

Objectives

The aim of this work was to determine the extent of population diversity among Pacific herring in Puget Sound, using time series data of adult spawning biomass, and ask the following questions:

Is there population diversity among Puget Sound herring that is likely to buffer the stock against environmental variability?

Does the "portfolio effect" apply to Puget Sound herring?

Is there coherence among Puget Sound herring populations, indicating they respond to environmental drivers similarly; and does coherence increase within geographic regions?

Methods

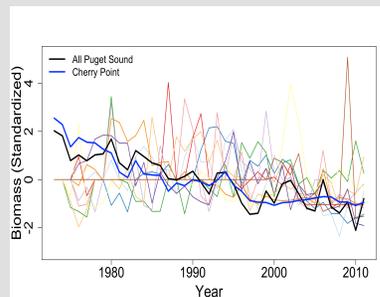
Statistical analyses were conducted using Washington Department of Fish and Wildlife annual time series data (1973-2011) of adult herring spawning biomass, calculated based on egg deposition and acoustic surveys.

Missing values were replaced with the long-term mean for each population, except where noted.

Correlations between time series of individual herring populations were calculated using Spearman's ranked correlation. All analyses were performed using R (2.14.12, The R Foundation for Statistical Computing).

Figure 1

Time series of individual herring populations, with missing data replaced by long-term means.



Results

1. Variability of individual stock biomass often far exceeds that of Puget Sound-wide biomass.
2. Biomass is more variable year-to-year at the individual population scale, as compared to the Sound scale.
3. A large proportion (0.32) of correlations among individual herring population were negative. Synchrony did not increase substantially within regions, though the replacement of missing values with long-term means did increase synchrony.
4. In all populations, their maximum proportional contribution to the total Puget Sound biomass exceeded their mean contribution, and in some cases by nearly 5x. Different populations contributed the bulk of biomass in different years, suggesting the importance of maintaining all populations in the system.

Figure 2

Coefficients of variation of individual populations are on average 3x greater, and range up to ~10x greater, than all Puget Sound stocks taken together.

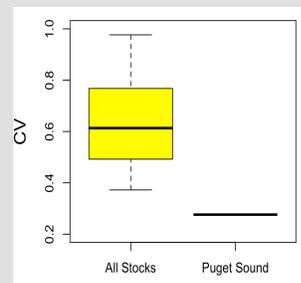


Figure 3

Correlations were calculated between herring population time series with missing values replaced by long-term means for that population.

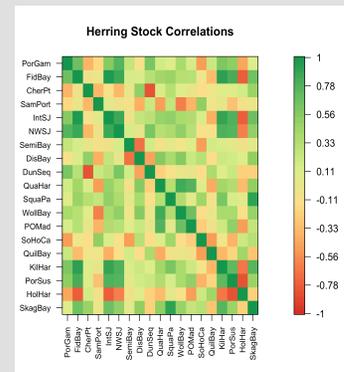


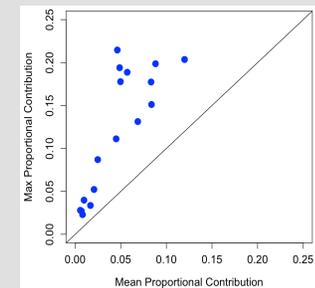
Table 1

Positive correlations among herring populations within different geographic regions. Correlations were calculated both with missing values replaced by long-term mean, and with missing values not replaced.

Region	NAs not replaced	NAs replaced
All	0.36	0.32
North	0.33	0.27
North-Central	0.29	0.20
Central	0.41	0.33
South-Central	0.5	0.5
South	0.66	0.66

Figure 4.

Correlations were calculated between herring population time series with missing values replaced by long-term means for that population.



Implications

1. The lack of coherence among individual populations, the high degree of variability in productivity within populations, and the shared contribution by several populations to the Sound-wide biomass through time, all suggest that there is a portfolio effect among Puget Sound herring. The stock's resilience depends on maintaining all populations in the system.
2. Genetic data suggests 3 independent Puget Sound stocks, but this grouping minimizes the population diversity of the 17 stocks in the "all other stocks" category. Objectives that are tied to the biomass of the Sound-wide population are appropriate, given the year-to-year variation in production among stocks.
3. The regional incoherence among populations, and the negative correlations between some, suggest that drivers of variation in spawning biomass occur on neither a regional scale nor a Sound-wide scale, but are local in nature. This further suggests the importance of conserving individual herring populations.

Next Steps: Study Panel

Dr. Francis and the Puget Sound Institute are convening an independent working group, comprised of local and national experts, to address ecosystem-based management of forage fish in Puget Sound. The aims and scope are currently being refined; the group will convene in August 2013. Please contact Tessa with comments, suggestions, or interest in participation.

Acknowledgements

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