Salish Sea Science Roundtable

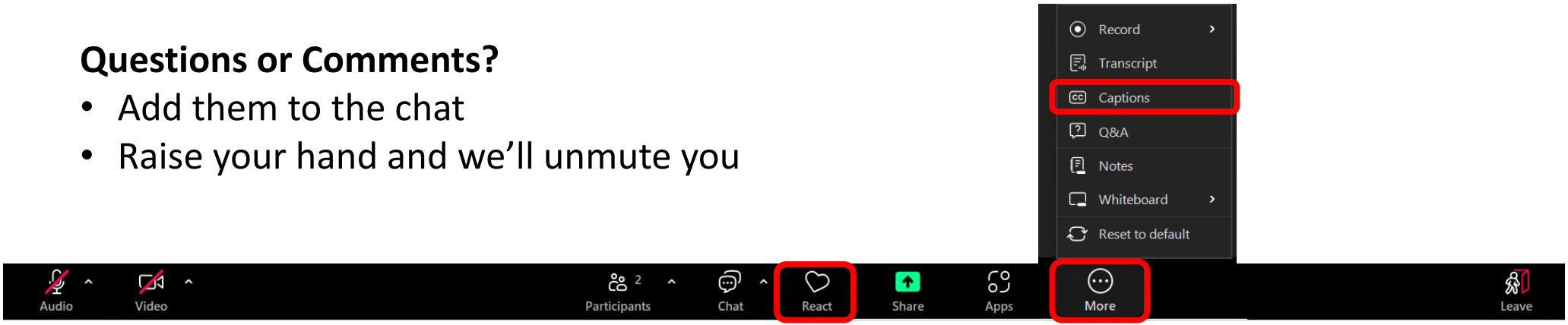
Navigating the Roundtable

Welcome! While we wait, please:

- Update your name to include your pronouns and organization
- Introduce yourself in the chat
- Message Sandra with any access needs

Questions or Comments?

- Add them to the chat
- Raise your hand and we'll unmute you



The slides and recording will be available on [Puget Sound Institute's website]

Land Acknowledgement

The UW Tacoma community acknowledges that we learn, teach, work and live on the ancestral land of the Coast Salish people. In particular, our campus is situated on traditional lands of the Puyallup Tribe of Indians. We recognize that this is a difficult and painful history, and we understand we must play an active role in remembering, not just what happened to Indigenous communities; post settlement, but also the rich history that existed long before colonization. This land acknowledgement is one small act in an ongoing process of honoring the past while working together with local Tribes to build a more inclusive and thoughtful community.

Transboundary Threats: European Green Crab in the Salish Sea

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Dr. P. Sean McDonald
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AIS Background

- Are not native to the ecosystem they are found in
- Introduced either intentionally (i.e., aquaculture) or unintentionally (i.e.,
-
-
- Invasions and their impacts are exacerbated by climate change
- Rates have increased globally, including Canada
- Social and economic impacts can be significant, especially for coastal communities

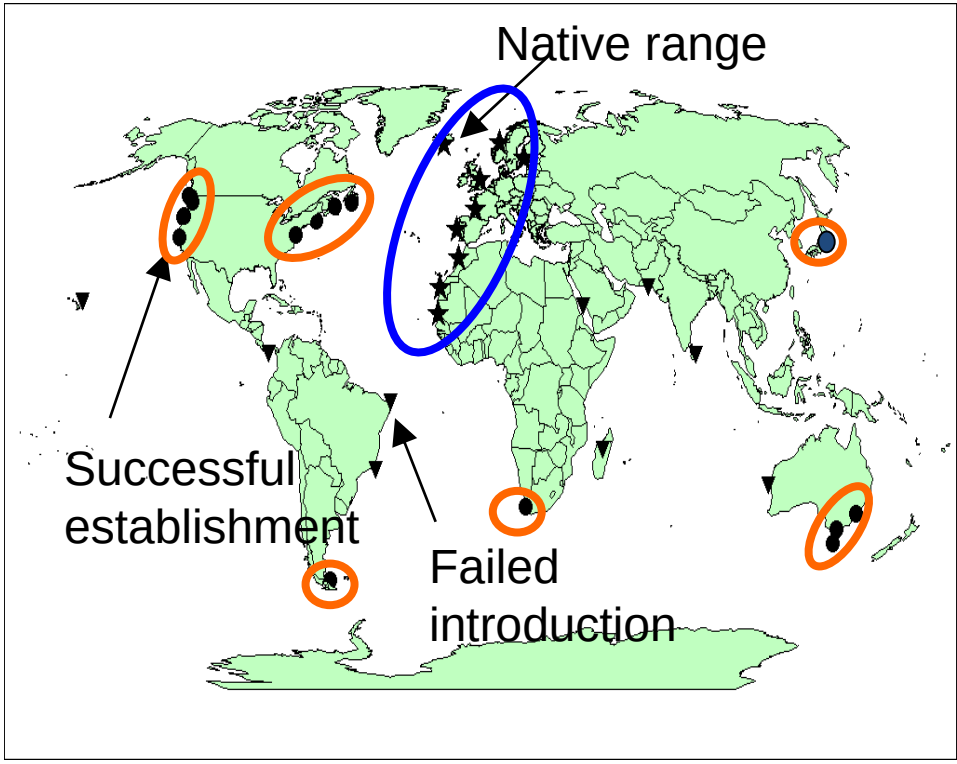
Recent UN Report: $423 BILLION USD Annually in Damages

European Green Crab (EGC)

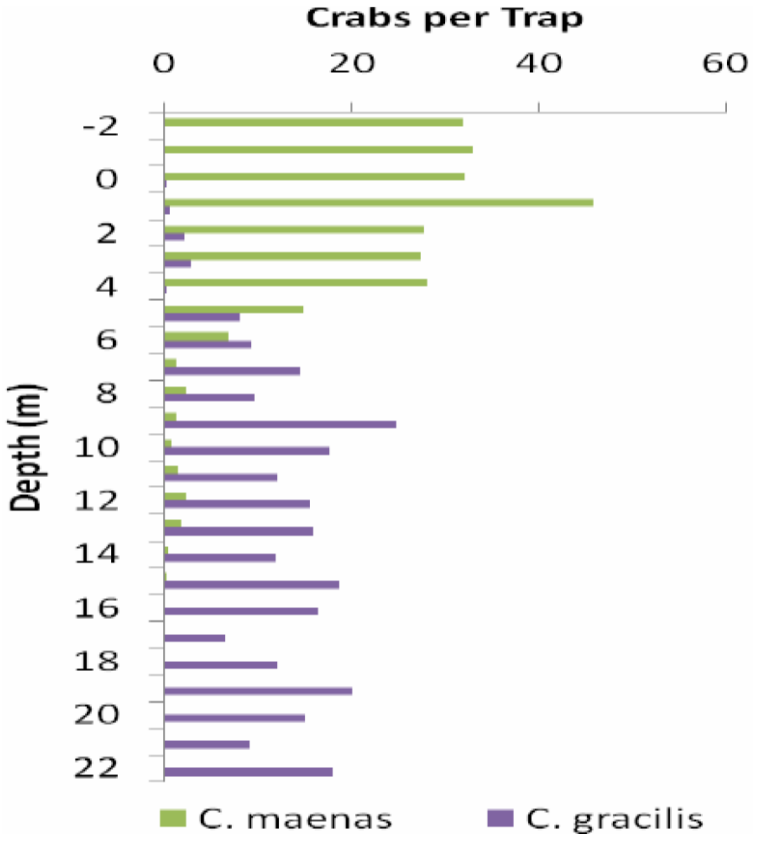
- Is a shore crab
- 5 spines
- Up to 10 cm
- Flattened last leg
- NOT always green

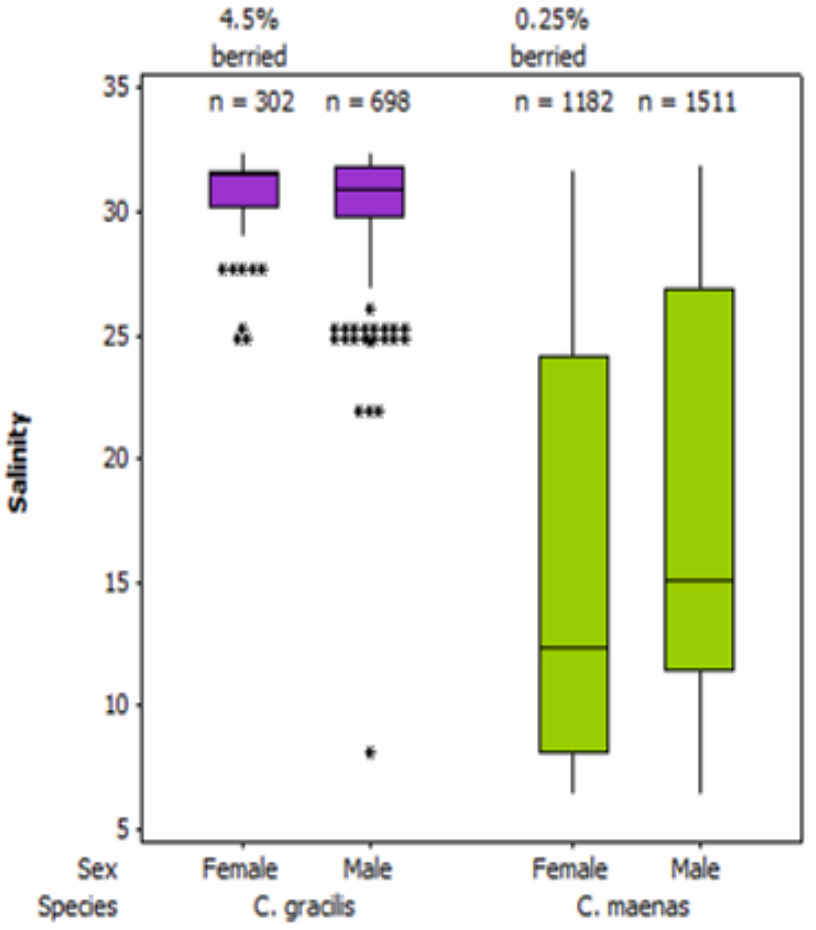
EGC Background

- On the IUCN List of World's 100 Worst Invaders
- Arrived in California in the late 1980s, had spread to BC by the late 1990s and has continued to spread north
    - adult detections in the Salish Sea in 2018, Haida Gwaii in 2020, SE Alaska in 2022, and Prince Rupert in 2023
- Known to outcompete native crabs, decimate shellfish beds, and destroy critical eelgrass habitats
- Good candidate for Transboundary collaboration
    - Efforts on one side of the border affect actions on the other!



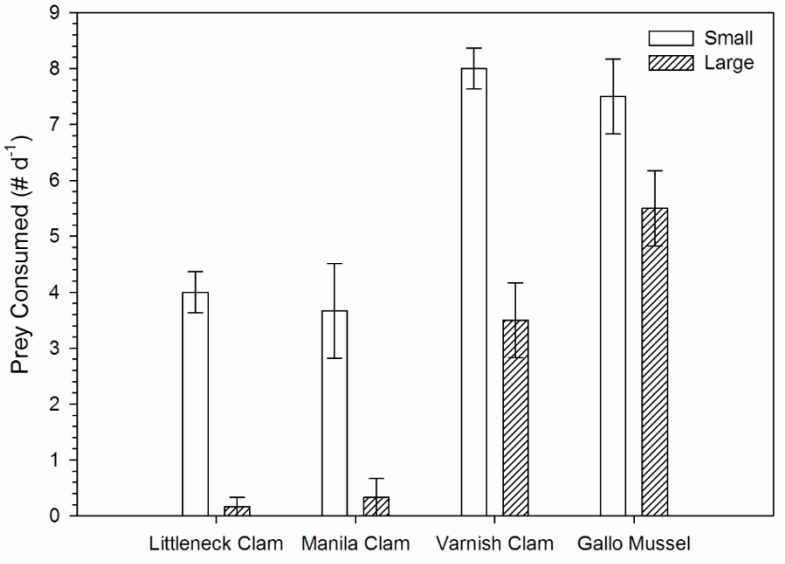
EGC Background – Broad Tolerances



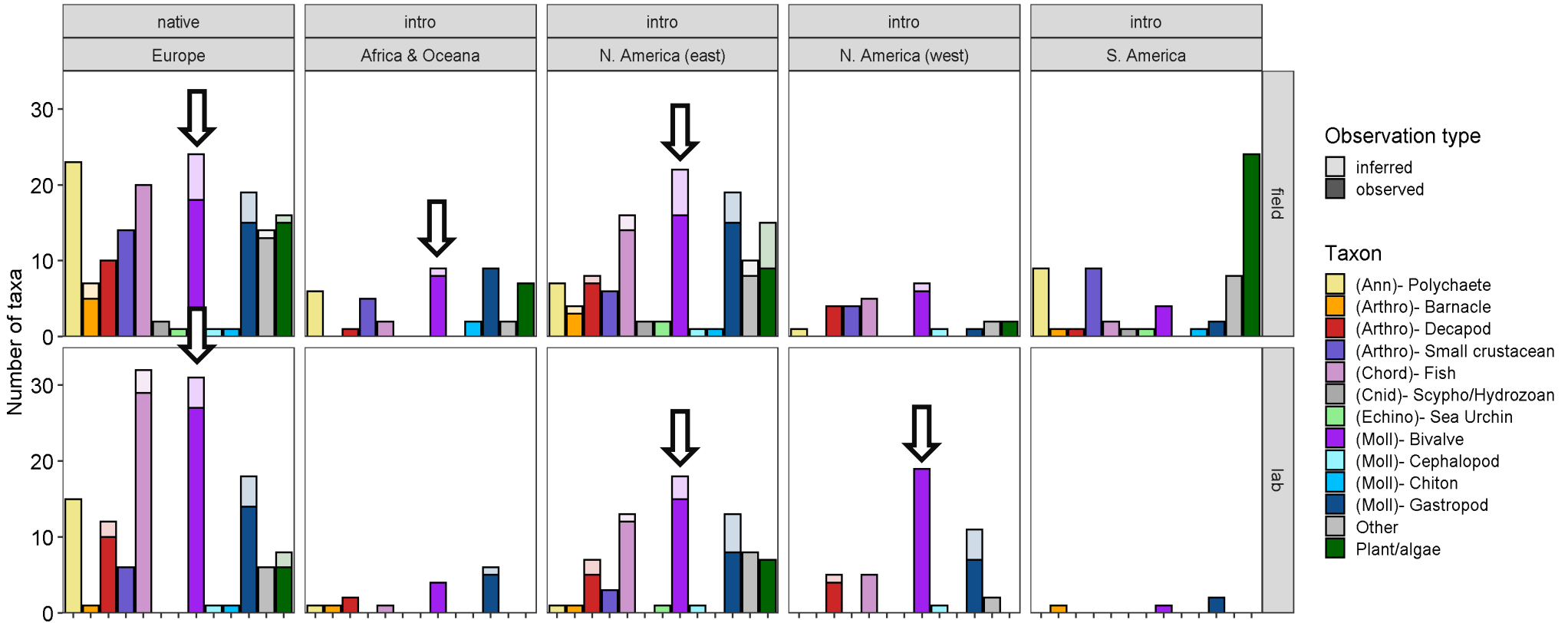


EGC – A Good Generalist/Great Invader

- EGC are impacting multiple ecosystem components:
  - Consume a wide variety of invertebrates, especially bivalves
  - Compete with and displace native crab species
  - Damage and destroy eelgrass meadows



EGC Impacts – Prey



EGC Impacts – Clam Trials

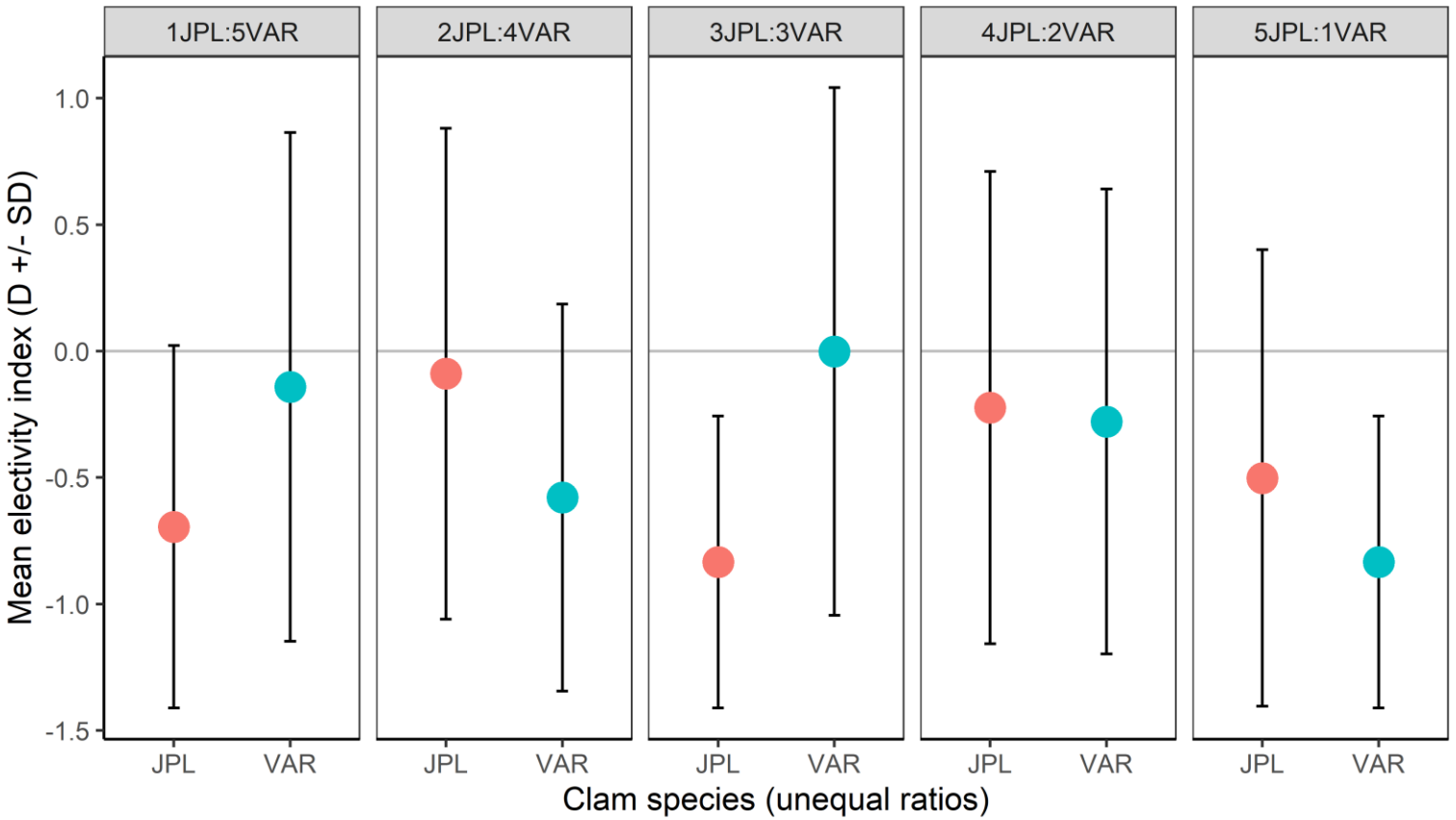
Lab Trials

- Tested a range of invert species
- Identified key species that could serve as indicators
- Determined per capita consumption rates for these indicator species

Mesocosms

- Field mesocosms used for more “natural” understanding
- Fixed number of Manila clams with varying densities of EGC
- Can calculate thresholds that can be used for management decisions

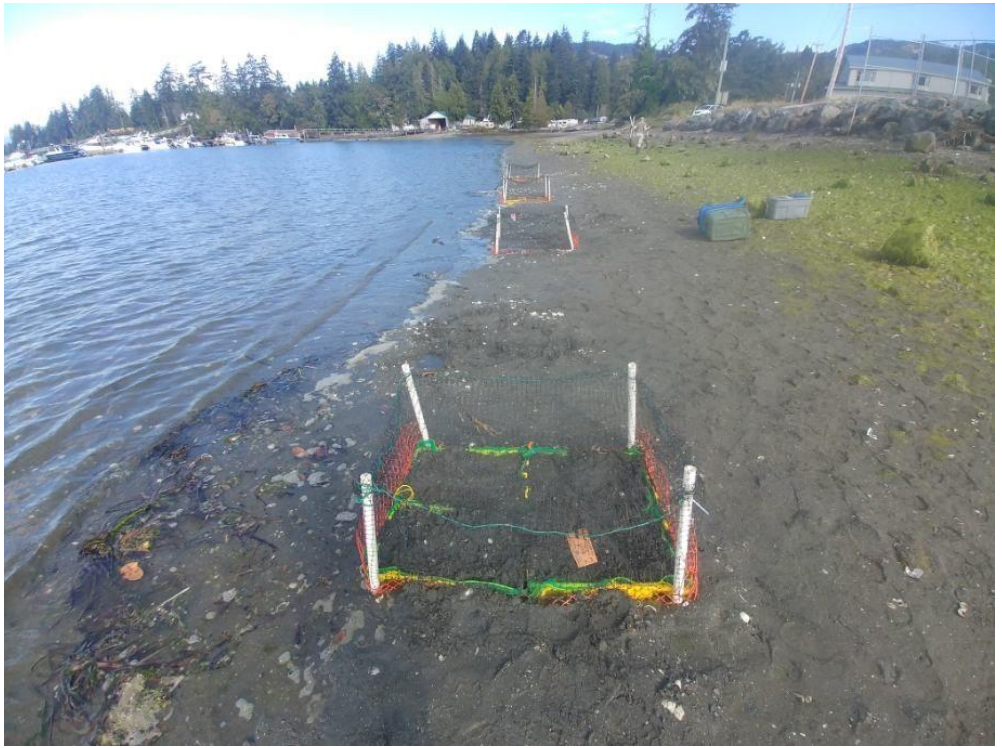
EGC Impacts – Clam Lab Trials

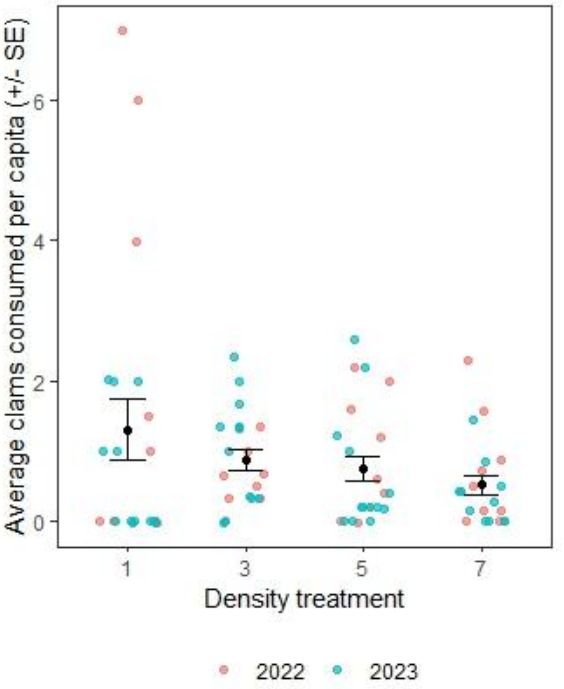


Results variable but:

Both varnish clam and Manila clam could be used as indicators

EGC Impacts – Clam Mesocosms





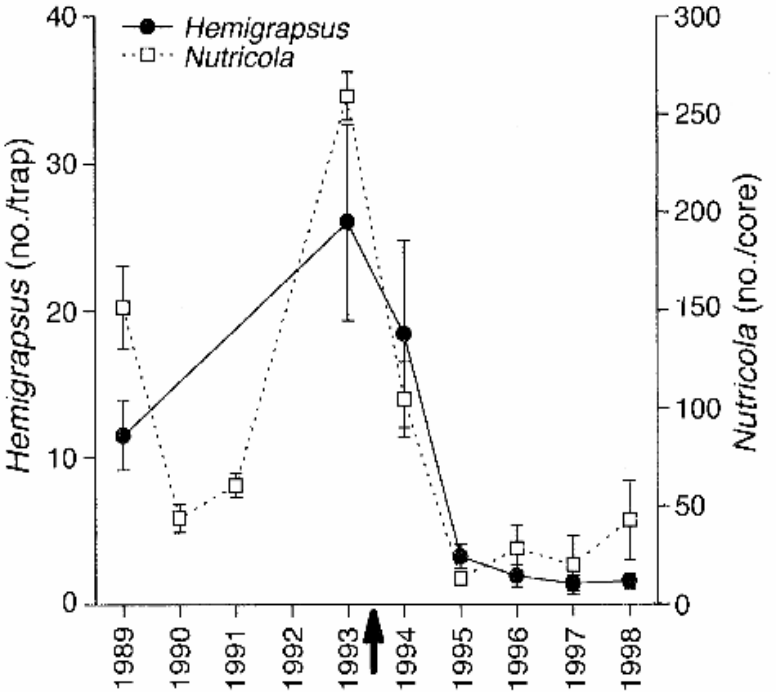
Again, results variable but:

Threshold may be possible

EGC Impacts – Crabs

- Both *Hemigrapsus* species widely distributed in BC

- Past studies have suggested strong EGC impacts



Grosholz et al. (2000)

EGC Impacts – Crabs

Bare sand
Low complexity
High complexity

x

High density prey (12)
Medium density prey (6)
Low density prey (3)

x

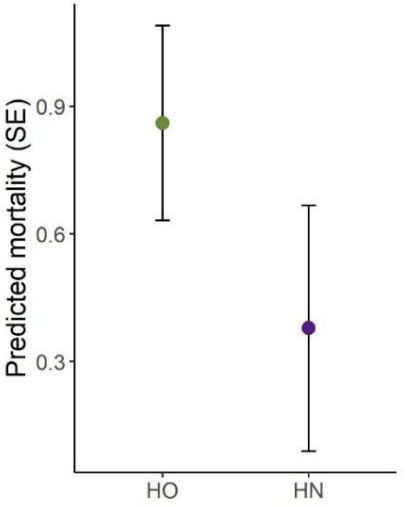
HN
HO

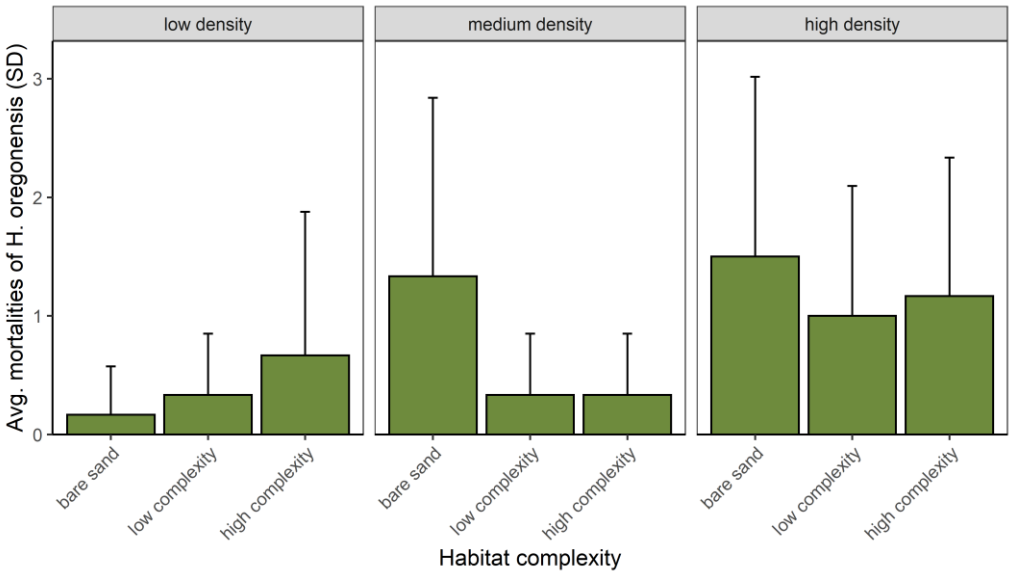
x n = 6 x

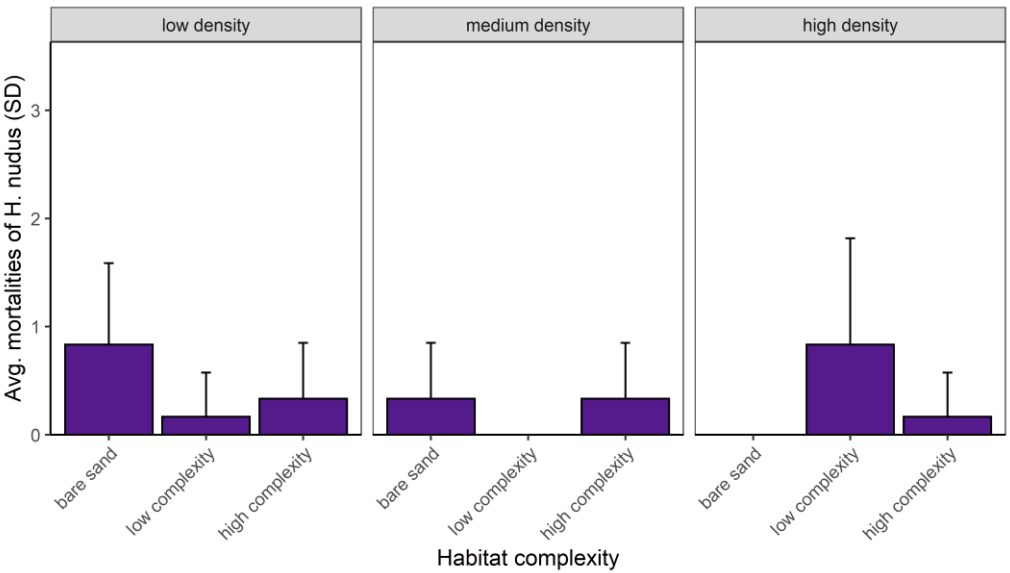
~6 hrs
@ 16 ˚C

EGC Impacts – Crabs

- Both *Hemigrapsus* species impacted
- *H. oregonensis* impacted across density and habitats



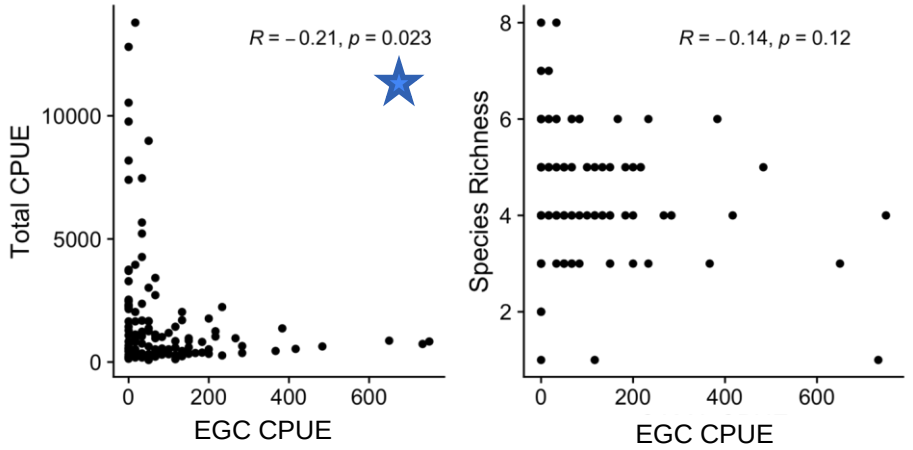




EGC Impacts

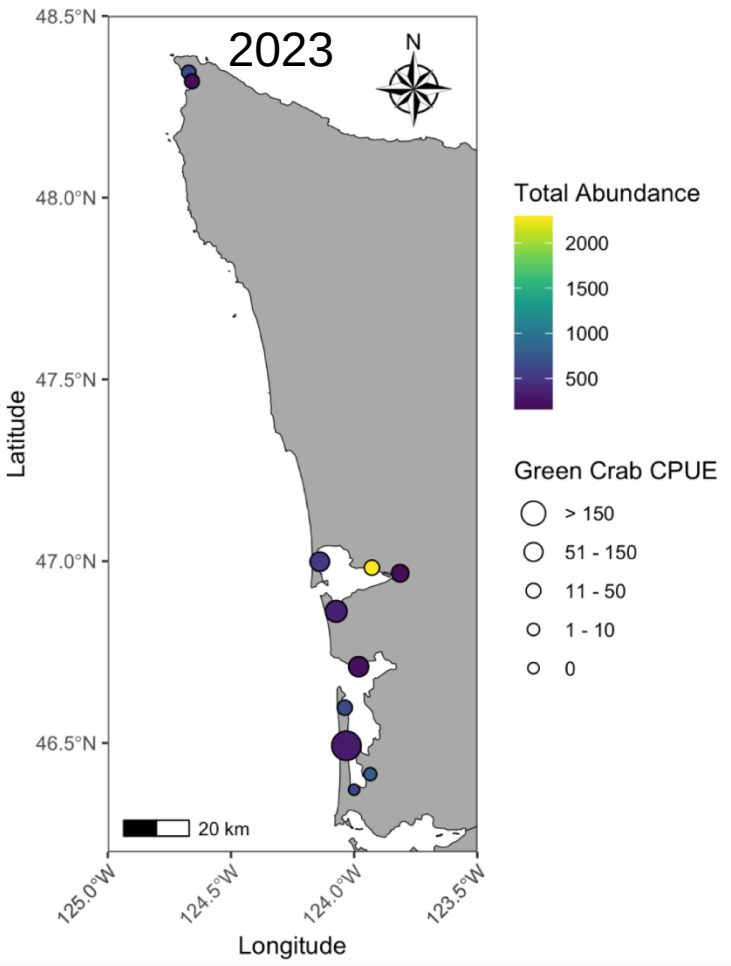
Rubinoff et al. (submitted)

WSG Crab Team Coastal Monitoring 2020-2023



ANOVA (ManyGLM)

$W_{1, 121} = 9.01$, $p = 0.001$



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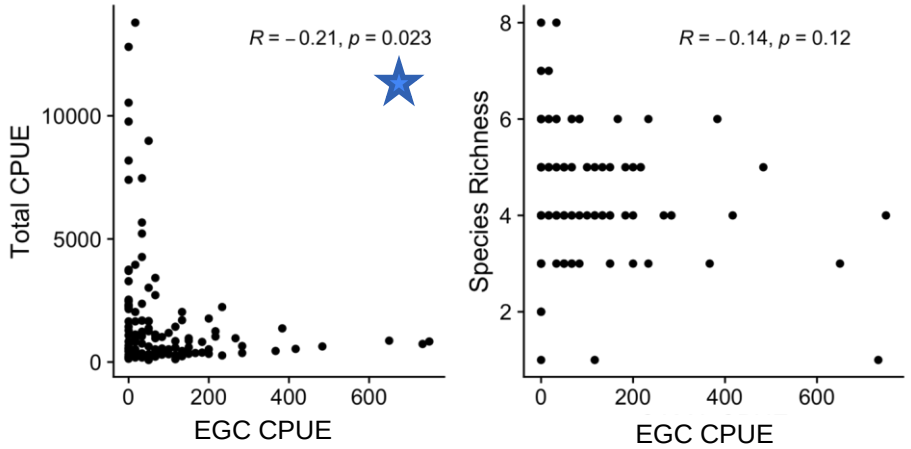

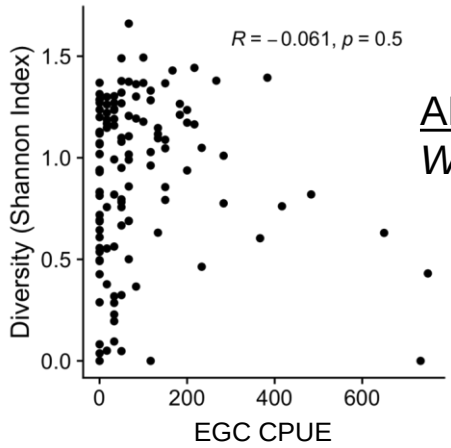

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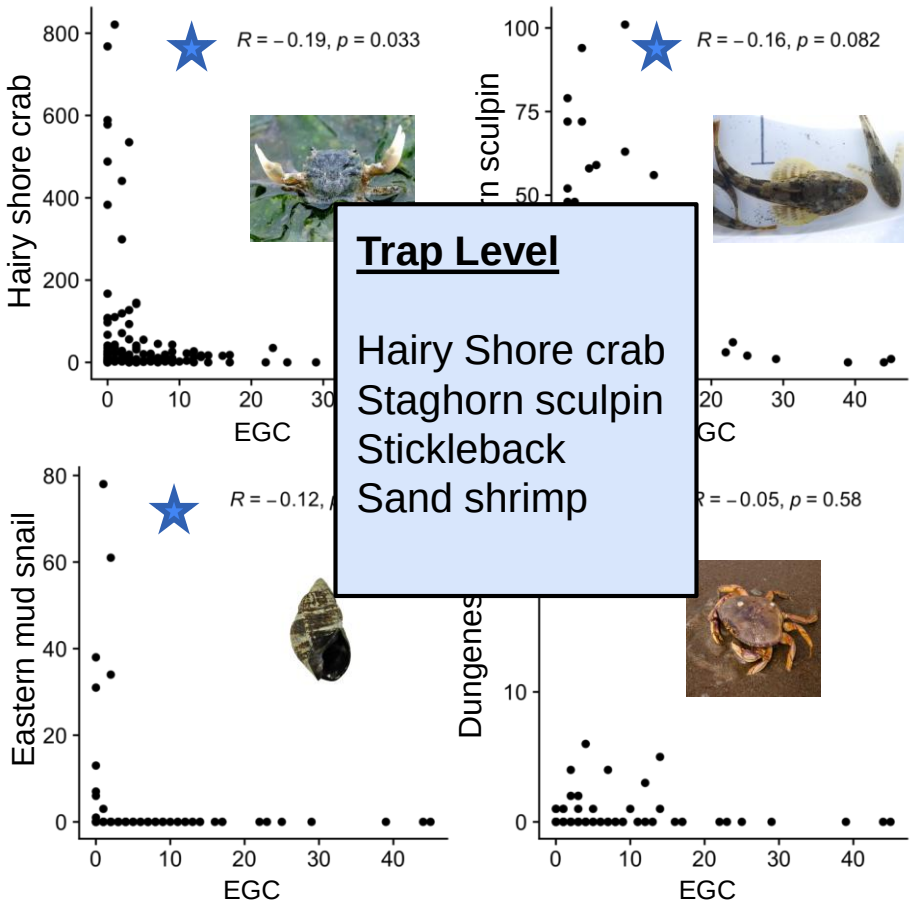
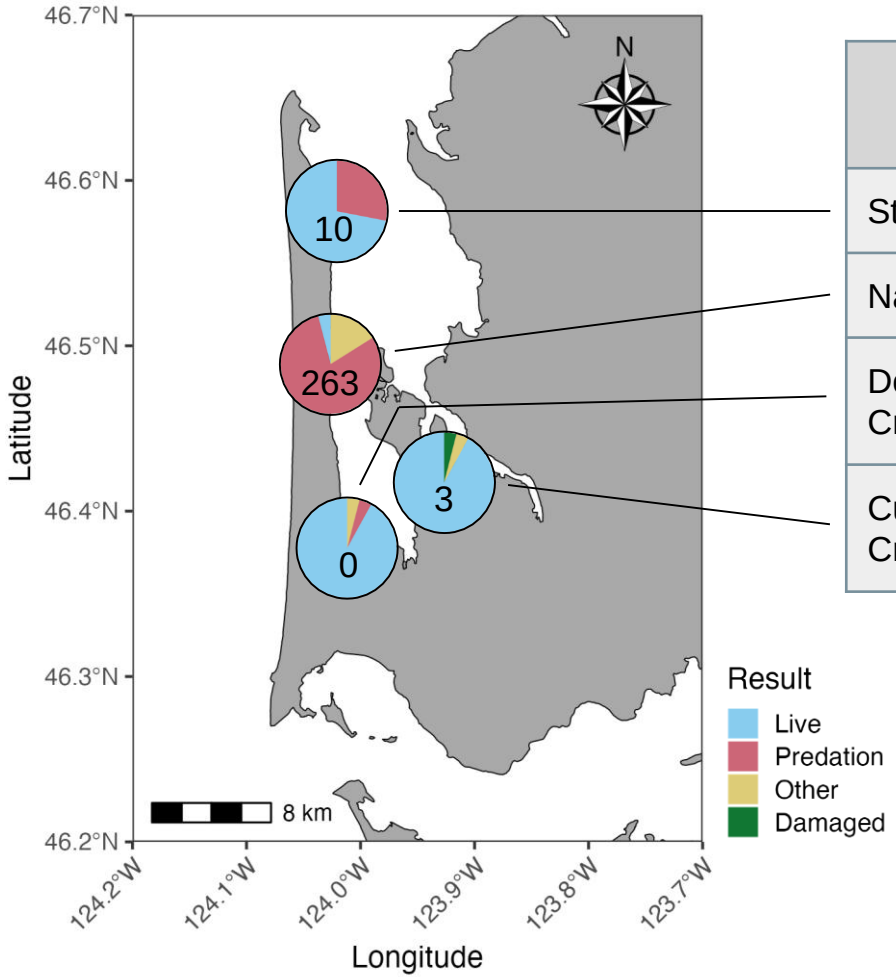


EGC Impacts

Rubinoff et al. (submitted)



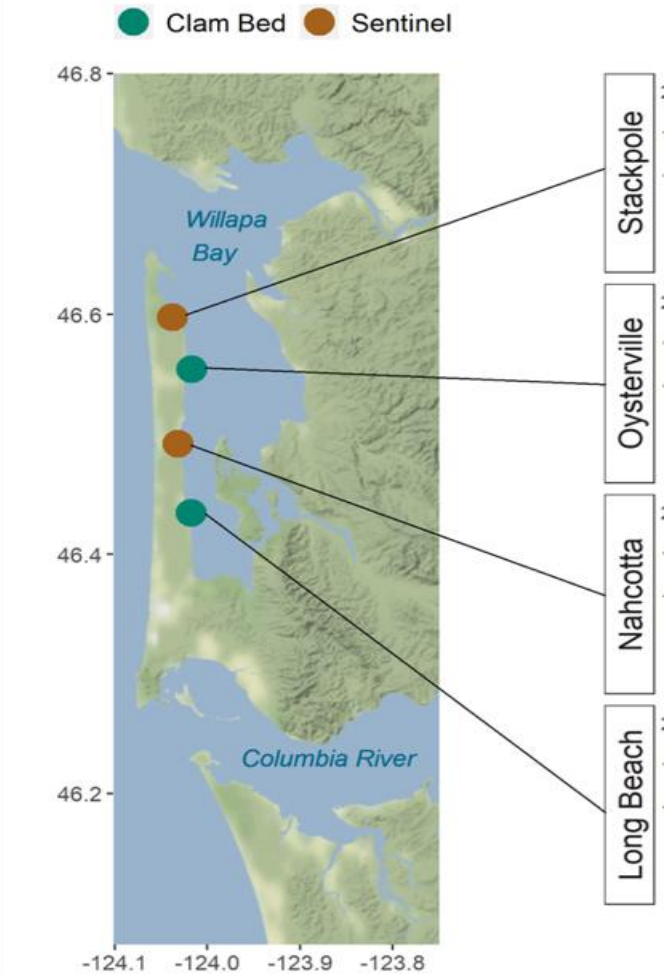
	2022 EGC CPUE	2023 EGC CPUE*	% HEOR Consumed
Stackpole	100	10	28%
Nahcotta	503	263	**80%**
Dohman Creek	0	0	4%
Cutthroat Creek	6	1	0%

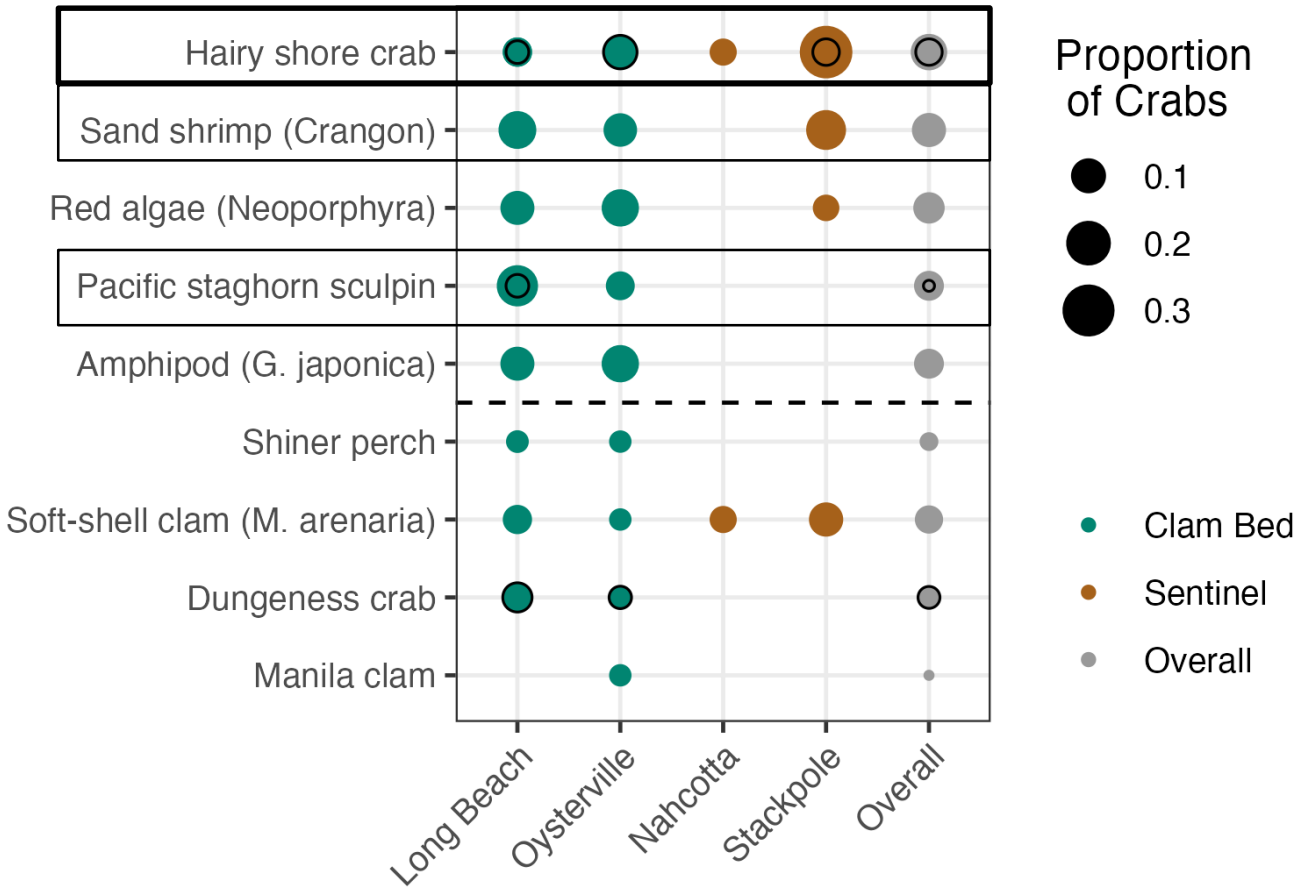
CPUE = N / 100 traps

- Most hairy shore crab consumed at the site with the most EGC

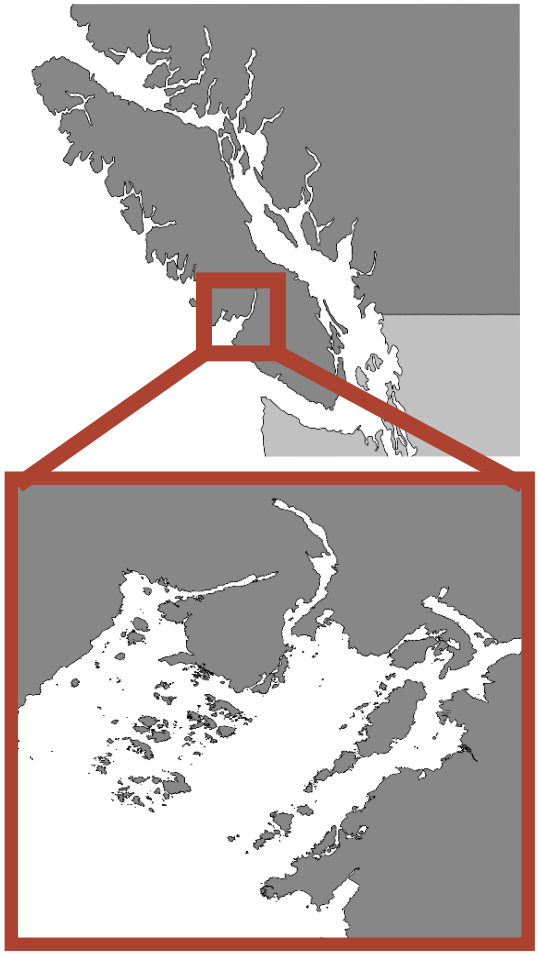
EGC Impacts

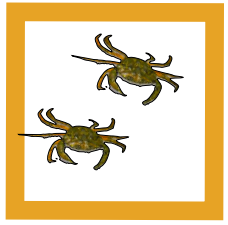
Fisher et al. (2023)



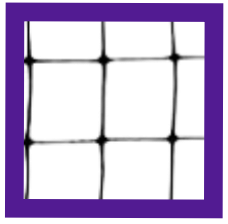


EGC Impacts – Eelgrass

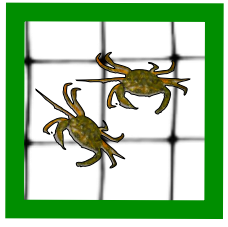




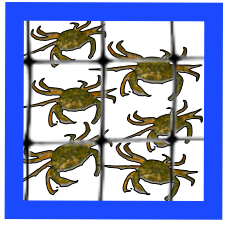
No enclosure
(ambient)



Empty enclosure
(0 crabs m^{-2})

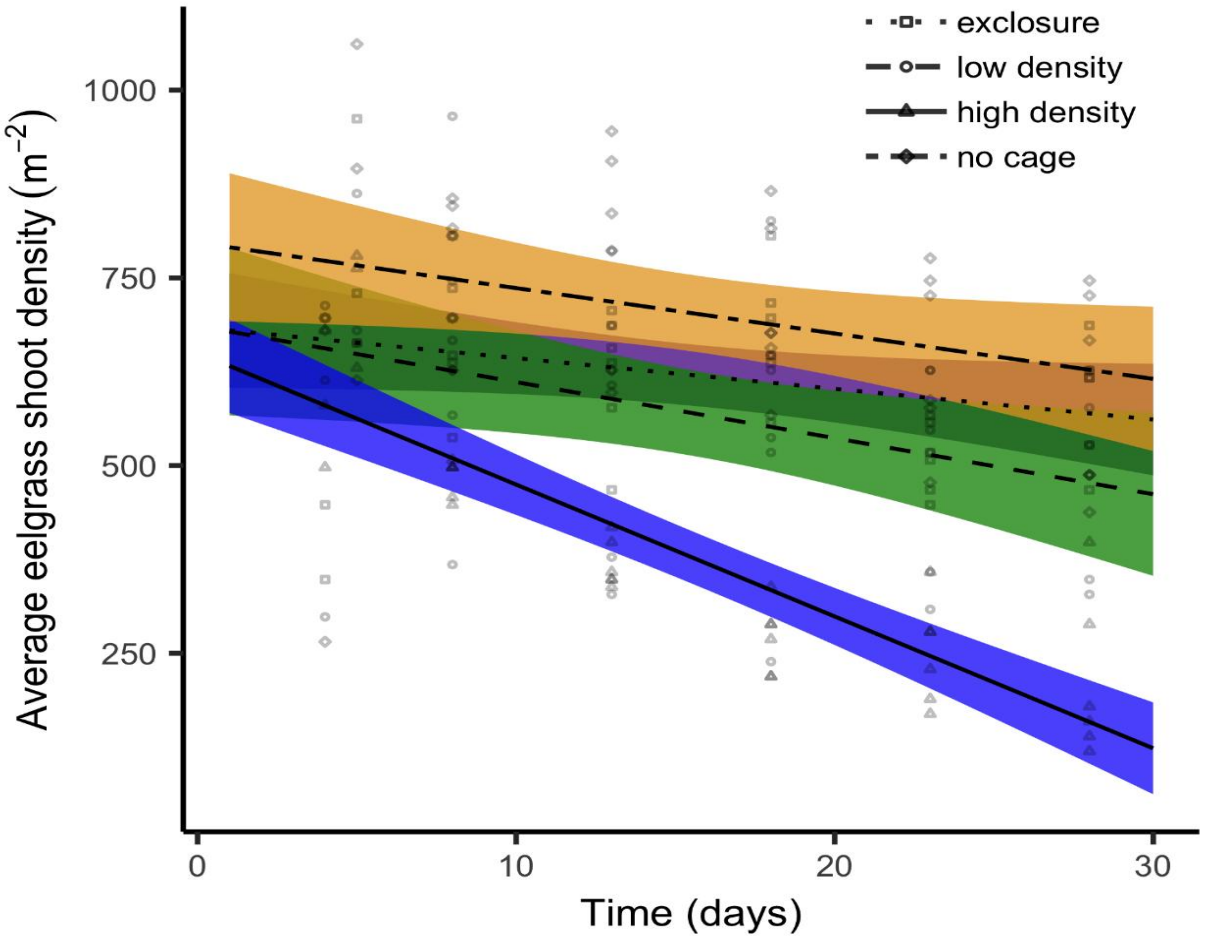


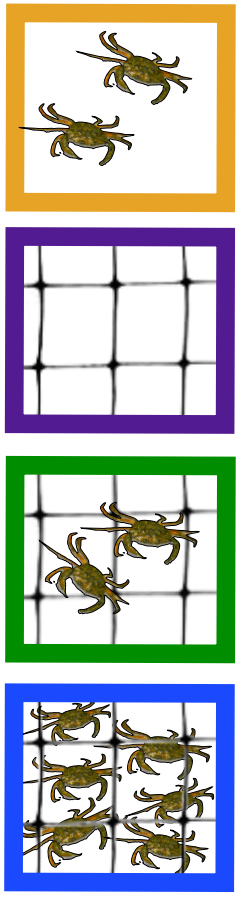
Low density
(1.4 crabs m^{-2})



High density
(5.6 crabs m^{-2})

EGC Impacts – Eelgrass





Howard et al. 2019

Larval Connectivity of the European Green Crab

Salish Sea Roundtable
May 13, 2025

Lily Engel[1,*], Laki Premathilake
Tarang Khangaonkar[1], Lysel Garavelli[1]

[1]Pacific Northwest National Laboratory
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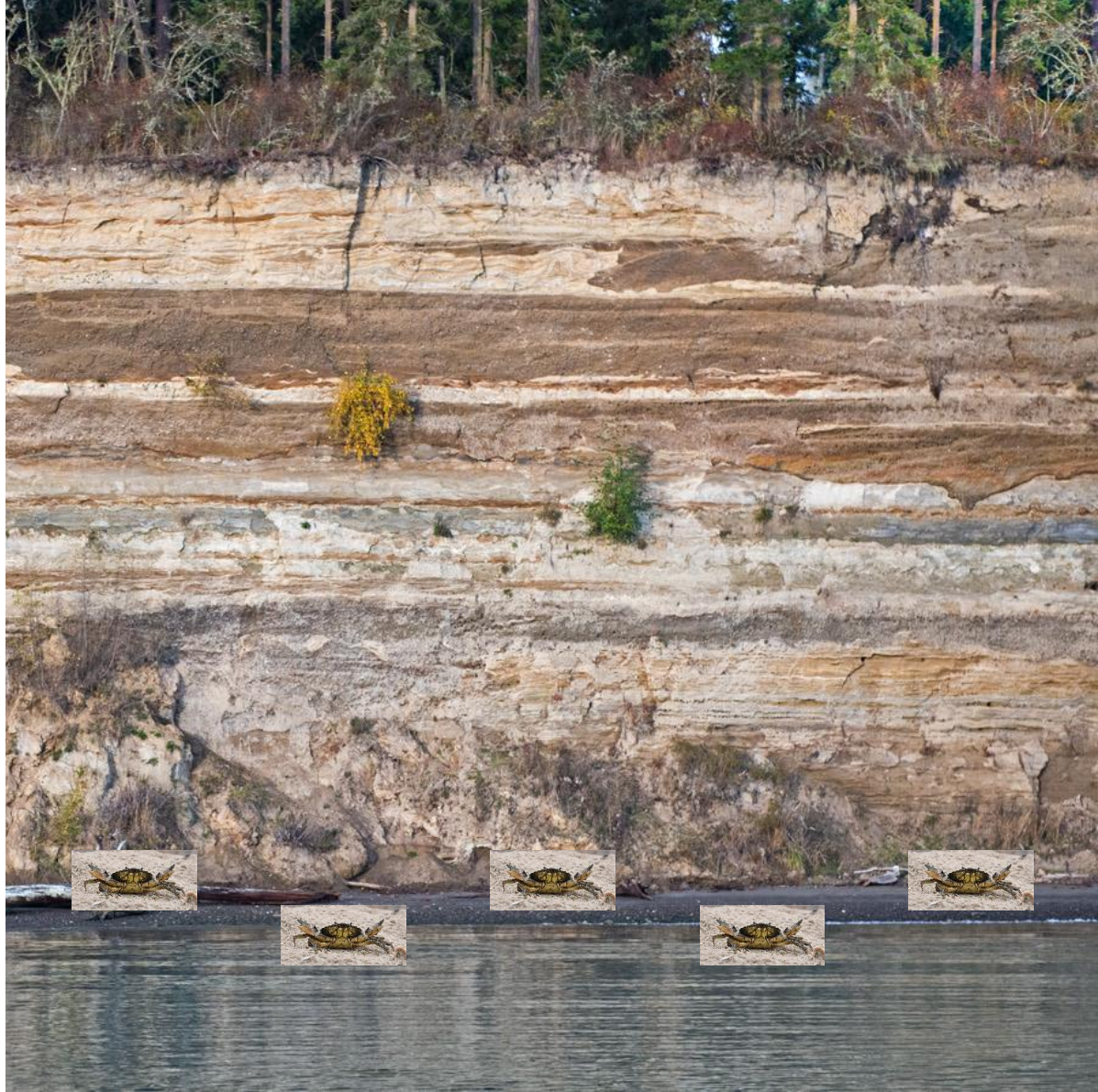
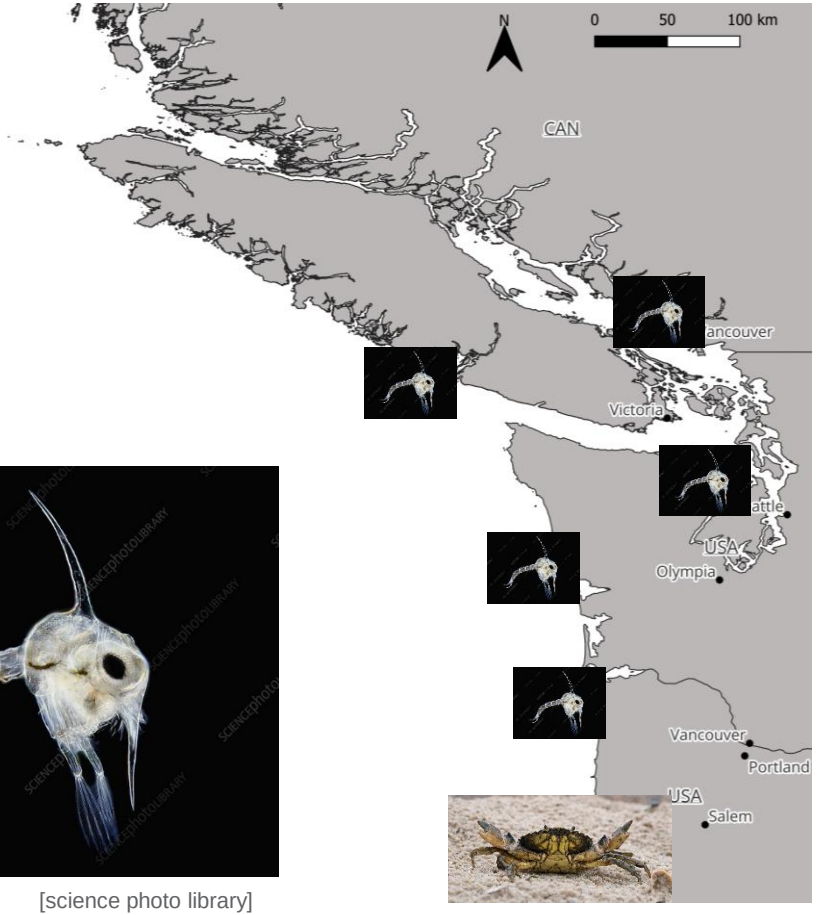
PNNL is operated by Battelle for the U.S. Department of Energy



Larval dispersal is key to the spread of the invasive European Green Crab (EGC)

[Hakai Magazine]



- Low mobility as adults
- Each female releases 185,000 larvae per spawning event
- Modeling fills the gaps between data samples

[science photo library]

Biophysical larval dispersal model for EGC

Pacific Northwest NATIONAL LABORATORY

SALISH SEA MODELING CENTER
UNIVERSITY of WASHINGTON

Velocities, temperature

Per location and time

ICHTHYOP

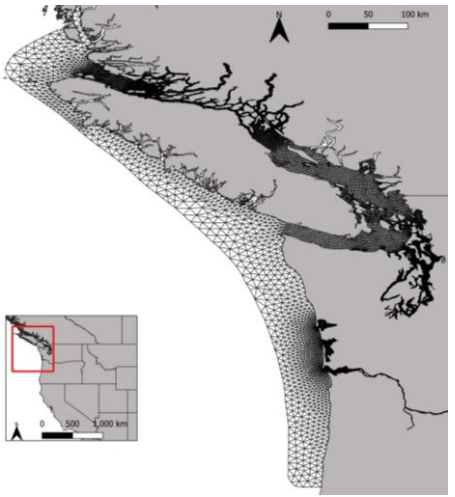
Individual-based model

Transport Growth
Behavior Mortality
[Lett et al. 2008]

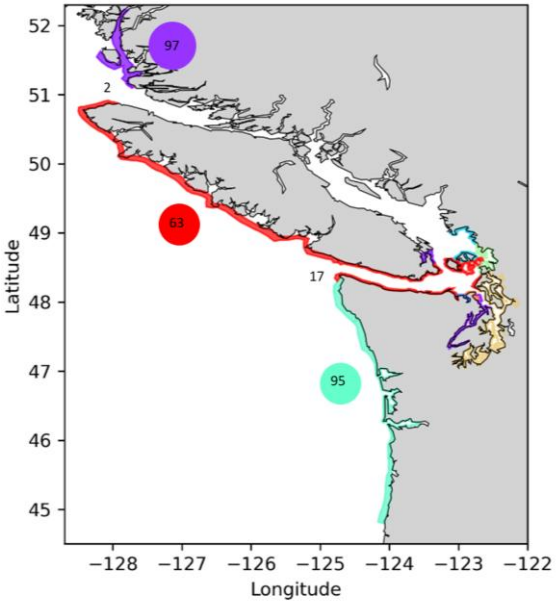
Larvae position at each timestep

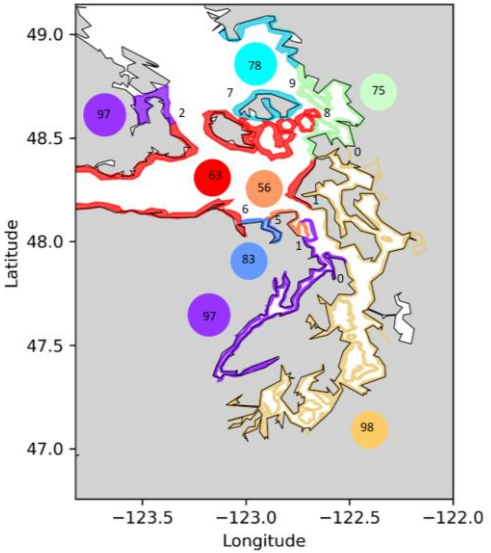
Hydrodynamic model
[Khangaonkar et. al 2018]

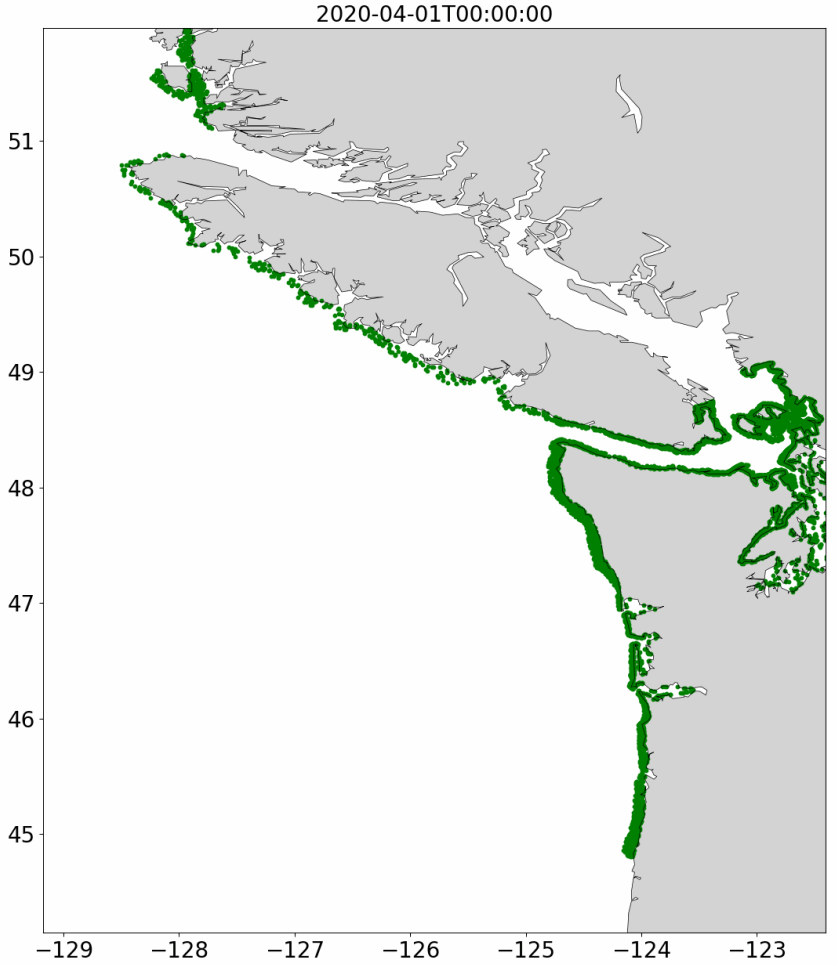
https://ssmc-uw.org/



Understanding larval connectivity between regions can help prioritize management efforts



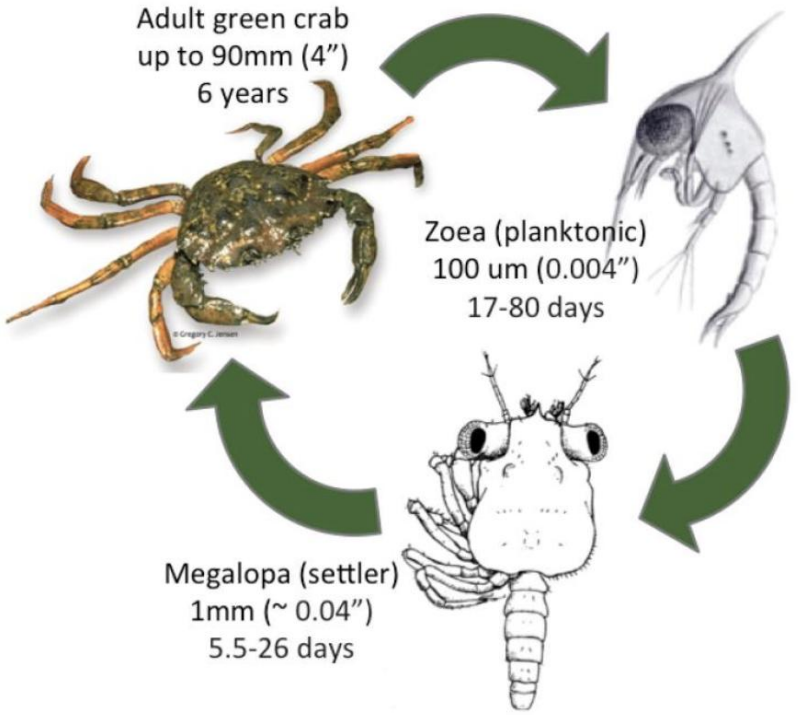




Engel L, Premathilake L, Barrier N, Khangaonkar T, Garavelli L (2025) Larval connectivity for European green crab management in the Salish Sea and surrounding waters. Mar Ecol Prog Ser 754:77-92. https://doi.org/10.3354/meps14778

Future work will include behavior and validation against the data

- **Use trapping data** to validate predicted settlement locations. Will include more data as well. **If you have trapping data, please share!**
- **Backward modeling** to understand current state of invasion
- Include more **larval behavior** in model (e.g., ontogenetic vertical migration)
- Evaluate EGC spread with **future scenarios**



[Grason et al. 2017]

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Marine Ecologist

Hannah Brown
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Program Lead

Elyse Kelsey
Student Assistant

Kate Litle
WSG Deputy Dir

Sean McDonald
(UW PoE/SAFS)

Lisa Watkins
Community Sci Specialist

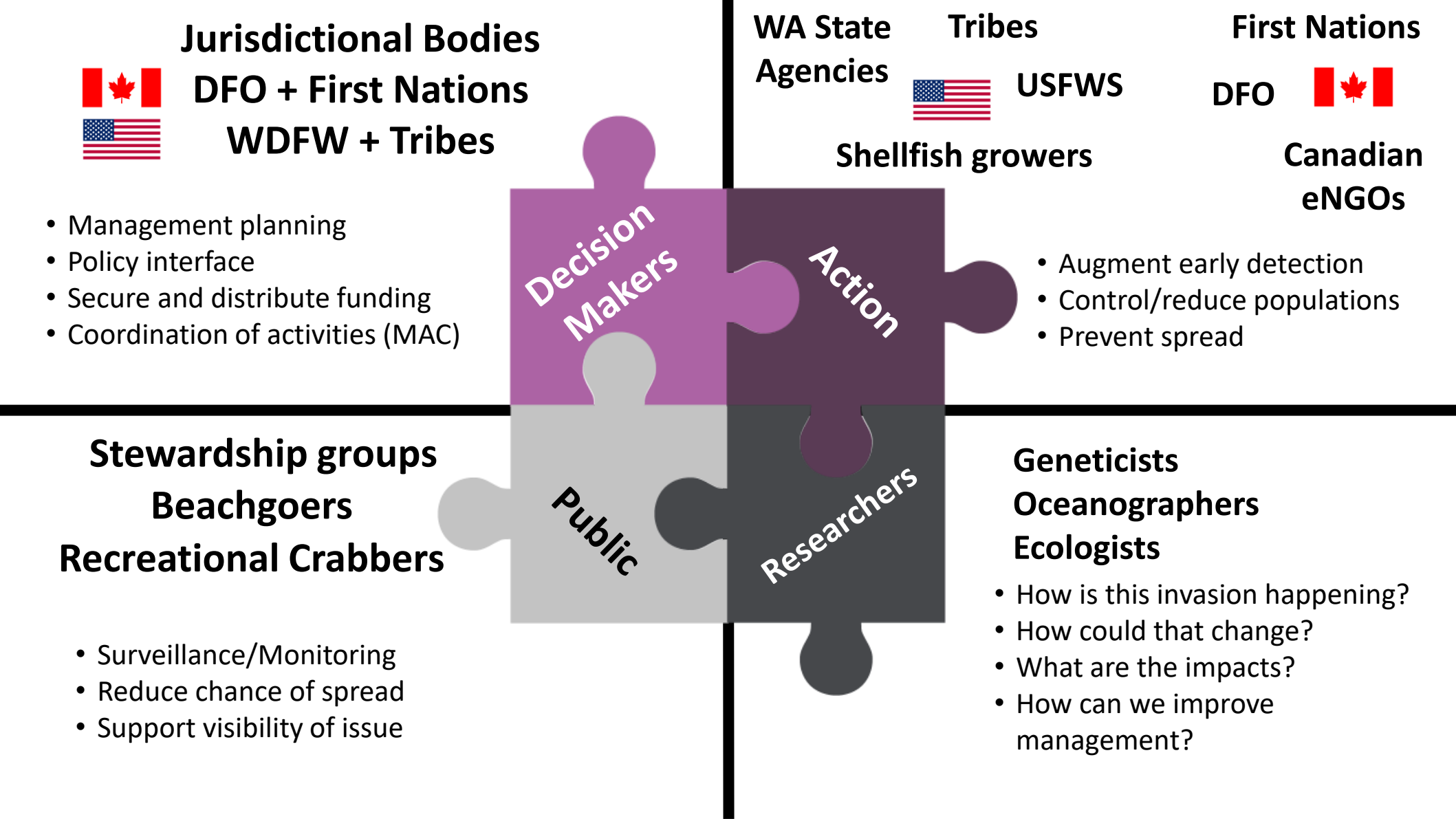
Monitoring

Management Advising

CRAB TEAM
WASHINGTON SEA GRANT

Technical Capacity Building

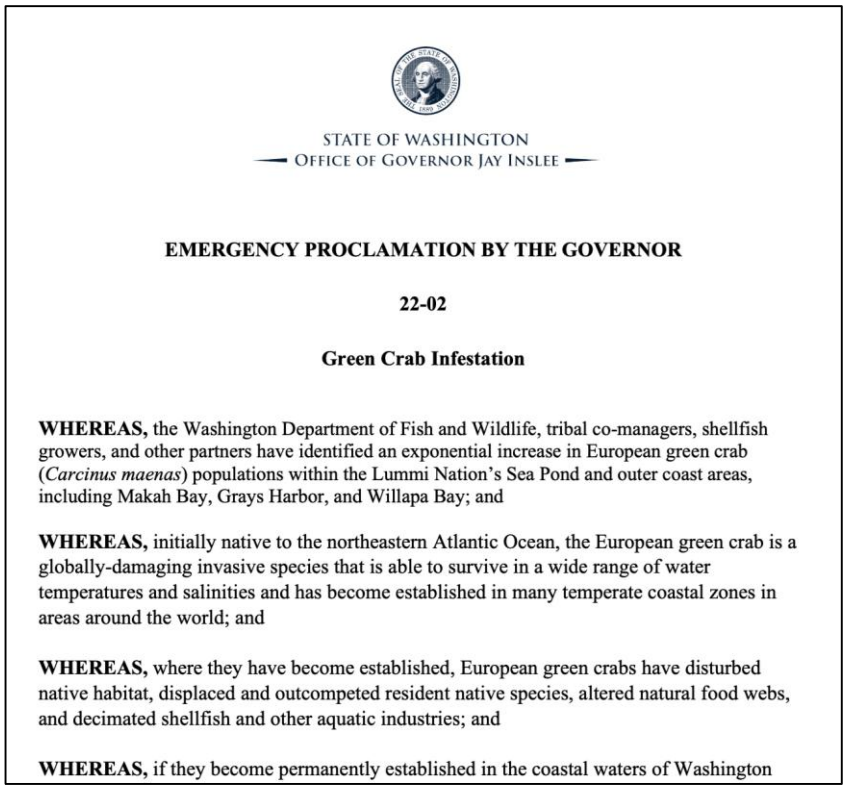
Applied Research


Jurisdictional Bodies
DFO + First Nations
WDFW + Tribes
• Management planning
• Policy interface
• Secure and distribute funding
• Coordination of activities (MAC)
WA State Agencies
Tribes
USFWS
First Nations
DFO
Shellfish growers
Canadian eNGOs
Decision Makers
Action
• Augment early detection
• Control/reduce populations
• Prevent spread
Public
Researchers
Stewardship groups
Beachgoers
Recreational Crabbers
• Surveillance/Monitoring
• Reduce chance of spread
• Support visibility of issue
Geneticists
Oceanographers
Ecologists
• How is this invasion happening?
• How could that change?
• What are the impacts?
• How can we improve management?

Decision Making

Jurisdictional Bodies
WDFW + Tribes

- Management planning
- Policy interface
- Secure and distribute funding
- Coordination of activities (MAC)



STATE OF WASHINGTON
OFFICE OF GOVERNOR JAY INSLEE

EMERGENCY PROCLAMATION BY THE GOVERNOR

22-02

Green Crab Infestation

WHEREAS, the Washington Department of Fish and Wildlife, tribal co-managers, shellfish growers, and other partners have identified an exponential increase in European green crab (*Carcinus maenas*) populations within the Lummi Nation's Sea Pond and outer coast areas, including Makah Bay, Grays Harbor, and Willapa Bay; and

WHEREAS, initially native to the northeastern Atlantic Ocean, the European green crab is a globally-damaging invasive species that is able to survive in a wide range of water temperatures and salinities and has become established in many temperate coastal zones in areas around the world; and

WHEREAS, where they have become established, European green crabs have disturbed native habitat, displaced and outcompeted resident native species, altered natural food webs, and decimated shellfish and other aquatic industries; and

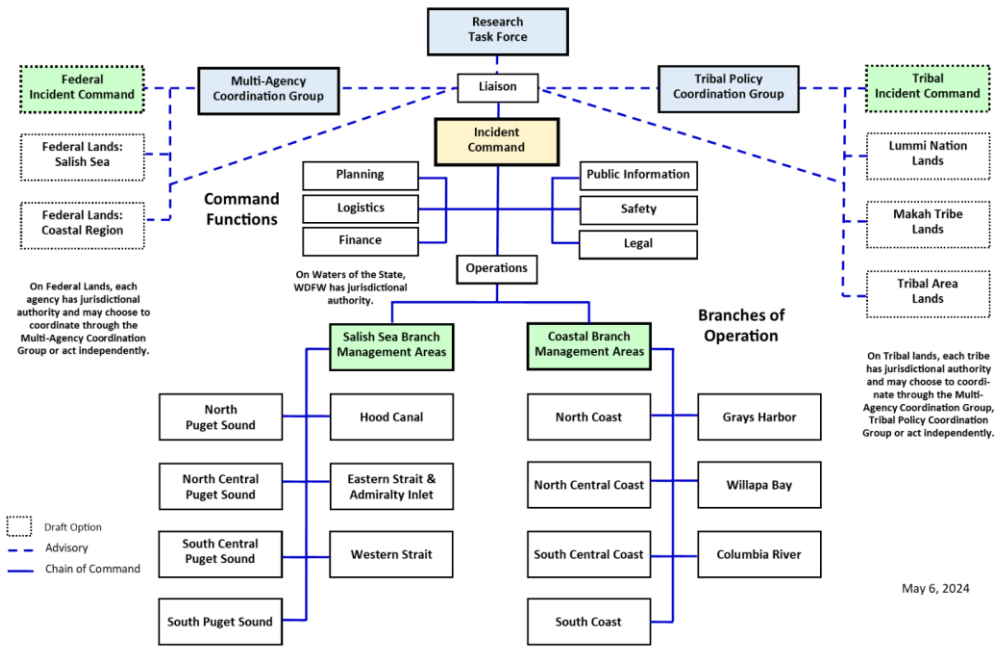
WHEREAS, if they become permanently established in the coastal waters of Washington

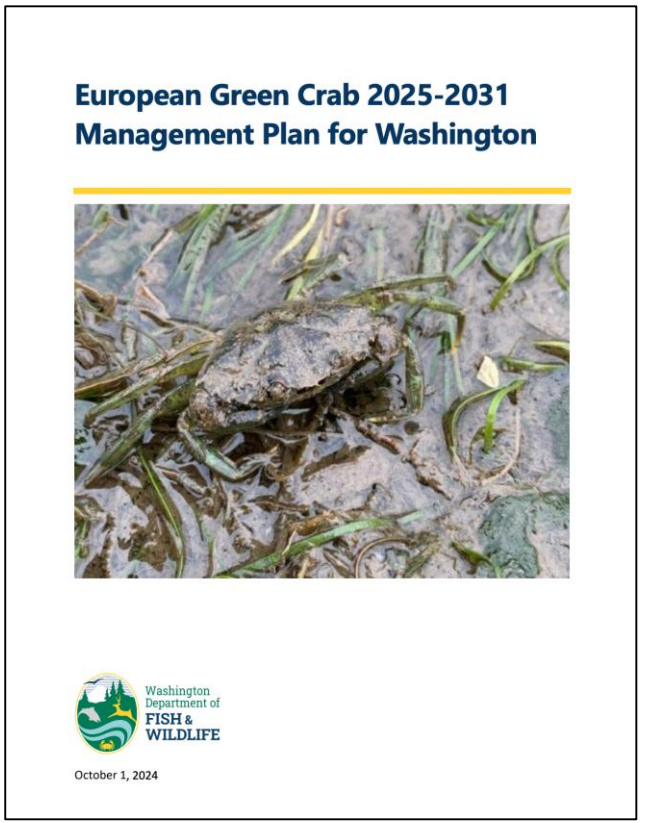
Decision Making

Jurisdictional Bodies
WDFW + Tribes

- Management planning
- Policy interface
- Secure and distribute funding
- Coordination of activities (MAC)

Incident Command System





Action

Tribes **USFWS** **Padilla Bay NERR**
NWSC **Shellfish growers**
Conservation Districts **WDFW, DNR**
First Nations **Canadian eNGOs**

- Trapping!
- Augment early detection
- Control/reduce populations
- Prevent spread

…many more

Public

Stewardship groups
Beachgoers
Recreational Crabbers

- Surveillance/Monitoring
- Reduce chance of spread
- Support visibility of issue

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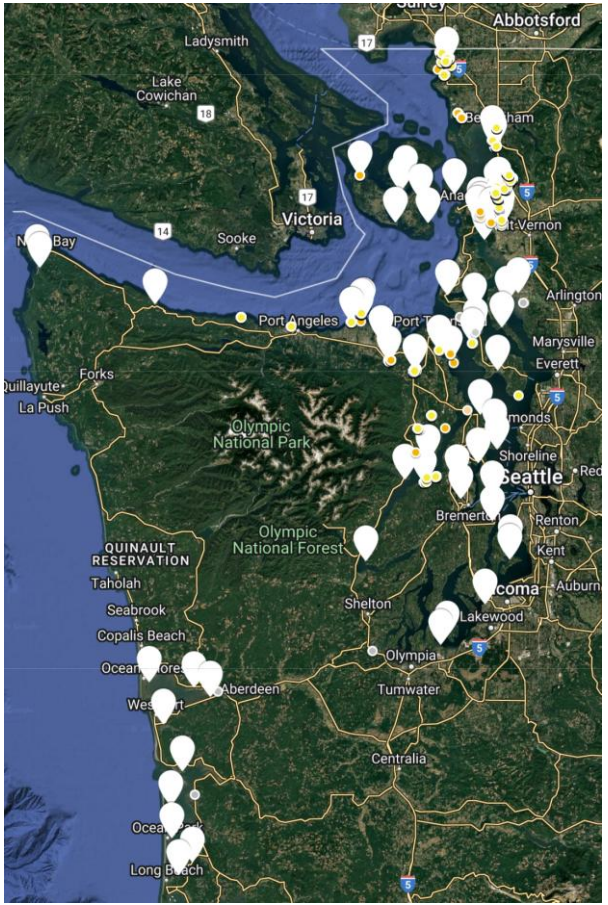
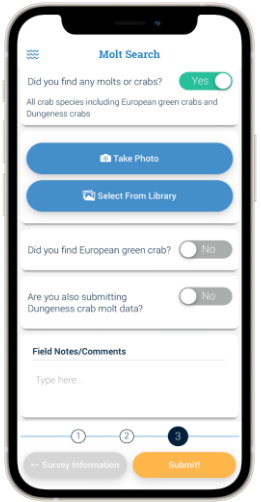
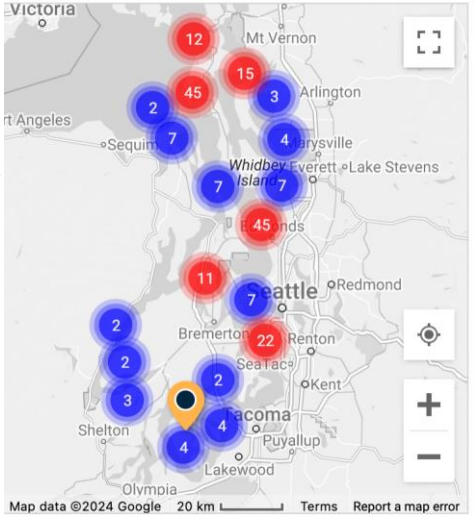


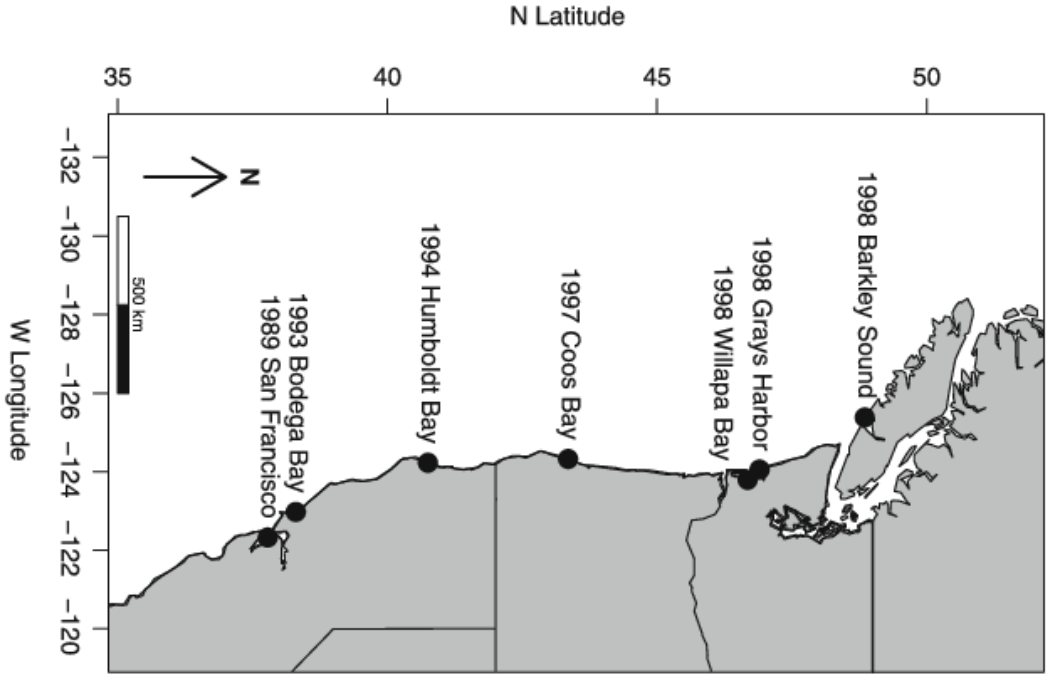
CRAB TEAM
WASHINGTON SEA GRANT

WSG CRAB TEAM/WSU
MOLT SEARCH

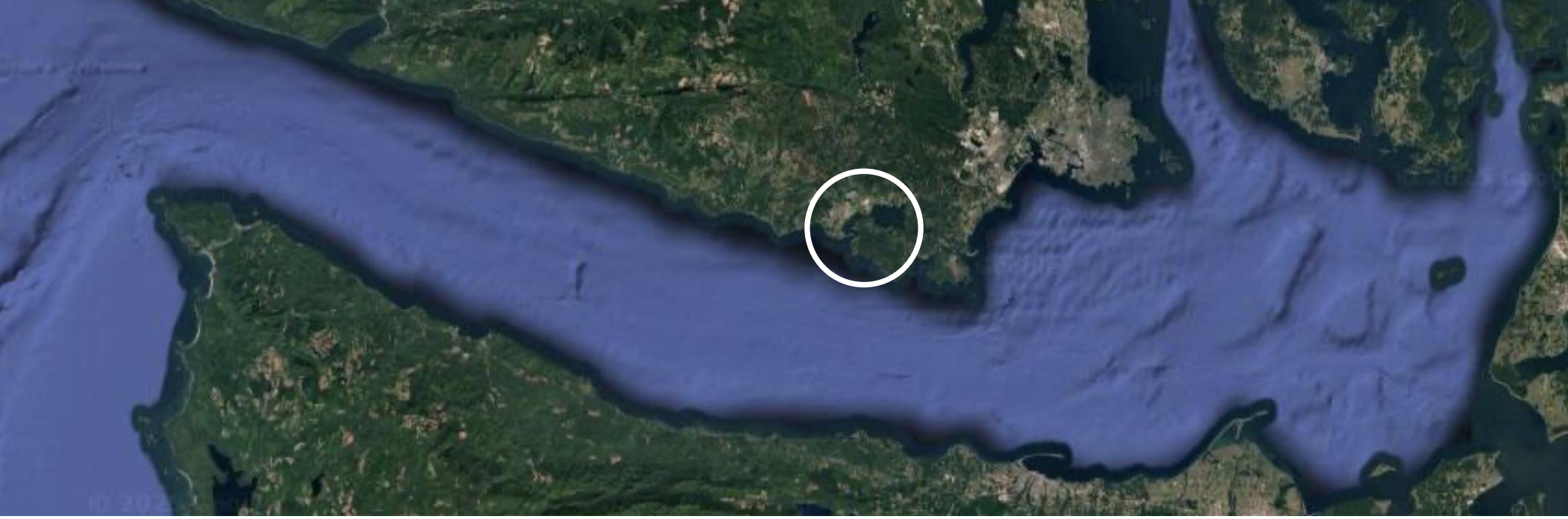




Management timeline



1998
Green crab in
coastal WA & BC



Green crab
in Sooke basin
2012

1998
Green crab in
coastal WA & BC

1998
Green crab in coastal WA & BC

2015
WSG Crab Team launched

Green crab
on San Juan Island
2016

1998
Green crab in
coastal WA & BC

Fisheries and Oceans Canada

Pêches et Océans Canada

Washington Department of FISH and WILDLIFE

Sea Grant Washington

PUGETSOUND PARTNERSHIP

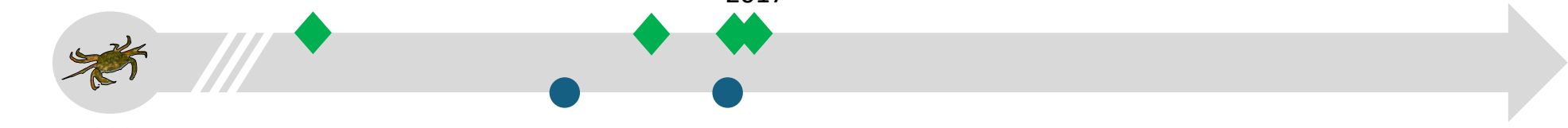
1998
Green crab in coastal WA & BC

2017
1st Transboundary meeting

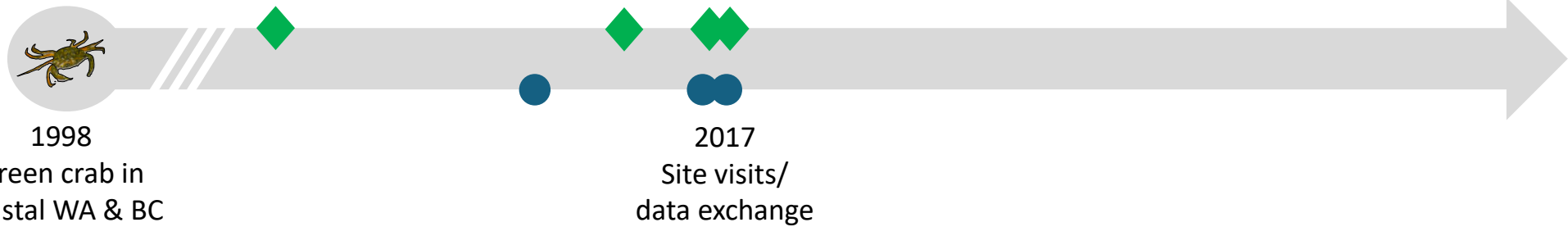
Major coastal pop increase 2017

1998 Green crab in coastal WA & BC

Green crab at
Dungeness Spit
2017



1998
Green crab in
coastal WA & BC



1998
Green crab in
coastal WA & BC

2017
Site visits/
data exchange

1998
Green crab in coastal WA & BC

2017
DFO creates AIS manager positions

1998
Green crab in coastal WA & BC

2018
Tech expertise exchange

Salish Sea Transboundary Action Plan for Invasive European Green Crab

March 2019

Canada Fisheries and Oceans | Sea Grant Washington | Puget Sound Partnership

TABLE OF CONTENTS

SIGNATORY PAGE

We, the undersigned, recognize European green crab management is essential for the protection of the Salish Sea and that the best way to provide that protection is through implementation of this Action Plan.

Washington Dept. Fish and Wildlife
Kelly Susewind, Director

[See Appendix D]
Department of Fisheries and Oceans Canada

Puget Sound Partnership
Sheila Sabandy, Executive Director

Washington Sea Grant
Russell Callender, Director

INTRODUCTION

The European green crab (EGC) is included on the International Union for Conservation of Nature's (IUCN's) list of 100 of the world's worst alien, invasive species (IUCN, 2018), it is classified as a prohibited level 1 species in Washington State (WAC 220-640-030), and is classified as a species for control in Canada. As an Aquatic Invasive Species (AIS), EGC devastates aquatic ecosystems, displacing native species, degrading and disturbing native habitats (including eelgrass), and altering food webs in a variety of locales worldwide. As a voracious consumer of bivalves, it also has caused significant harm to shellfish industries, particularly on the US East Coast. EGC pose serious risks to the economy and ecology of the Salish Sea (Mach and Chan, 2014).

However, it is possible to manage EGC in the Salish Sea to avoid the calamitous results of EGC invasions seen elsewhere around the world. There is time to act to prevent this harm through a successful process of early detection, rapid assessment, and adaptive response.

There is currently only one documented, established population (self-sustaining) of EGC in the Salish Sea: Sooke Basin in British Columbia. As of October 2018, the EGC has been found at several other Washington State locations, including Dungeness Spit (USFWS Dungeness National Wildlife Refuge), Dungeness Landing River Park, Sequim Bay, Westcott Bay, Padilla Bay, Fidalgo Bay, Lagoon Point, and Kala Point and Scow Bay (collectively labeled as Pt. Townsend; Figure 1). With the exception of Dungeness Spit, only one to six crab have been captured at each location. In British Columbia, the EGC has been collected at Becher Bay, Port Renfrew, and Witty's Lagoon, in addition to Sooke (Figure 1).

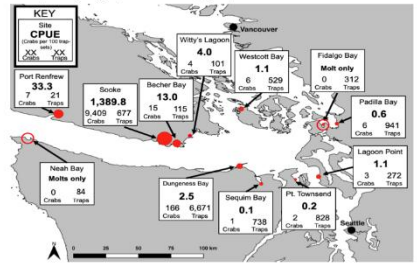
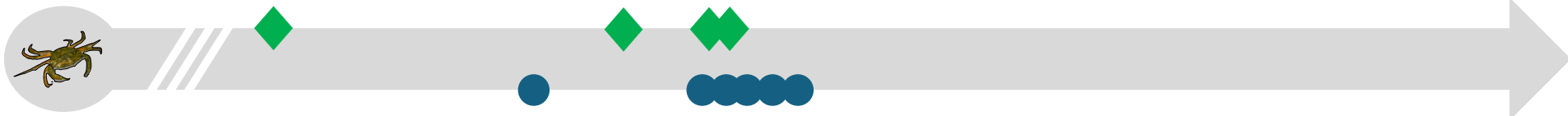


FIGURE 1. Locations of European green crab found in the Salish Sea and trapping efforts associated with those captures. Map of catch per unit effort (CPUE) of European green crab at all detection sites within the Salish Sea. The size of site markers is scaled (logarithmically) with CPUE, which is defined as average number of EGC per 100 trap-days, including all trapping effort recorded since 2012. Because effort varies substantially geographically, actual catch (number of crabs) and effort (trap-days) for each location are reported below CPUE. Map data current as of 10/15/18.

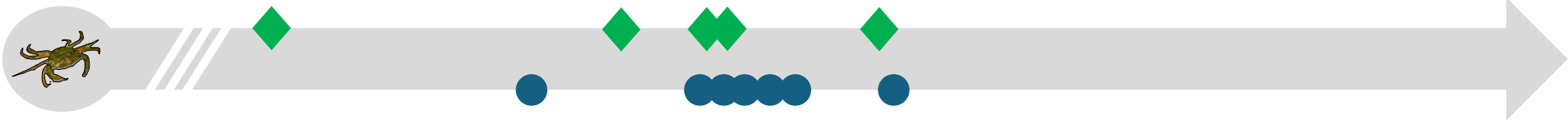


1998
Green crab in coastal WA & BC

2018
Salish Sea Transboundary Action Plan

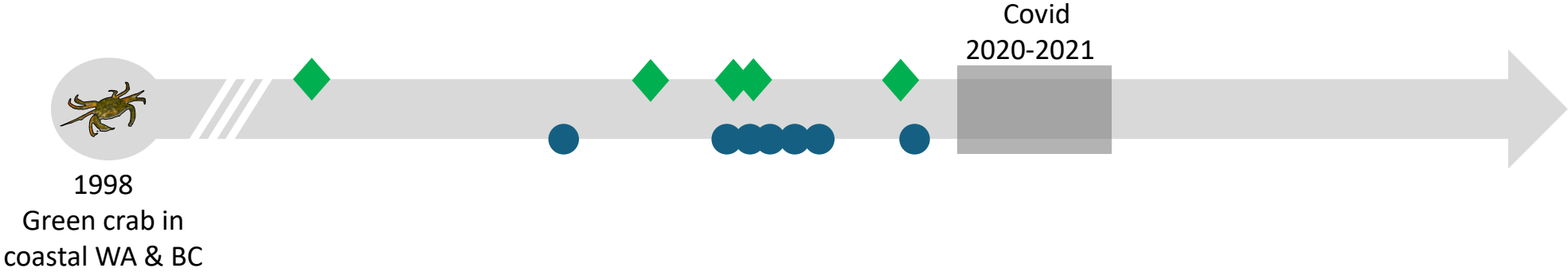
Lummi Sea Pond
2019

1998
Green crab in
coastal WA & BC

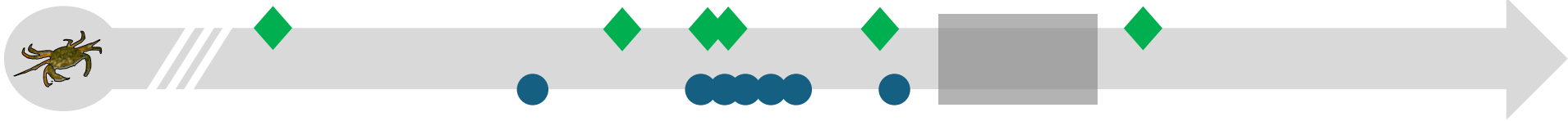


1998
Green crab in
coastal WA & BC

2019
Lummi Nation
removal trapping


Covid
2020-2021
1998
Green crab in
coastal WA & BC

Green crab at
Annette Is, AK
2022



1998
Green crab in
coastal WA & BC

STATE OF WASHINGTON
OFFICE OF GOVERNOR JAY INSLEE

EMERGENCY PROCLAMATION BY THE GOVERNOR

22-02

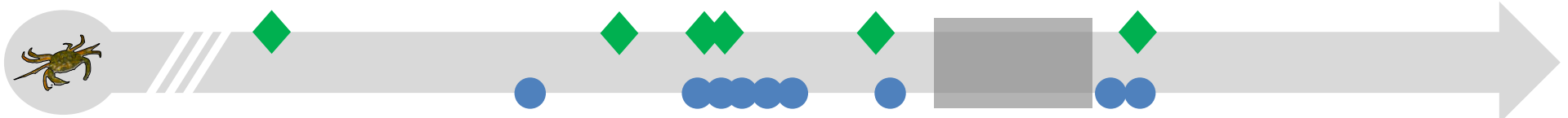
Green Crab Infestation

WHEREAS, the Washington Department of Fish and Wildlife, tribal co-managers, shellfish growers, and other partners have identified an exponential increase in European green crab (*Carcinus maenas*) populations within the Lummi Nation's Sea Pond and outer coast areas, including Makah Bay, Grays Harbor, and Willapa Bay; and

WHEREAS, initially native to the northeastern Atlantic Ocean, the European green crab is a globally-damaging invasive species that is able to survive in a wide range of water temperatures and salinities and has become established in many temperate coastal zones in areas around the world; and

WHEREAS, where they have become established, European green crabs have disturbed native habitat, displaced and outcompeted resident native species, altered natural food webs, and decimated shellfish and other aquatic industries; and

WHEREAS, if they become permanently established in the coastal waters of Washington



1998
Green crab in coastal WA & BC

2021-2022
WA emergency declarations

STATE OF WASHINGTON
OFFICE OF GOVERNOR JAY INSLEE

EMERGENCY PROCLAMATION BY THE GOVERNOR

22-02

Green Crab Infestation

WHEREAS, the Washington Department of Fish and Wildlife, tribal co-managers, shellfish growers, and other partners have identified an exponential increase in European green crab (*Carcinus maenas*) populations within the Lummi Nation's Sea Pond and outer coast areas, including Makah Bay, Grays Harbor, and Willapa Bay; and

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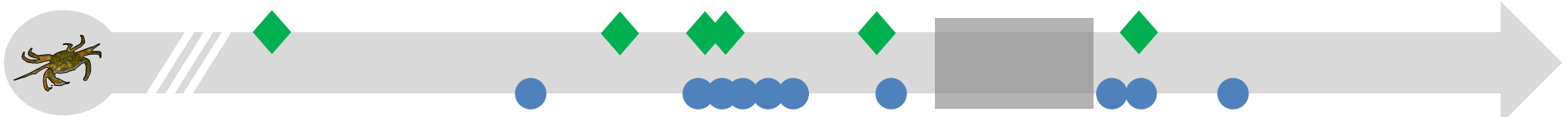
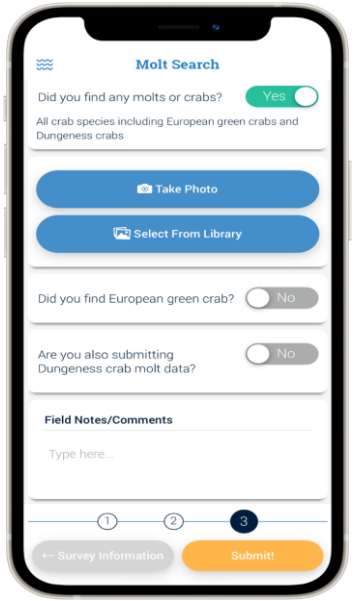
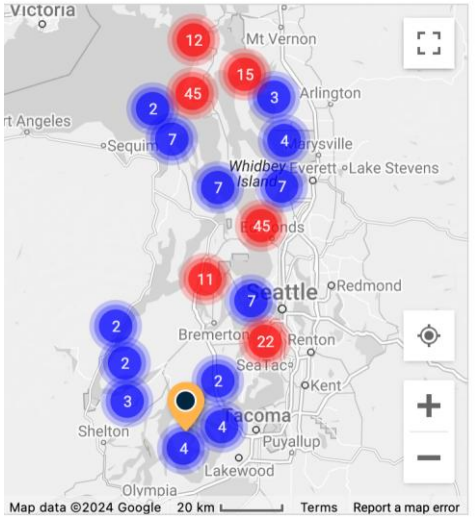
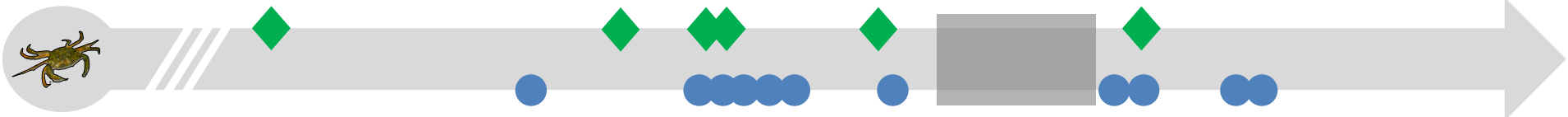


1998
Green crab in coastal WA & BC

2023
Multi-Agency Coordination (MAC) group formed

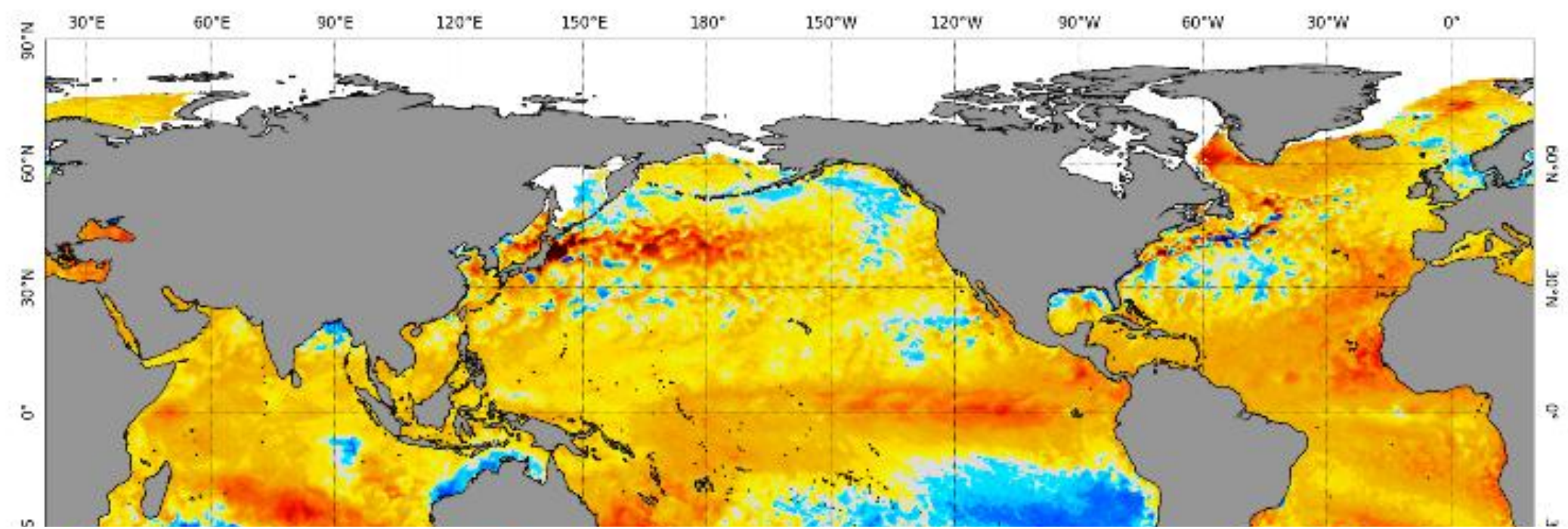






1998
Green crab in coastal WA & BC

2023
WSG Crab Team Molt Search launched



El Nino
pop increase
2024

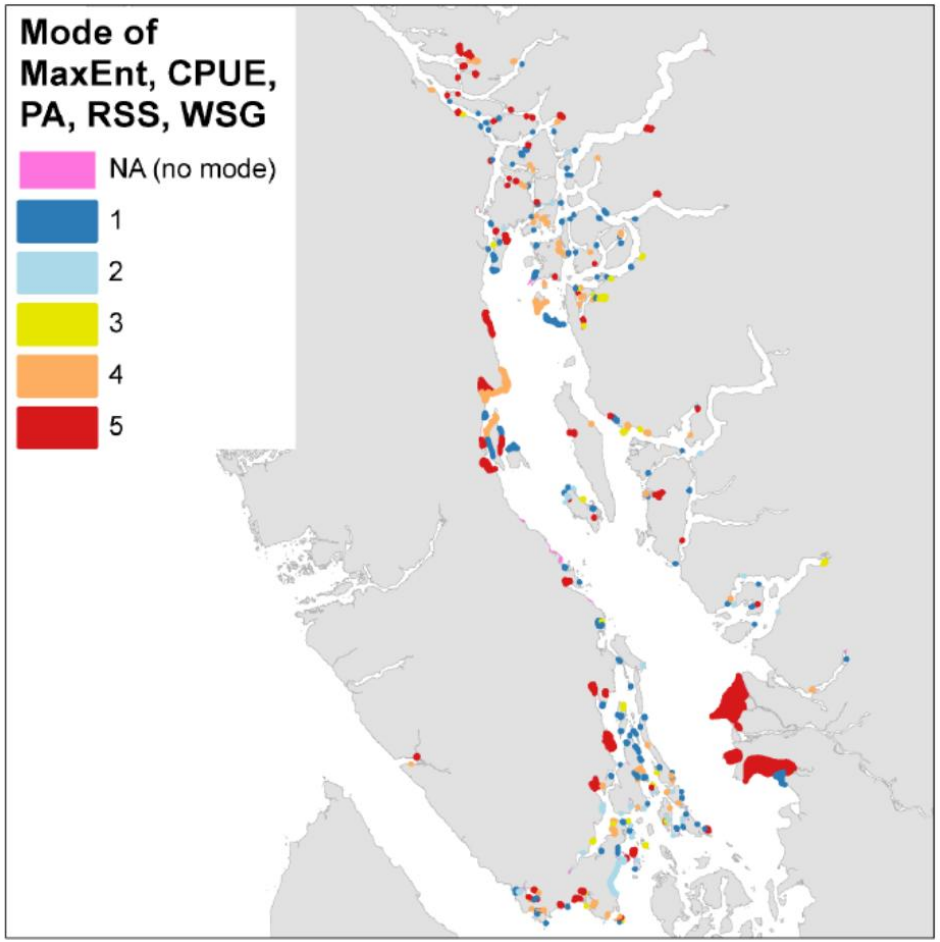
1998
Green crab in
coastal WA & BC

2024
Quinault Tribe
Emergency declaration

EGC – Identification of Monitoring Sites

MaxEnt	• SDM from Lyons et al. 2020 • Uses occurrence records of EGC throughout west coast N. America
CPUE and PA	• Both boosted regression tree models (BRT) • Two models: **linear** (CPUE) and **logistic** (P/A) • Use DFO catch data from WCVI
RSS	• Rapid Site Selection tool • Initially an interim site selection tool from AIS Science (Pacific) to inform rapid response needs (e.g. Haida Gwaii)
WSG	• Washington Sea Grant site selection tool • Developed by Crab Team for early detection work in WA

EGC – Identification of Monitoring Sites



- Multi-model approach was used to identify EGC early detection sites in the Salish Sea
- Provides a robust and scalable method to identify monitoring sites for other AIS using best available information

Takeaways

There is no quick fix. Management will require continued effort to reduce spread and impact.

Management requires transboundary cooperation.

Efficacy and efficiency are enhanced by working together and learning from each other.

~300 volunteers!

Coastal Restoration Society

DFO

Fisheries and Oceans Canada

Jamestown S'Klallam Tribe

Lower Elwha Klallam Tribe

Lummi Nation

Makah Tribe

NW Straits Commission

Pac County Veg Management

PNNL

Samish Indian Nation

Shoalwater. Bay Tribe

Stillaguamish Tribe

Stillwaters Environmental Center

Suquamish Tribe

Swinomish Indian Tribal Community

U.S. Fish and Wildlife Service

WA Ecology – Padilla Bay NERR

WDFW

WA DNR – Aquatic Reserves

<u>Shellfish growers</u>

David Beugli, Kyle Deerkop, Warren Cowell, Kim Patten, and Bill Dewey

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PNW National Lab
lily.engel@pnnl.gov

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UW/ WSG Crab Team
psean@uw.edu

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