover than did control wetlands; and (5) certain amphibians have well defined water depth requirements for breeding that are vulnerable to hydrologic change.

The research results have been applied to develop preliminary guidelines for managing urban hydrology in conjunction with wetlands. Incorporated in a computer-based model, these guidelines will be refined as more data become available.

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[2] University of Washington College of Forest Resources, AR-10, Seattle, WA 98103

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EPA REGION 10'S URBAN PESTICIDE/FERTILIZER INITIATIVE

Karl H. Arne[1]

The improper home and yard use or overuse of pesticides and fertilizers can lead to environmental hazards. Runoff can carry pesticides and fertilizers to aquatic environments, both surface and groundwater. Birds and other non-target animals have been killed because of ingesting pesticides applied to lawns or gardens, and residential over-application, or application in the wrong conditions, of fertilizers are common. In addition, pesticide use can result in a significant potential for human exposure.

State and federal pesticide program resources are directed mainly at agricultural and commercial uses. Few education, surveillance, or enforcement resources are expended in urban settings. In the Seattle area, neither the Cooperative Extension Service nor the local health departments have significant resources to devote to alternative home pest management, proper yard and garden fertilization procedures, and training programs. As a result, when faced with pest control or garden problems, homeowners may opt for chemical control applied either by themselves or by a professional pest control company, because they are not aware of alternative management possibilities.

To address the problems associated with pesticide and fertilizer use in urban areas, EPA Region 10 has begun work on an Urban Pesticide/Fertilizer Initiative. The goals of this project are to inform urban users about environmental problems of pesticide and fertilizer use and to promote pest control and fertilization practices that are environmentally sound. This will be done by collecting information on alternative pest control and fertilization methods and making it available to extension offices, pest control officers, and the general public.

[1] U.S. Environmental Protection Agency, Region 10, Seattle, WA 98101

MICROBIAL DEGRADATION OF TOXICANTS: HOPE FOR PUGET SOUND SEDIMENTS?

Russell P. Herwig and James T. Staley[1]

Puget Sound has several sediment sites that contain elevated concentrations of toxicants including heavy metals, pentachlorophenol, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs). Previous research about toxicants in Puget Sound has been directed toward (1) learning the distribution of toxicants in the water, sediments and biota; (2) evaluating the toxicity contained in marine waters and sediments using a variety of bioassays; and (3) determining the community structure at sample sites. The goal of this study is to examine the biodegradation of toxicants in Puget Sound and the microorganisms responsible for this degradation.

At one time many toxicants were thought to be totally resistant to biological degradation. However, in recent years various investigators have described both mixed and pure cultures of microorganisms capable of transforming many of these compounds, often into harmless products. Nationally, several environmental microbiology studies have examined contaminated groundwater and terrestrial soil sites, but little work is being done on the degradation of toxicants in the marine environment. The physical, chemical, and biological properties of marine environments suggest that the microorganisms capable of toxicant degradation in Puget Sound will be different from microorganisms found in non-marine sites.

Our laboratory has recently begun to examine the degradation of PAHs and pentachlorophenol in Puget Sound, and we will isolate marine microorganisms that contribute to this activity. In our presentation, we summarize the literature on the microbiology of toxicant degradation with regard to those compounds contaminating Puget Sound and also outline our Puget Sound research procedures. The long-term goal of our research group is to understand the biological degradation of toxicants in Puget Sound and to participate in the development of methods for the *in situ* bio-remediation of toxic sites found in Puget Sound.

[1] University of Washington, Department of Microbiology, Seattle, WA 98195

THE ENVIRONMENTAL VALUE OF CULTURAL RESOURCES, ARCHEOLOGY, AND HISTORY IN CONTEMPORARY PUGET SOUND NATURAL RESOURCES MANAGEMENT

David G. Rice[1]

It is not commonly understood that cultural (archeological and historical) resources are as valuable a source of information regarding past environments and climates as they are regarding prehistoric and historic human activities. In fact, one of the major weaknesses in contemporary, applied ecological studies is the lack of time depth in the historical record of key environmental information, especially hydrology and flood events, catastrophic events such as earthquakes and volcanic eruptions, regional patterns of delta building and estuary siltation, and changes in regional biological resources.

Prehistoric archeological sites along the Puget Sound littoral have the potential to contribute important information about changes in micro-environments within the region, especially over the last 3,000 years. In addition, cultural resources of the early historic period may be valuable in describing local/regional environmental conditions and changes in those conditions during the historic period. Indeed, archeologists and historians have special environmental expertise and a legitimate and appropriate role in working with biologists and wetland ecologists to assess baseline conditions for past environmental settings as well as for reconstruction of environmental conditions from the historic record.

This presentation illustrates some of the applications of this kind of information to contemporary environmental studies important to the effective management of Puget Sound, such as patterns of habitat preservation and degradation, and harbor pollution effects. Finally, studies are recommended which would make better use of archeologists and historians, and of the cultural resources which exist, in historical environmental studies in the Puget Sound region.

[1] U.S. Army Corps of Engineers, Seattle District, Box C-3755, Seattle, WA 98124-2255

CONTROL AND PREVENTION OF PARTICULATE POLLUTION IN PUGET SOUND AQUATIC SYSTEMS

M. Pat Wennekens[1]

Particulate pollution is the most ubiquitous, widespread and serious form of pollution impacting Puget Sound aquatic systems. The term "particulate pollution," as contrasted to "sediment pollution," serves to underscore the fact that a wide array of particles contributes to the physical and toxological degrada- tion of Puget Sound aquatic environments. The term "sediment" commonly alludes to deposited material, and wastewater engineering terms such as "total suspended solids, "settleable solids", and "turbidity," refer to the *physical* presence of various concentrations of (fine), usually suspended inorganic and organic particles. Methods of the control and prevention of particulate pollution will differ, however, depending on which of two physically and hydro-geochemically distinct sets of particles are being dealt with:

a) Particles ranging in size from boulders to sands which move along the bottom by sliding, rolling and saltation (hops and jumps) and which induce "bedload" pollution, and
b) Fine to ultra-fine, inorganic/organic, pollutant- carrying particles which are clay- to colloid-sized, surface active, comparatively slow to settle, and which induce "suspensoid" pollution.

"Bedload" pollution is primarily physical, usually localized, relatively long-lasting and slow to flush. "Supensoid" pollution is *the* most serious form of particulate pollution, due to its pollutant-binding properties and the relative ease with which its fine particles are broadcasted.

Control and prevention of particulate pollution obviously rest with strict and aggresive "zero discharge" source control. "Zero Discharge" is not an altruistic utopia but a necessity. *Prevention* rather than promoting "acceptable levels of pollution" must become the norm of regulatory practices.

[1] Olympic Environmental Council, Hydro-Phyta Geoscience, 399 Norman Street, Sequim, WA 93382

DISTRIBUTION OF HABITATS AND SUMMER STANDING CROP OF SEAGRASSES AND MACROALGAE IN PADILLA BAY, WASHINGTON, 1989

Douglas A. Bulthuis[1]

The channels, seagrass and macroalgae beds, and intertidal flats in Padilla Bay were mapped during the summer of 1989. Seagrasses, principally *Zostera marina* L., provided the most important habitat, covering about 2300 hectares of the total 3900 hectares in the Padilla Bay National Estuarine Research Reserve. *Zostera japonica* Aschers. & Graebn. was distributed higher in the intertidal than *Z. marina* and covered about 250 hectares. Reported from Padilla Bay for the first time, the seagrass *Ruppia maritima* is widely but very sparsely distributed over about 100 hectares. Large accumulations of *Ulva* and *Enteromorpha* covered about 70 hectares in the southern part of Padilla Bay. Density of *Zostera marina* ranged up to 441 shoots/m^2 and of *Z. japonica* up to 1095 shoots/m^2. The standing crop of seagrasses ranged from 12 to 103 g dry weight/m^2 at 13 seagrass covered sites at which macroalgae biomass ranged from less than 1 to 190 g dry weight/m^2. Within one *Ulva*-covered site, the macroalgae standing crop averaged 526 g dry weight/m^2.

The sediments in most of Padilla Bay are sandy, with silt and clay the dominant particle size only in the southeastern corner. The seagrass beds in the bay are one of the largest, continuous beds of seagrass in Washington State and along the Pacific Coast of North America.

[1] Padilla Bay National Estuarine Research Reserve, Washington State Deptartment of Ecology, 1043 Bay View-Edison Road, Mount Vernon, WA 98273

GETTING THE MESSAGE OUT: THE CITY OF SEATTLE'S VOLUNTEER STORM DRAIN STENCILING PROJECT

Jennie S. Goldberg[1]

The illegal dumping of used motor oil and other hazardous materials into storm drainage systems continues to be a major source of nonpoint source pollution to Seattle's creeks and lakes and to Puget Sound. Often it occurs because people do not understand the connection between storm drains and the receiving waters. Effective education efforts can increase public awareness and lead to a change in behavior.

The Storm Drain Stenciling Project involves organizing volunteers to paint the message, "DUMP NO WASTE...DRAINS TO STREAM (or LAKE or BAY)", on the street next to storm drain inlets. This "hands-on" form of activity is an effective education tool because it provides individuals an opportunity to do something to protect clean water and encourages responsible stewardship of our city's waterways. Stenciling next to storm drain inlets alerts passers-by to the fate of run-off water and the materials carried with it from buildings and streets. The message is highly visible and discourages would-be dumpers from polluting.

Participation by volunteers is enhanced by making it easy for individuals and businesses to stencil neighborhood inlets. The city provides all the materials needed: paint, traffic safety vests and flags, gloves, stencils, street use permit, drainage maps of the area and information sheets. These "kits" are loaned to individuals, businesses, groups or schools free of charge.

Stenciling activities compliment and reinforce other on-going water quality education efforts currently conducted by Seattle's Drainage and Wastewater Utility, such as distribution of written materials. Other benefits to the city include an increased public awareness that assists in its efforts to reduce pollutants in storm drain discharges and reduces the costs related to cleaning catch basins and storm drain lines.

[1] City of Seattle Drainage and Wastewater Utility, 710 Second Avenue, Room 660, Seattle, WA 98104

RESPONSE OF JUVENILE PACIFIC SALMON (*ONCORHYNCHUS* SPP.) TO PILE DRIVING OPERATIONS IN PUGET SOUND SHORELINE WATERS

James J. Anderson [1], *Robert Donnelly* [1], *Blake E. Feist* [1], *Mike Macauley* [2], *Robert T. Miyamoto* [2], *and Mark Stoermer* [2]

Current regulations prohibit pile driving activities in Puget Sound waters from March 15 to June 15 each year. However, the rationale that migrating juvenile Pacific salmon (*Oncorhynchus* spp.) might be driven towards deeper water in order to avoid the disturbance created by pile driving activities has yet to be supported by solid evidence. An understanding of the effect of pile driving on pink and chum salmon ecology near construction sites in Puget Sound is essential if we are to effectively balance our environmental and industrial needs.

A pilot study was initiated to assess the potential effects of pile driving on juvenile salmonid ecology. The behavior and distributions of juvenile pink and chum salmon, with and without pile driving activities, at the Everett Homeport site (near the mouth of the Snohomish River) was monitored daily during the closure period. School size, frequency, and general behavior were recorded. In addition, length, weight, and stomach contents were measured, the underwater acoustic environment was characterized, and tides, weather and salinity were recorded.

Preliminary results indicate that pile driving has subtle effects on salmon behavior and school size. Environmental factors are being determined.

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IMPACT OF PURPLE LOOSESTRIFE ON WATERFOWL HABITAT AT MONTLAKE FILL, UNIVERSITY OF WASHINGTON

Estella Leopold[1], Kristina Lau[2], and Michael Pollack[3]

Purple loosestrife (*Lythrum salicaria*, Lythraceae) is a tall aquatic and exotic weed which has invaded certain local wetlands in the Seattle area during the last 10 years. We hypothesize that loosestrife competes with and displaces native aquatic plant species that supply natural food and habitat for waterfowl. The Montlake Fill (a former landfill) has four small ponds, of which two are dominated by dense strands of purple loosestrife, one is partially invaded, and one pond has no loosestrife.

Observations of waterfowl use of the ponds made during the months of April and May 1990, for a total of 21 days, tended to confirm the hypothesis that the usage of ponds by waterfowl is lower on habitats invaded by purple loosestrife than on ponds dominated by native wetland plant communities.

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GRAY WHALE FEEDING ON *CALLIANASSA* SHRIMP IN BENTHIC INTERTIDAL HABITATS IN PUGET SOUND

Winner of the award for Best Student Poster at Puget Sound Research '91

Laurie A. Weitkamp[1]

Initial observations and documentation of gray whales (*Eschrichtuis robustus*) feeding on intertidal sandflats dominated by ghost shrimp (*Callianassa californiensis*) were made in June 1990 in Puget Sound. The whales created large feeding pits at an elevation of -0.7 to -2.4 ft. MLLW, along 12 miles of sand beaches with high ghost shrimp densities (250/m^2). The feeding pits averaged 2.9 m long, 1.6 m wide, with an area of 3.7 m^2. Observations indicated that only one-fifth of the ghost shrimp biomass found outside the pits (1058 g/m^2) remained in the sediments inside them (218 g/m^2), suggesting an average of 3.1 kg shrimp had been removed from each pit.

Although pit dimensions are comparable to those reported for gray whales feeding in other habitats, the biomass available to whales feeding on ghost shrimp is 2 to 6.5 times greater than that from other benthic resources from the outer coast of North America and the Bering and Chukchi Seas. This apparent consumption of ghost shrimp suggests an increasing exploitation of benthic resources in the North Pacific by the expanding gray whale population, possibly indicative of its former role in structuring estuarine and coastal benthic communities.

[1] Fisheries Research Institute, University of Washington, WH-10, Seattle, WA 98195

THE EFFECTS OF LANDFILL LEACHATE FROM PADILLA BAY ON THE ABUNDANCE OF HARPACTICOID COPEPODS, AND BIOASSAY MEASUREMENTS OF SEDIMENT TOXICITY USING *RHEPOXINIUS ABRONIUS*

Jim Wiggins[1]

Landfills are disposal sites for various municipal and industrial wastes. Landfill leachate, whether from seepage through the landfill as a result of rainfall or as direct runoff from discarded liquid wastes, affects various marine communities within Puget Sound. Combining chemical analyses, sediment bioassays for toxicity analyses and *in-situ* community sampling allows for a thorough determination of the degree of impact leachate has on a system.

I have studied a site where landfill leachate enters Padilla Bay. Acting for the EPA, the Washington Department of Ecology found no significant amounts of priority pollutants in this area in 1986.

In conjunction with a sediment bioassay using the amphipod *Rhepoxinius abronius* to determine sediment toxicity, two areas where leachate enters a shallow mud bay and one environmentally similar but clean site were analyzed for the abundance of epibenthic harpacticoid copepods. The area exposed to the leachate runoff showed no significant decline in harpacticoid copepod abundance compared to the clean site but the amphipod sediment bioassay showed a significantly higher mortality than the clean site. The analysis of another area that had visible signs of oil contamination showed a significantly higher abundance of harpacticoids than the clean and leachate-affected area and had the highest mortality in the amphipod bioassay (100% mortality using the top 2 cm of sediment).

Through more analyses of the oil contaminated site, the top 2 mm of sediment showed similar bioassay results as the clean site, indicating a natural sediment "cap" over the toxic sediments.

Local harpacticoid copepod species, predominantly *Harpacticus* sp. and *Tisbe* sp. (a portion of the epibenthos) reside in the sediment surface layer. The sediment is oxidized, high in humic content and well mixed. This study indicates that the sediment surface layer provides adequate conditions to support an epibenthic community by separating it from toxic benthic sediments.

[1] Aqua-Terr Systems, 1117 North Garden Street, Bellingham, WA 98225

THE SORPTION BEHAVIOR OF BUTYLTINS IN TWO PUGET SOUND MARINAS

David W. Templeton[1]

The use of tributyltin (TBT) as a biocide directly releases highly toxic tributyltins into the aquatic environment. Sediments can act as a repository for significant amounts of TBT and its degradation products, dibutyltin (DBT) and monobutyltin (MBT). The bound butyltins may then be available for uptake by benthic organisms and serve as a source of contaminants to the water column through diffusive flux and desorption events. This study investigated factors that control the partitioning (the ratio of sediment and water column concentrations) of butyltin compounds in impacted sediments by examining the correlation between partition coefficient, grain size, and total volatile solids (TVS) for Port Townsend Marina and Cap Sante Marina (Anacortes).

The top three centimeters of sediment were obtained with a bottom grab. Overlying water samples were pumped from twelve centimeters off the bottom during slack and ebb tide conditions. Butyltin levels were determined by capillary gas chromatography with flame photometric detection. Percent mud (<63 μm) was determined by wet sieving and differential settling rate methods. Total volatile solids were defined as loss after ignition when ashed for two hours at 550°C.

Marina butyltin partition coefficient values ranged from 500 to 2500 μg/kg dry sediment per ng/L seawater. Port Townsend Marina sediment percent mud ranged from 14 to 36, with percent volatile solids in the range of 1.11 to 1.72. Cap Sante Marina sediment percent mud ranged from 90 to 98, with percent volatile solids in the range of 3.4 to 5.5. Correlation data is not available at this time.

The degradation rates of butyltins in sediment have been demonstrated to be much slower than those in the water column. By predicting the partitioning of butyltins in marina sediments, the long term impacts on the Puget Sound ecosystem can be better evaluated by applying the correct degradation rates.

[1] Western Washington University, Battelle NW Marine Science Lab, 439 W. Sequim Bay Road, Sequim, WA 98382

A VIABLE ALLIANCE FOR AGRICULTURE AND THE ENVIRONMENT

Nancy Tucker and Page Crutcher[1]

The purpose of our project is to assess the effectiveness of interactive pollution reduction and recycling methods for agricultural enterprises which support a viable alliance for agriculture, water quality, and wildlife.

The poster demonstrates the use of on-site natural systems to address the widespread and serious environmental problems caused by non-point water pollution. Dairy farms have been identified as contributing to nonpoint source pollution. We propose a practical and technical demonstration of dairybarn wastewater treatment utilizing biofiltration. The project could demonstrate to the dairy industry and the public at large, a new low-technology, sustainable, environmentally sound process for dairybarn wastewater treatment.

Utilizing introduced fields of cattails for biofiltration of liquid dairybarn wastes may reduce and improve the quality of effluent from dairybarns to secondary and tertiary levels of treatment. Concentrated biofiltration of dairybarn wastewater would significantly reduce bacterial and nutrient nonpoint source pollution caused by the current procedure of over-saturating huge tracts of farm fields with liquid wastes. The proposed process will also reuse excessive nutrients more efficiently, as the biofiltrating cattails are palatable and nutritionally sufficient for heifers and non-lactating cattle feed. The process will also recycle valuable groundwater by allowing the treated water to be utilized again during the daily washdown of the loafing barns and milking parlors.

The poster also identifies potential cash crops that could dramatically increase economic viability of agricultural lands near major metropolitan areas. Procedures for habitat improvement and landscape management that honor rural character are also highlighted.

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PUGET SOUND

RESEARCH '91

GUEST SPEAKER

DEEP TIME AND SHALLOW POLICY

Bruce Brown

Thank you very much. This is a sort of homecoming for me.

I grew up in Seattle watching Captain Puget and Ivar Haglund sing "Acres of Clams." We talked about mosquito fleets, not swarms; and the underground took you back in time, not across town.

I always loved Seattle, of course, with the mountains and water all around, but I didn't really give its physical situation much thought until I went away to college.

There I found that almost everybody I met hated where they were from. When I talked about watching phosphorescence burning in the waters around our sailboat on hot August nights on the Sound, the room around me often grew silent with disbelief. My friends from Masapequa and Hackensack had no come-back.

I suppose in my telling the Sound resembled the Spanish main more than itself. In fact, I remember the frustration of trying to get tourists to see through the murky veils in which the Sound often wraps herself. Once a member of the family interrupted a tourist on a ferry to correct his description of the Sound, "No, not grey. Grey-GREEN."

In time I realized—like Dan Chasan—that water is the link. If you want to get to the heart of what is happening in the Northwest, you need to get down to the water line that snakes through so much of this region and dominates the landscape even more than Mt. Rainier.

The Pacific Northwest makes it easy of course, perhaps even excessively so in the eyes of the people of Fir Island, and the little town where I live, Sumas, Washington. Last month I stood at my living room window and watched a 20-cubic foot chest style freezer and a Hide-A-Bed float by and finally beach themselves in the middle of the cow pasture across the road.

It doesn't take too many experiences like this to convince you that water is the ruling element hereabouts. Trouble is, our inclination culturally is to do something about that. The history of the "management"—and I use the term advisedly—of inland and off-shore waters is not a pretty one in either the Old or New World.

Here in America, Long Island Sound, Lake Erie, San Francisco Bay are among the great bodies of water that have withered under our hand, despite a

formidable array of protective laws and the expenditure—especially in recent decades—of huge sums of money to partially restore or mitigate the damage.

Looking at the Atlantic salmon situation, there were 433 laws on the books in the state of Maine to protect salmon when the fish became extinct in the waters of the state in the late nineteenth century. Similarly, scores of Washington dams, from Aldwell Dam on the Elwha River to Grand Coulee on the Columbia, were built in violation of Washington State laws during this century.

We know a great deal more about what is going on in the environment around us today—as this conference splendidly illustrates—but I sometimes wonder how different the underlying process really is. I remember when I was a reporter at the *Seattle Post-Intelligencer* during the 1970s I bet my city editor that you could choose a state environmental law at random, go in, and find a non-enforcement scandal.

He took me on the bet, and the result was some of the investigative reporting that lay behind my first book, *Mountain in the Clouds.* Now in Thursday's *P-I* we have a story by Rob Taylor revealing that four of the largest air polluters on Puget Sound have been effectively exempted by the state from toughening air quality standards.

Watching this process repeat itself over centuries, one inevitably begins to ask, why? Why do we always hurt the one we love? Seriously, though, why are we unable to prevent ourselves from wasting large common aquatic resources? I sometimes think of it as a matter of shallow laws and deep time.

American law places a great deal of importance on things like property rights, and the sanctity of the contract. And even where the law is intended to achieve broader aims, it is constantly impinged upon by individuals advancing what are perceived as property rights. This is good in some respects, but it has spelt the ruin of virtually every significant common resource. Some have suggested that the only way to end "The Tragedy of Commons" is to "privatize" public resources, but I believe the problem goes deeper than that.

Let's consider where we're at in the later 20th century. Despite the Diet Pepsi challenge, Puget Sound area residents still live in an area where rain—or other forms of precipitation—is the predominant meteorological phenomenon. This causes a net flow of nutrients off the land into the sea that is incessant, except for periods of glaciation.

As recently as 10,000 years ago, ice advanced to cover the entire Puget Sound trough, burying everything from the Cascades to the Olympics. We know from the geological record that this has happened again and again. The devastation that has accompanied these repeated ice advances is almost incomprehen-

sible. So too is the resiliency of the biome necessary for life to recolonize the area again and again.

Puget Sound plays a crucial role in this cycle. It's effects are evident everywhere from the moderating influence it has on regional temperatures, to its support of a great complex of aquatic life. It's nice to have the Sound there for all the reasons that the lifestyle bimbos from the East Coast and California media are always talking about, but it *matters* because it makes it possible for life in the region to survive across millennia.

In the past one way that Puget Sound has contributed to the basin beyond its shores is by production of wild salmon. We know that the Sound provides a rich feeding ground for salmonids where it is healthy, and some species of salmonids, such as the Chinook, may never leave it. This has the effect of making the Sound's tributary rivers more productive than they otherwise would be, and increasing the size of their native salmon runs.

These fish, as some of you who are familiar with *Mountain in the Clouds* know, function as nature's primary means of reversing the predominate nutrient flow, and returning organic material from the ocean to the land. A great biological engine of enrichment and regeneration, they not only support countless aquatic and riverine predators, but actually increase their own progeny's chances of survival through their curious rites of mass spawning and death.

In the not too distant past Puget Sound supported great populations of wild salmon—we know this from the record of their slaughter. These fish were one nexus in a complex web of life which sustained this region for millions of years, judging by the fossil remains giant Smilodonicthys left in the cliffs along the Washington Coast.

Today the situation for many wild Western Washington salmon is perilous. Numbers can get numbing, but to give you an idea of how bad wild coho production has gotten in some rivers, the Nooksack has fallen so low that it actually produces fewer of the fish annually than Breckenridge and Johnson creeks, two small streams near my home which are tributary to the Fraser.

The modern peril of many stocks of wild Puget Sound salmon is not just a problem for the fish for a few years, and it's not just a problem for the fishermen who live off them, or the industries that live off the fishermen. It's a problem for most life in the region, and its effects will be felt ten thousand years from now.

All this is true, too, in a broader sense for the Sound itself. The great body of water that has gathered us together over the last two days presents us with a

challenge. It makes me think of a Nicole Hollander cartoon I saw recently which had a TV game show host in a life support suit.

"And Now!" he said, "for the red rain coat and the last piece of beach-front property in the world......What is 'The Greenhouse Effect?'"

"Oh Bummer. I can't remember," replied the off-screen contestant.

Things aren't that bad yet, but Puget Sound is just about our last chance to prove that America is capable of not trashing an important inland waterway.

I hope we are equal to that challenge, so that 500 years from now, some tourist can speak of the grey waters of the Sound, and a native (whatever and whomever they may be at that time) can correct lovingly, "No, not grey. Grey-green..."

Thank you again.