Status of the European Green Crab, *Carcinus maenas*, (aka 5-spine crab) in Oregon Estuaries.
Report for 2023

Sylvia Behrens Yamada yamadas@science.oregonstate.edu
Integrative Biology, Oregon State University
3062 NW Snowberry Place, Corvallis, OR 97330

Cameron Royer royerca@oregonstate.edu
Integrative Biology, Oregon State University

Shon Schooler shon.schooler@state.or.us
South Slough National Estuarine Research Reserve
Charleston, OR 97420

Andrea Randall jaoskemmer@centurylink.net
PO Box 6, Chinook, Washington 98614

Jennifer Fisher jennifer.fisher@noaa.gov
NOAA Fisheries – NWFSC Hatfield Marine Science Center,
Newport, OR 97365

Report prepared for:
Stephen H. Phillips, Program Manager
Aquatic Nuisance Species Project
Pacific States Marine Fisheries Commission
205 SE Spokane Street, Suite 100, Portland, Oregon 97202
503-595-3100; Fax: 503 595-3232
stephen_phillips@psmfc.org
http://www.psmfc.org

Executive Summary

The European green crab (*Carcinus maenas*) has persisted in Oregon and Washington coastal estuaries since the late 1990s. A strong year class arrived during the 1998 El Niño, but numbers decreased and remained below 1 per trap per day until the arrival of the 2015-2016 El Niño. Since then, numbers have increased to an average of around 4-6 crabs per trap per day for intertidal sites (Figure 2) and ~ 9 per trap per day in the shallow subtidal. Measurable ecological impact is predicted to occur at around 10-20 per trap per day (Grosholz et al. 2011). Recruitment of young green crabs between the two major El Niños of 1997/1998 and 2015/2016 has been sporadic, with many years of recruitment failures. But after the 2015/2016 El Niño, recruitment has been good every year. The Davidson Current transporting larvae from California during the winter no longer appears to be the only source of larvae for our coastal estuaries (Behrens Yamada, Fisher and Kosro 2021). Now that the populations in Oregon, Washington and British Columbia have built up, we have evidence for local larval production and seeding from a genetically distinct population on Vancouver Island (Alan Shanks and Carolyn Tepolt, pers. com**.).**

This report summarizes catch data of adult green crabs collected by various researchers from Nehalem, Tillamook, Netarts, Salmon, Siletz, Yaquina, Siuslaw, Umpqua, Coos, and Coquille estuaries (Schooler et al. 2023). Catch data for young-of-the-year, or Age-0, green crabs at the end of their first growing season was collected from five estuaries (Figure 1) These include:

- Coos Bay, sampled by Shon Schooler and staff of South Slough National Estuarine Research Reserve,
- Yaquina, Netarts and Tillamook estuaries, sampled by Sylvia Yamada and Cameron Royer of Integrative Biology, Oregon State University, and
- Willapa Bay, sampled by Andrea Randall and Washington Department of Fish and Wildlife staff.

This is the 26th year that we have collected abundance and size data for Age-0 green crabs. Our goal is to link recruitment patterns of these young crabs in the 5 estuaries to ecological ocean indicators experienced by these organisms when they were larvae rearing in the plankton.

Outreach Activities by Sylvia Behrens Yamada in 2022

Date	Talks / Outreach Activities in 2022	Location
April 10, 2023	Trapping demonstration and talk to Dr. Sally Hacker's Marine Biology Class (BI 450): *European Green crabs in Oregon: are they now established?*	Hatfield Marine Science Center, Newport, Oregon
April 22, 2023	Presented talk: *Self Recruitment of the European Green crab in Oregon Estuaries*	Pacific Estuarine Research Society Meeting, Bellingham, Washington
April 27, 2023	Interview with Dina Pavlis' radio show. *Beyond your Front Door* on European Green crabs	KXCR Florence, Oregon https://soundcloud.com/user-772733150/the-european-green-crab-invasion
May 26, 2023	Presented talk: *European Green Crabs, are they here to stay?* to Dr. Grant Mitman's and June Mohler Mitman's Biology class.	Tillamook Community College, Tillamook, Oregon
May 30, 2023	Gave talk to Toastmasters Club: *European Green Crabs, are they here to stay?*	Corvallis Toastmasters Club, Corvallis, Oregon
June 7, 2023	Lightening Talks: *European Green crabs, are they here to stay?*	Integrative Biology, Oregon State University, Corvallis, Oregon
Aug. 8 2023	Talk to ESA. *Ocean warming favors range expansion and abundance of non-native species.*	Ecological Society of America, Climate Change Impacts on Coastal Ecosystems, Portland, Oregon
Sept. 28, 2023	Guest lecture to Scarlett Arbuckle's Coastal Ecology and Resource Management class (FW 426).	Hatfield Marine Science Center, Newport, Oregon
Oct. 26, 2023	Talk to PICES: *Multiple larval sources for Oregon and coastal Washington green crab populations***.**	PICES-North Pacific Marine Science Organization, Seattle, Washington

Introduction

European green crabs (*Carcinus maenas)* made their way to the east coast of North America in sailing ships in the early 1800s (Say 1817). They arrived in San Francisco Bay during the 1980s, most likely as hitchhikers on aerial shipments of Atlantic seafood or baitworms. From there, green crabs spread naturally via larvae carried in ocean currents. By 2000, they had dispersed as far north as Port Eliza on the northern west coast of Vancouver Island, British Columbia. Since then, green crabs were found around the Bella Bella area on the Central British Columbia coast (2010), on Haida Gwaii (2020), Metlakatla in south-east Alaska (2022), and in the inland Salish Sea (2016) (Behrens Yamada et al. 2017, 2021a, Grason et al. 2018). These range expansions were predicted from temperature data and habitat suitability models (Behrens Yamada 2001, Carlton & Cohen 2003, Therriault et al. 2008).

The green crab is a voracious predator that feeds on many types of organisms, including commercially valuable bivalve mollusks (e.g., clams, oysters, and mussels), polychaete worms, and small crustaceans (Cohen et al. 1995). It also competes with native juvenile Dungeness crabs (*Cancer magister*) and shore crabs for food and shelter (McDonald et al. 2001, Jensen et al. 2002, Behrens Yamada et al. 2010). Larger, more aggressive native crab species, such as the red rock crab (*Cancer productus*) and the Pacific brown rock crab (*Cancer antennarius*), have been shown to offer biotic resistance to this invader, but only in the cooler and more saline lower parts of estuaries (Hunt and Behrens Yamada 2003; Jensen et al. 2007). Scientists, managers, and shellfish growers are concerned that increases in the abundance and distribution of this efficient predator and competitor could permanently alter native communities and threaten commercial species such as juvenile Dungeness crab, juvenile flatfish, and bivalves (Lafferty and Kuris 1996, Jamieson et al. 1998, Behrens Yamada et al. 2010).

On the West Coast, the northward range expansion and abundance of green crabs is linked to favorable ocean conditions for larval transport (Behrens Yamada et al. 2021a, 2021b). Warm temperatures and strong northward moving coastal currents, especially during El Niño events, are correlated with range expansions and the appearance of strong cohorts of young green crabs in Pacific NW estuaries (Behrens Yamada & Gillespie 2008; Behrens Yamada & Kosro 2010, Behrens Yamada et al. 2015, 2021a, 2021b).

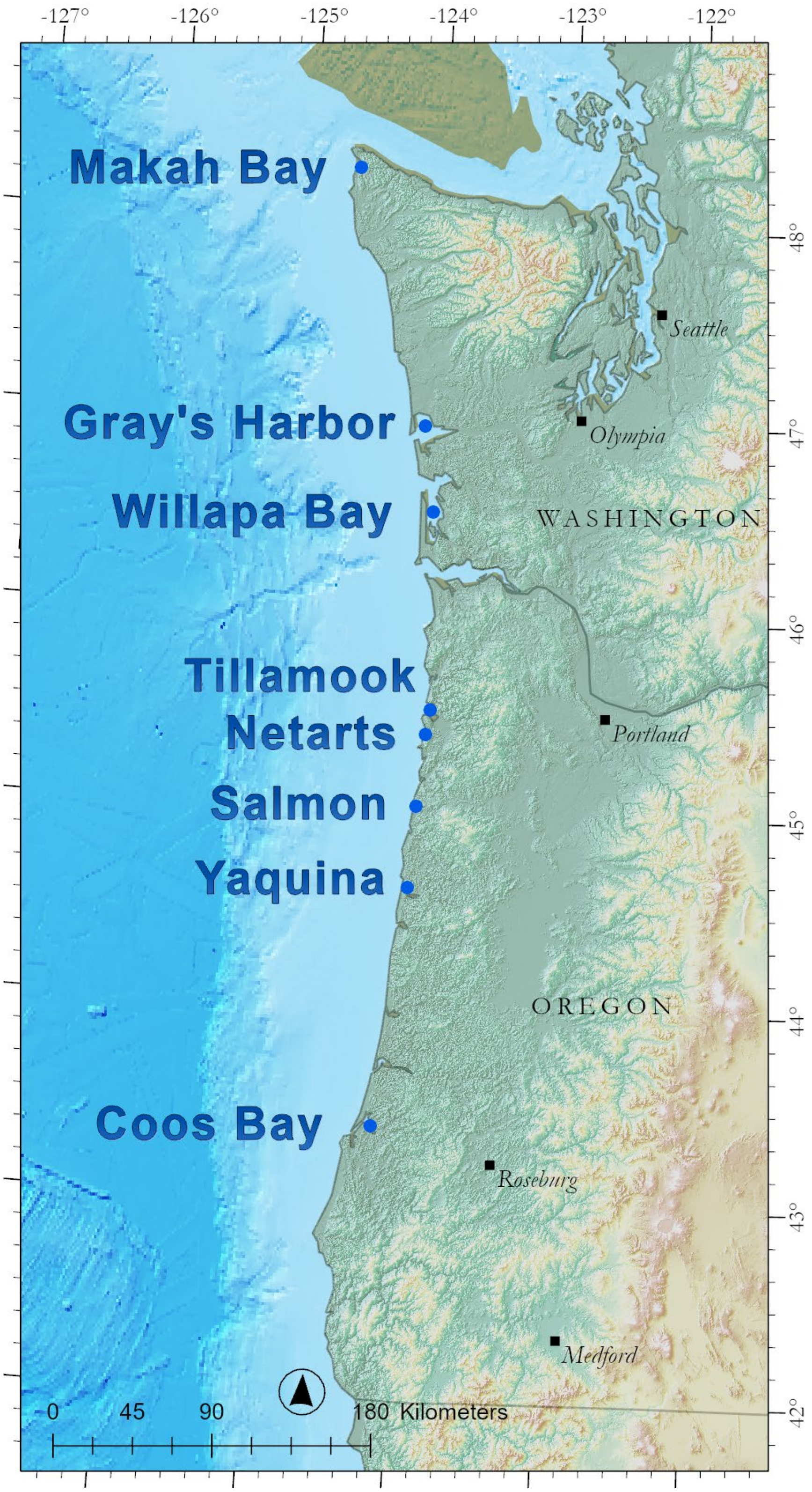


Figure 1. Major sampling sites in Oregon and Washington coastal estuaries.

Goals

Our objectives are twofold: 1) to document the abundance of Age-0 green crabs by setting crayfish traps in the high intertidal zone in the fall, and 2) to link these patterns to ocean indices with the goal of finding clues about the possible larval sources for these young crabs.

Under ideal conditions, the peaks and troughs of size frequency distributions can identify cohorts and shifts in peaks over time can be interpreted as growth. The abundance of Age-0 green crabs in the fall can be correlated with inter annual variation in winter ocean temperature and currents patterns during their larval life in the previous winter. Larvae from the south are carried north by the warm Davison Current during the winter and the resulting young crabs typically reach 30-50 mm in carapace width by the fall. Larvae originating from the north would be carried in in Shelf break Current and would arrive after spring transition when the currents shift. Those crabs are expected to be smaller in the fall than those originating from the south.

While size frequency distributions and ocean indices can give us clues as to the origin of larvae, only genetic analysis can give us definite answers. Since 2016 we have been preparing crab samples from various estuaries and sending them to Carolyn Tepolt of Woods Hole Oceanographic Institute for genetic finger printing. So far, she has determined that larvae originating from a genetically distinct population on Vancouver Island (Sooke Basin) have been transported to Makah Bay, Gray's Harbor, and Willapa Bay, Washington and to Tillamook Bay and Netarts Bay, Oregon (Figure 1). These results are extremely interesting as is the observation by Alan Shanks of the Oregon Institute of Marine Biology that local reproduction can also take place. During the first 3 months of 2010, a mini- El Niño year, Alan collected early instar green crab larvae at Jordan Cove, in Coos Bay. These early instar larvae had to be locally produced. We now have evidence for larval sources from the south, the north, and from Oregon estuaries.

In the future we hope to be able to estimate the relative contribution of these three larval sources by using clues from size frequency distributions, genetic analysis, and ocean indicators of favorable temperatures for larval survival and the origin of water masses off Newport, Oregon. For example, the presence of northern (or southern) copepods in plankton samples is a proxy for transport of water masses (and possibly green crab larvae) from the north (or from the south).

Sampling Methods for Age-0 Green Crabs

Table 1. Types of traps used for sampling young *C. maenas* in Oregon and Washington estuaries. Size selectivity is given in carapace width (CW).

Trap Type	**Description**	**Dimensions**	**Tidal Height**	**Size Selectivity**
Gee Crayfish trap	Galvanized wire mesh (1 cm) cylinder with two 5.6 cm entrance holes.	23 cm diameter 41 cm long	High	25-70 mm
Frabill Crayfish trap	Wire mesh (0.5 cm) cylinder with two entrance holes expanded to 5.7 cm	23 cm diameter 41 cm long	High	25-70 mm
Pitfall trap, Willapa	Water-filled 5-gallon bucket embedded into the sediment	31 cm diameter 37 cm high	High	All sizes

The four Oregon estuaries were sampled at least three times for Age-0 crabs with crayfish traps while Willapa Bay was only sampled once in October. Coos Bay and Yaquina Bay were typically sampled monthly throughout the spring and summer. Since green crabs are patchily distributed, we did not choose our sites randomly. Instead, we preferentially sampled sites that have harbored green crabs in the past, such as tidal marshes, gradually sloping mudflats, and tidal channels where salinities remain above 15‰ and water temperatures range between 12°-22° C in the summer (Behrens Yamada and Davidson 2002). Green crabs are noticeably absent or rare from the cooler, more saline mouths of estuaries, which are dominated by the larger and more aggressive red rock crab, *Cancer productus* (Hunt and Behrens Yamada 2003).

Results

Catches of adult *C. maenas* decreased after the arrival of the strong 1997/1998 El Niño cohort. Between 2002 and 2014 average catches dropped below 1 per trap (Figure 2). Slight increases in catches follow minor recruitment events in 2003, 2005, 2006, 2010 (Figure 4). Catches increased after the 2015-2016 El Niño and leveled off between 4 and 6 per trap in Coos and Yaquina estuaries. (Figures 2, 3). Abundance patterns in other estuaries mirror this pattern. These increases since the 2015-2016 El Niño are directly attributed to good recruitment over the last 9 years (Figure 4). Average catches of *Carcinus maenas* in Oregon are still below 10-20 per trap per day, the level at which significant ecological impact can be expected (Grosholz et.al. 2011). Although it should be noted that catches in some hotspots such as shallow, enclosed bays such as the Coos History Museum can be significantly higher (Shooler et al. 2023).

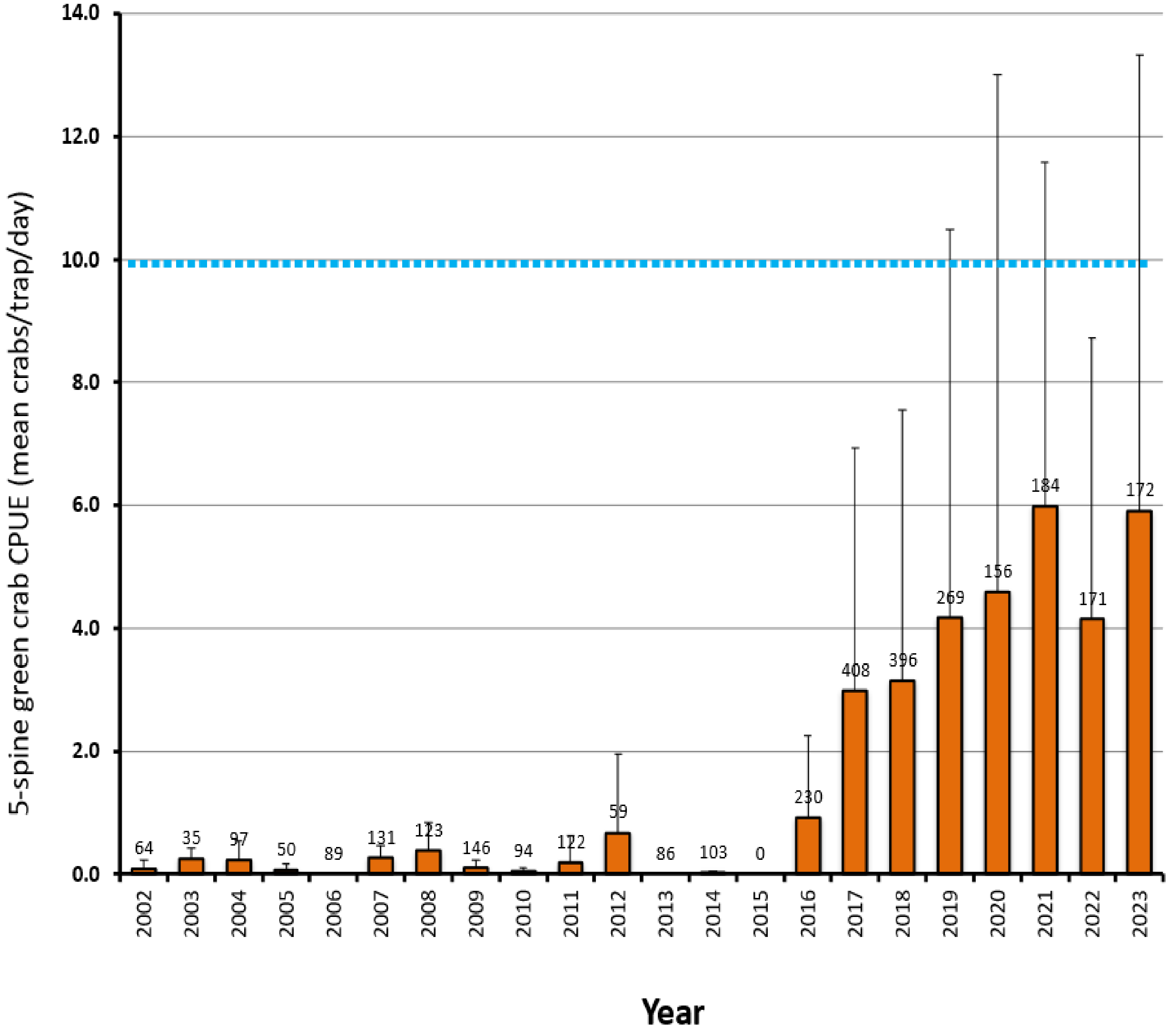
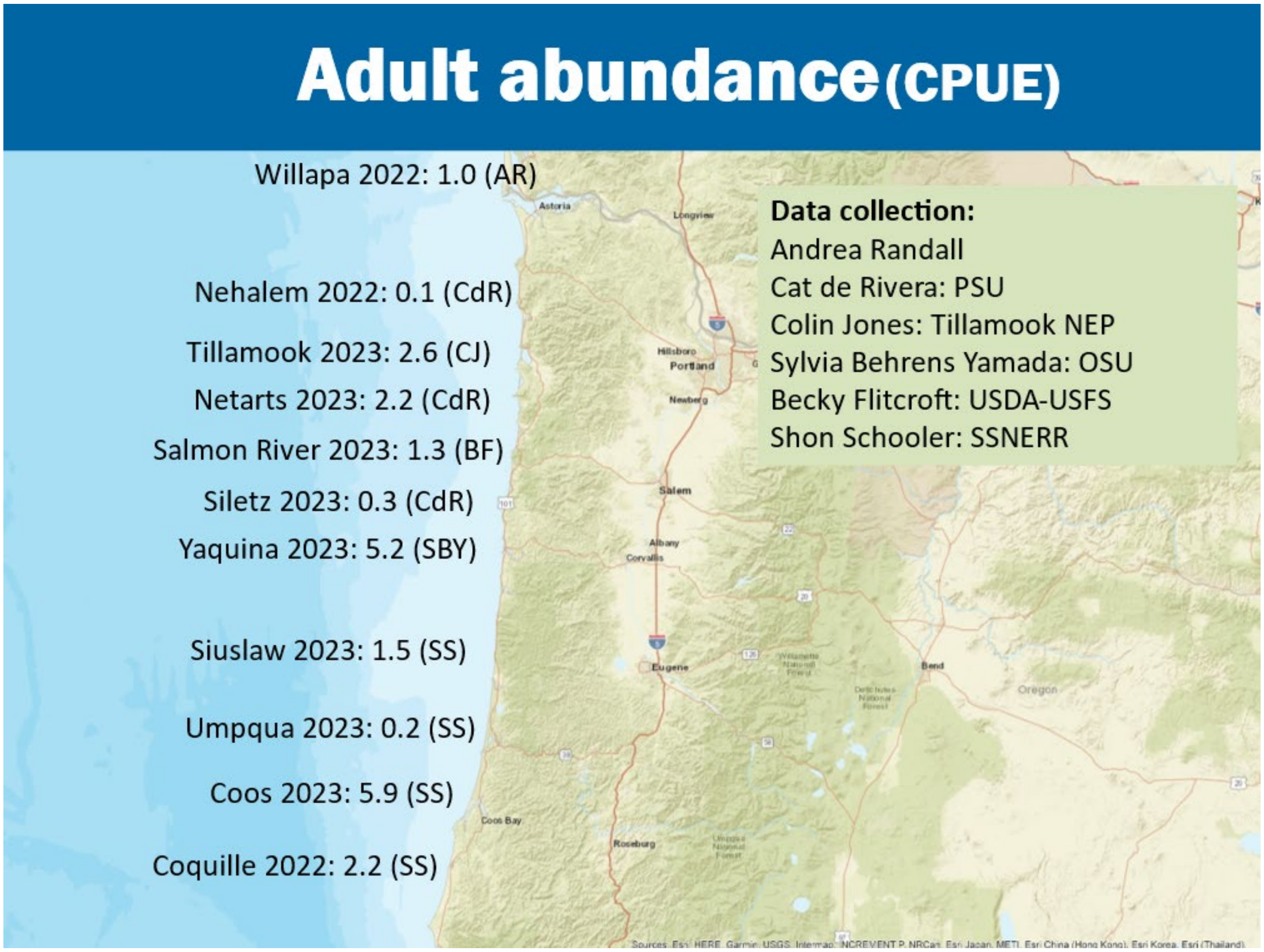


Figure 2. Relative abundance of adult *Carcinus maenas* captured in Fukui fish traps in Coos Bay estuary, expressed as mean number of crabs/trap/day. Dashed line shows estimated threshold for ecological impact. Numbers above bars indicate # of traps. Error bars indicate standard deviation. No Fukui traps were deployed in 2015. Other Oregon estuaries exhibited similar patterns (Behrens Yamada et al. 2019).



Adult abundance (CPUE)

Willapa 2022: 1.0 (AR)

Nehalem 2022: 0.1 (CdR)

Tillamook 2023: 2.6 (CJ)

Netarts 2023: 2.2 (CdR)

Salmon River 2023: 1.3 (BF)

Siletz 2023: 0.3 (CdR)

Yaquina 2023: 5.2 (SBY)

Siuslaw 2023: 1.5 (SS)

Umpqua 2023: 0.2 (SS)

Coos 2023: 5.9 (SS)

Coquille 2022: 2.2 (SS)

Data collection:
Andrea Randall
Cat de Rivera: PSU
Colin Jones: Tillamook NEP
Sylvia Behrens Yamada: OSU
Becky Flitcroft: USDA-USFS
Shon Schooler: SSNERR

Figure 3. Relative abundance of adult green crabs in Oregon estuaries and Willapa Bay, Washington. See Acknowledgements for contact information for contributing researchers.

Recruitment strength of Age-0 <u>Carcinus maenas</u>

Age-0 green crabs typically enter crayfish traps once they reach ~25 mm in carapace width in late summer and fall. As can be seen from Figure 4 and Appendix 2, the appearance of Age-0 green crabs is synchronous between estuaries. A good year, (or a poor year) in one estuary is a good (poor) year in all the others. In 1998, Age-0 green crabs in Oregon and Washington coastal estuaries averaged around 100 per 100 traps (Figure 4). The years between 1999 and 2014 exhibited sporadic recruitment to the population, including years of recruitment failure. The years 2003, 2005, 2006 and 2010, when winter sea surface water temperatures were above 10ºC, the critical temperature for successful larval development, green crab recruitment was moderate. During and after 2015-2016 El Niño green crabs recruited well every year, even in 2020 and 2021 when sea surface temperatures were cool.

Age Structure of Carcinus maenas in Oregon and Washington Estuaries

Prior to 2016 we were able to estimate the age structure of crabs in the estuaries, based on their growth from a mark- recapture study, and from shifts in size frequency distributions over time (Behrens Yamada et al. 2005, 2021a). This was possible because typically only one strong year class appeared every few years and it was easy to follow its size frequency distribution over time. For example, during the summer, male crabs between 50- 74-mm carapace width, and weighing less than 100 g, with green or yellow carapaces would represent Age-1; crabs 75-84 mm and weighing >100 g, Age-2; and those >85 mm and weighing >150 mg, Age-3+. Female crabs of the same age would typically be one molt smaller. Crabs caught in the fall that were ≤50 mm and weighing ≤ 30 g were classified as Age-0. With the arrival of 9 strong, sequential year classes, it is no longer possible to accurately assign year classes because the size-frequency distributions overlap. Since green crabs live for 6 years (Behrens Yamada et al. 2005), year classes 2018- 2023 would have been present in the population in 2023.

While Age-0 crabs were easily characterized before 2016, that is no longer the case, because we have evidence of late settlers that arrive in the Shelf-Break Current from the north during the summer. We estimate that these crabs would be <30 mm in carapace width in the fall and, depending on their subsequent growth rate, could overlap in size with settlers that arrive in the winter from the south in the Davidson Current. The presence of larval sources from the north and from local sources no longer allows us to predict year class strength of Age-0 crabs from ocean conditions that were formerly associated with the warmth and strength of the Davidson Current from California. Bearing this in mind, we will continue to characterize Age-0 crabs as those ≤50 mm in carapace width and weighing ≤ 30 g in the fall, even though it is possible that crabs from a prior year class could be included.

Ocean Conditions and Recruitment Strength ofAge-0 Carcinus maenas

The European green crab has persisted in Oregon and Washington coastal estuaries for over 28 years. Between the two strong El Niños of 1997/1998 and 2015/2016, significant recruitment to the

Oregon and Washington estuaries occurred only after warm the winters of 1998, 2003, 2005, 2006, 2010 and 2015 (Figure 3). Three ocean indicators were consistently good predictors of year class strength. They were winter sea surface temperature off Newport, Pacific Decadal Oscillation (PDO) for March, a regional indicator of ocean temperature, and southern copepod anomaly. The latter is a proxy for the northward transport of water masses (and green crab larvae) from California. Regressions of year class strength against these indicators were highly significant and explained 61%,75% and 70% of the inter-annual variability respectively. These regressions suggest that larvae were carried north from California in the warm Davidson Current, especially during strong El Niño events (top panels of Figures 5-7; Behrens Yamada and Kosro 2010, Behrens Yamada et al. 2015). The predictive power of these ocean indicators, however, is much lower when the years 2016-2023 are included (Behrens Yamada, Fisher and Kosro 2021b). In other words, recruitment of young green crabs in 2018, 2019, 2020, 2021, 2022 and 2023 was higher than predicted from winter ocean surface temperature, March PDO and from the transport of water masses (and larvae) from the south (bottom panels of Figures 5-7). Since the last strong El Niño of 2015-2016, green crab breeding populations have built up everywhere, thus increasing the possibility of larvae arriving from multiple sources.

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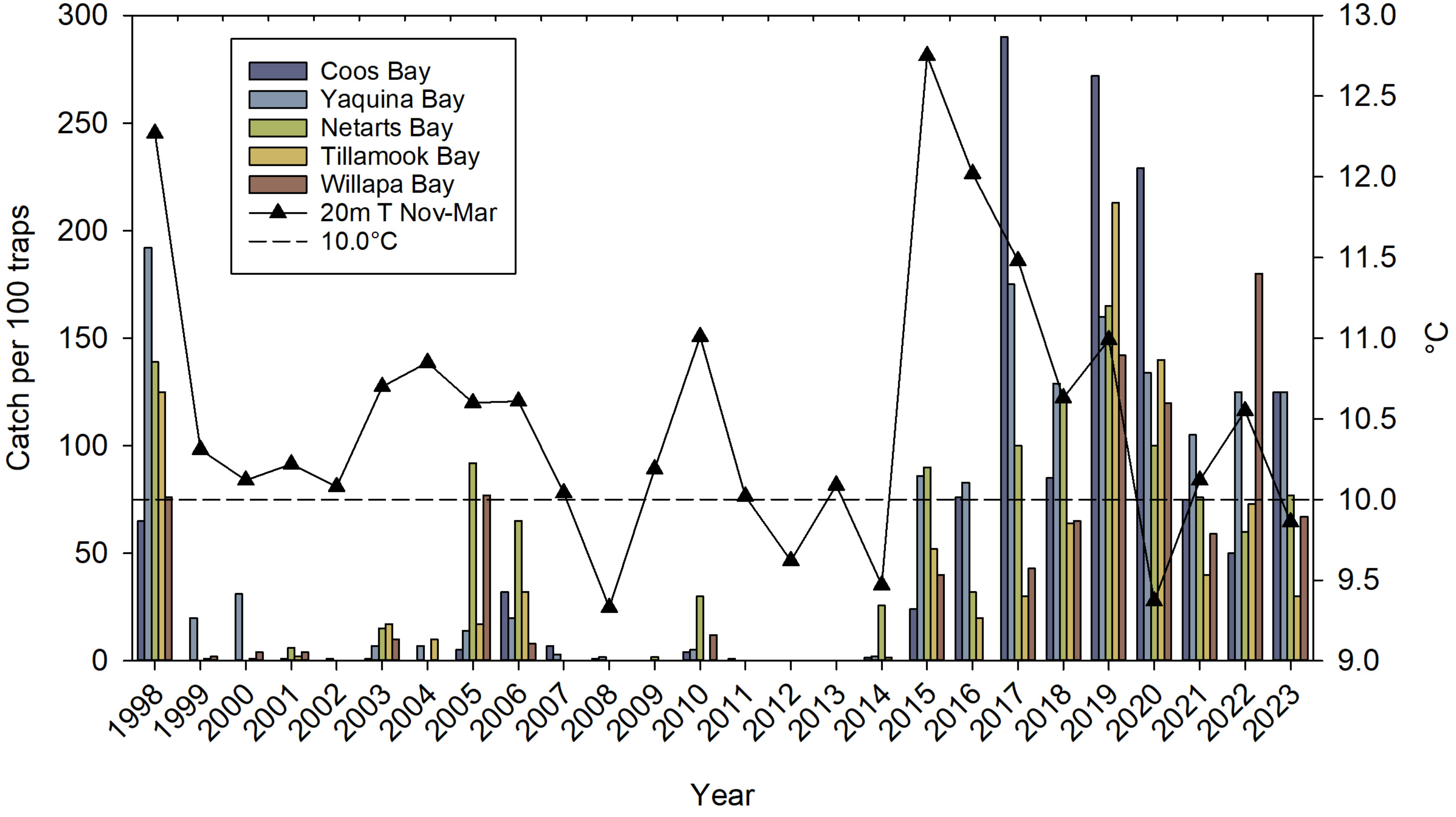
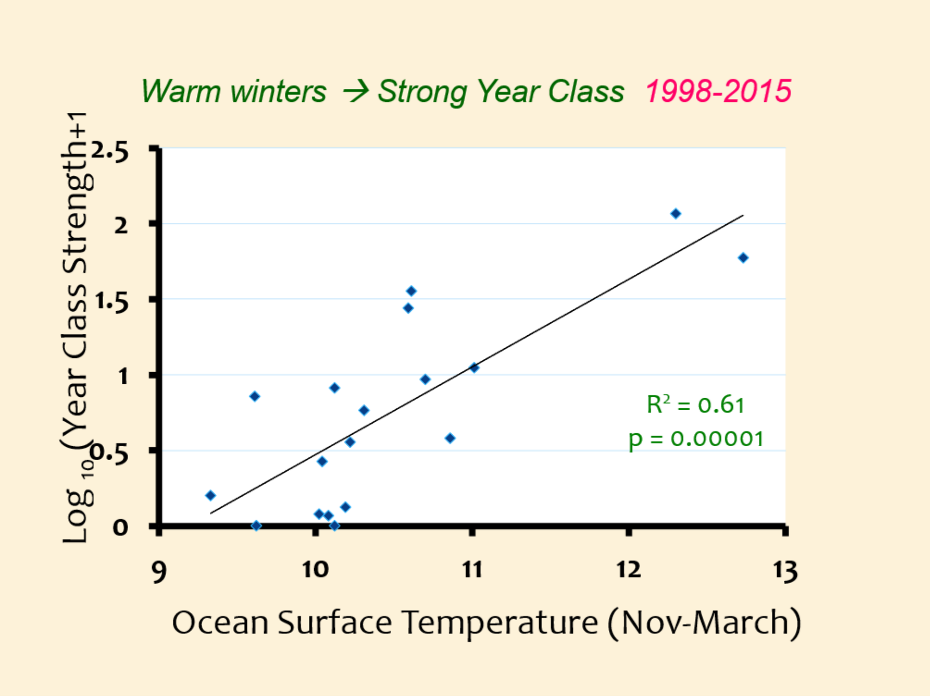


Recruitment of Age-0 Crabs

Figure 4. Relative Abundance of Age-0, or Young-of-the-Year, *Carcinus maenas* in coastal estuaries, expressed as average number per 100 traps, per day. Superimposed is the mean winter surface water temperature (November to March) off Newport OR (NOAA Fisheries ocean ecosystem indicators for 2022). The stippled line indicates the critical water temperature of 10ºC below which larvae cannot develop. Note that years 2020 and 2023 have higher recruitment than predicted by winter surface water temperatures.



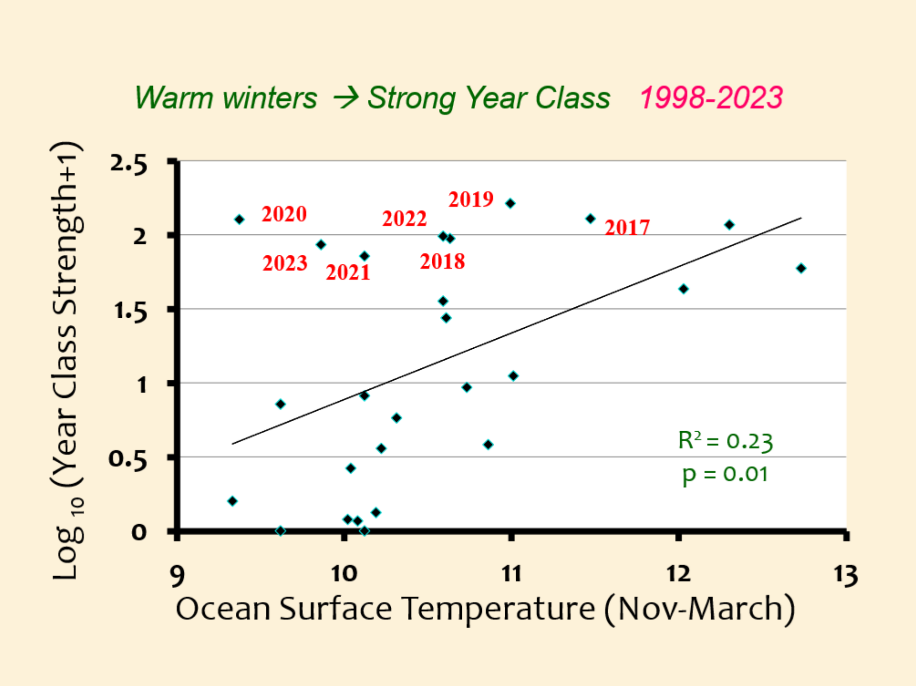


Figure 5. Regression of *Carcinus maenas* year class strength at the end of their first growing season against ocean surface temperature off Newport during the previous winter. From 1998-2015 (top) the R,^{2} or percentage of interannual variability explained by regression, was 61%. The addition of recent years brought the R^2 down to 23%.

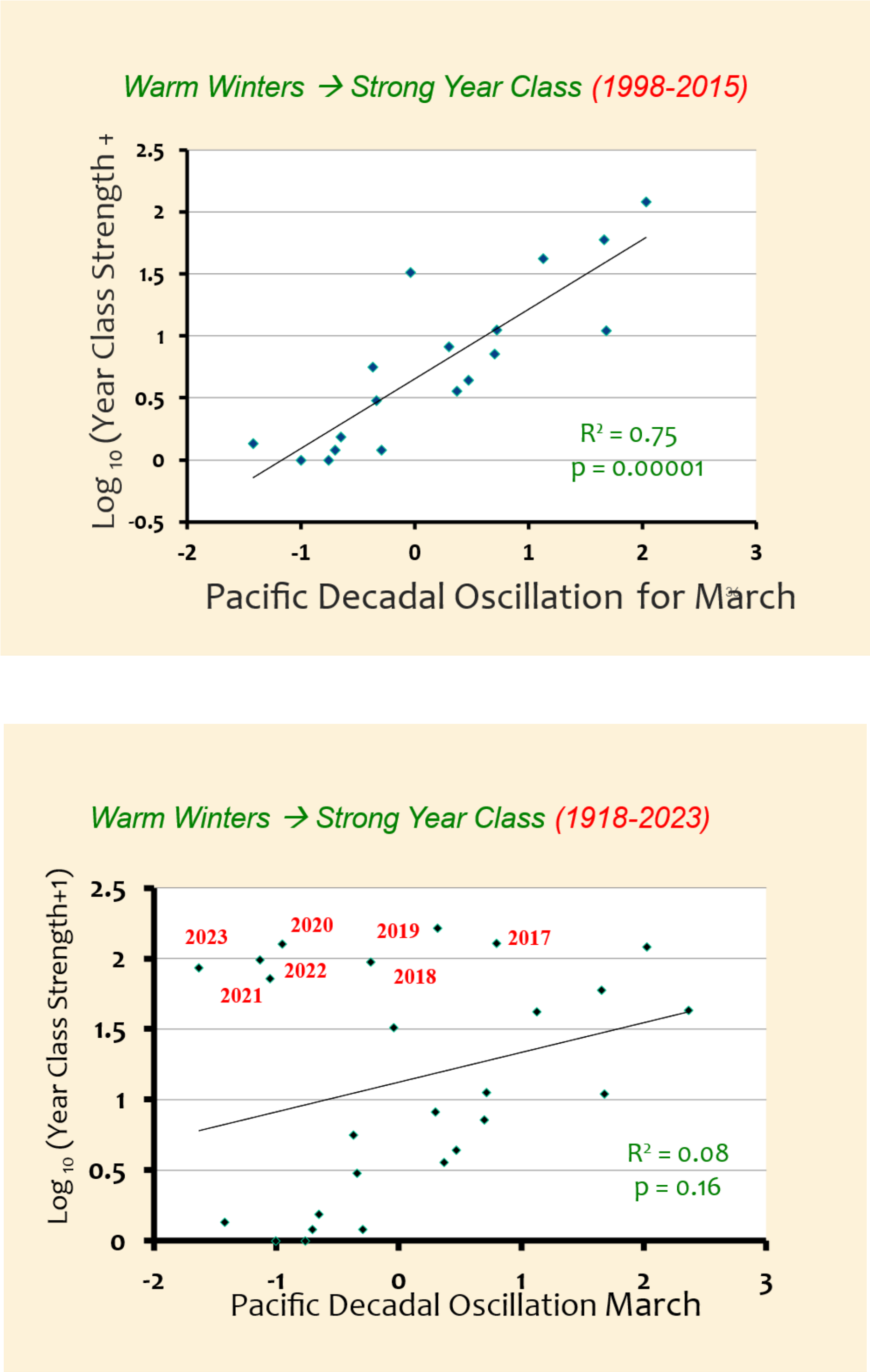


Figure 6. Regression of *Carcinus maenas* year class strength at the end of their first growing season against March Pacific Decadal Oscillation, a regional measure of ocean temperature. From 1998-2015 (top) the R^2 or percentage of interannual variability explained by regression, was 75%. The addition of recent years brought the R^2 down to 8%.

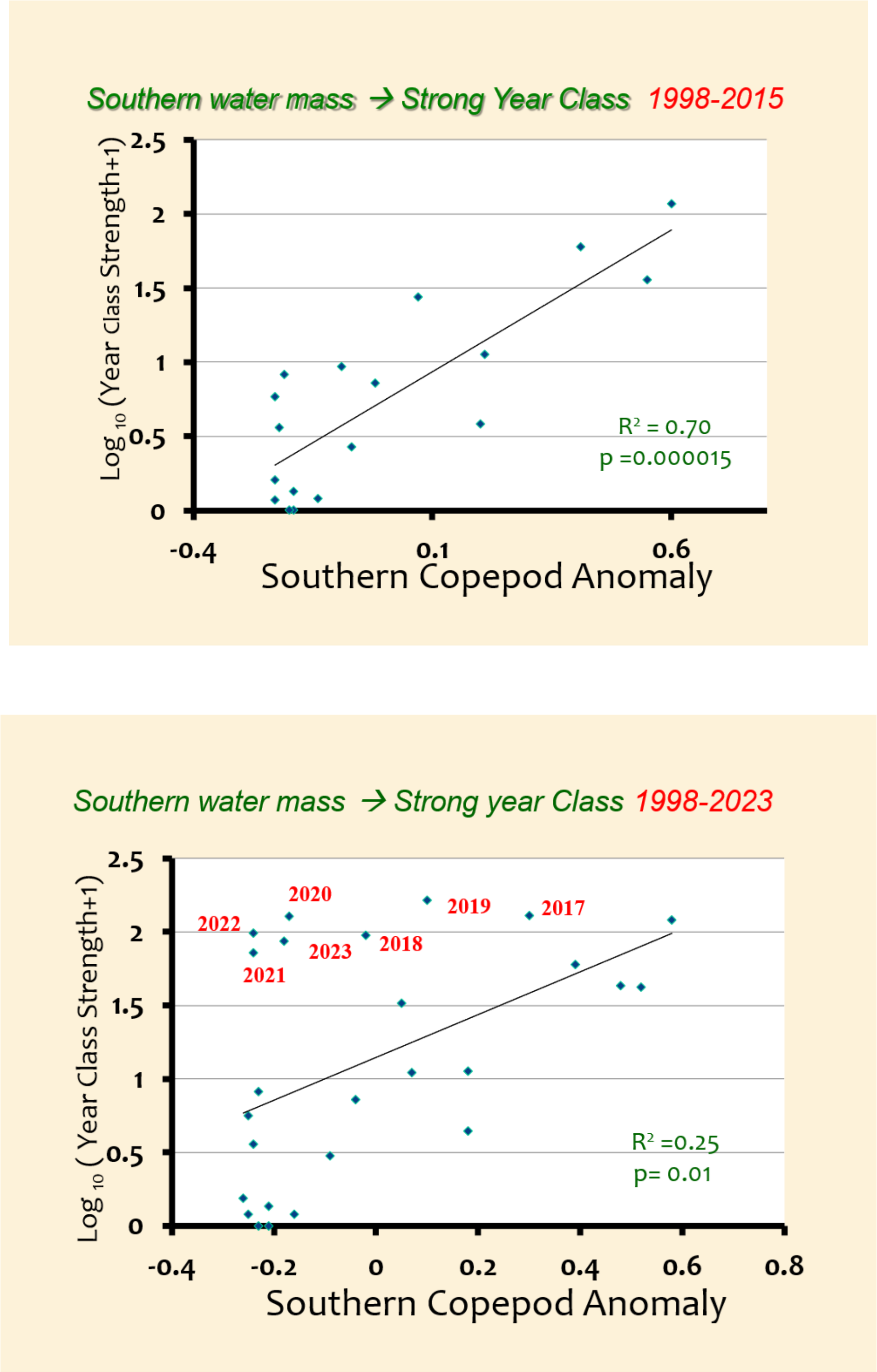


Figure 7. Regressions of *Carcinus maenas* year class strength at the end of their first growing season against southern copepod anomaly, a proxy for southern water sources. From 1998-2015 (top) the R^2 is 70%, but for the period from 1998 – 2022 it is reduced to 25%.

Discussion

While green crabs in Oregon and Washington are no longer rare, they are not as abundant as in some of the inlets on the west coast of Vancouver Island, where average catches of over 20 crabs per trap is not unusual (Behrens Yamada and Gillespie 2008; Gillespie et al. 2015, Katie Gale, pers. com.). Hunt and Behrens Yamada (2003), Jensen et al. (2007), and Claudio DiBacco (pers. com.) found that high densities of green crabs occur primarily on wave protected shellfish beaches with freshwater influence where larger adult native crabs are rare or absent. In Oregon and Washington estuaries, and in the inlets of the west coast of Vancouver Island, green crabs occur higher on the shore, and in more marginal habitats than larger adult native crabs: *Cancer magister* (Dungeness), *Cancer productus* (red rock), *Cancer antennarius* (brown rock crab) and *Cancer gracilis* (graceful crab). These larger native crabs are less tolerant of low salinity microhabitats. In the absence of competition and predation from these larger crabs, green crabs appear to flourish. In 2022, one *Carcinus maenas* was found on the open coast at Boiler Bay by the Hatfield Marine Biology class and a few gravid female green crabs were documented by a private individual at Cape Kawanda. As this species increases in abundance it may become more common on wave exposed sites on the open coast.

Prior to 2016 the ocean indices suggested that green crab larvae were transported north from established populations in California during favorable ocean conditions during the winter. The observation that in 2018, 2019, 2020, 2021, 2022 and 2023 more young green crabs were trapped than predicted, supports the view that we now have additional larval sources from Oregon, and from the north. Alan Shanks (pers. com.) discovered first instar *Carcinus* zoea in plankton tows at Jordan Cove, Coos Bay in the winter of 2010, a mini-El Niño year. These had to be locally produced. Densities of green crabs in Oregon and Washington coastal estuaries may now be high enough to represent self-sustaining populations. Carolyn Tepolt, a geneticist at the Woods Hole Oceanographic Institute, has evidence that larvae from a genetically distinct population on Vancouver Island have seeded estuaries to the south: Makah, Grays Harbor, Willapa, Tillamook, and Netarts Bays. It is not known what the relative contribution of these two additional larval sources is and how that might change with ocean conditions and global warming.

Green crabs, with an average of ~6 and a maximum of ~20 per trap in two Oregon estuaries, are expected to soon have measurable effects on native species including bivalves. Washington growers have already reported green crab predation on small clams and seed oysters (Larissa Pfleeger & Andrea Randall, pers. com.). Outreach efforts to educate the public, boaters, and shellfish growers about the dangers of transporting non-native Aquatic Nuisance Species (ANS) should continue. Such efforts could delay the spread of ANS in general and could prevent or delay the establishment of green crabs in locations from which they are still absent, such as Hood Canal and the northern Salish Sea. In recent years green crab populations have spread to various locations in Salish Sea (Grason et al. 2018, Behrens Yamada et al. 2017, 2021a), including hotspots such as bays and lagoons. Intense trapping efforts are ongoing to reduce the breeding populations in these high water retention habitats (Bobbie Buzzell, pers. com.).

Acknowledgements

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Pacific States Marine Fisheries Commission covered the travel costs for Sylvia Behrens Yamada and hourly wages for Andrea Randall and Cameron Royer. Shon Schooler is maintaining the green crab database including number of crabs caught, CPUE, and individual crab variables (sex, size, weight, and condition) for the 5 major estuaries since 2002 and for the Salmon River since 2022. Bait was purchased at Pacifica Sea Food and Safeway.

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Appendix 1. Relative abundance of crab species and sculpins (Numbers/trap/day) in Oregon and Washington coastal estuaries during **2023**.

Coos Bay

					Mean CPUE (Catch/trap/day)								# Traps
Site	Date	Trap Type	Zone	# *Carcinus maenas*	*Carcinus maenas*	*Hemigrapsus oregonensis*	*Hemigrapsus nudus*	*Cancer magister*	*Cancer magister* (Recruits)	*Cancer productus*	Sculpins	
Joe Ney	9/13/23	crayfish	high	6	1	2.5	0	4.33	4.33	0	0	6
Metcalf	9/13/23	crayfish	high	9	1.5	1.17	0	0.17	0.17	0	0.67	6
History Museum	9/14/23	crayfish	high	23	3.83	0	0	0	0	0	0.17	6
Isthmus	9/14/23	crayfish	high	8	1.33	0	0	0	0	0	0	6
Kentuck	9/15/23	crayfish	high	11	1.83	0	0	0.67	0.67	0	0	6
Transpacific	9/15/223	crayfish	high	18	3.0	0	0	0.67	0.67	0	0	6
Total Average CPUE				75	2.08							36

Yaquina Bay

					Mean CPUE (Catch/trap/day)							# Traps
Site	Date	Trap Type	Zone	# *Carcinus maenas*	*Carcinus maenas*	*Hemigrapsus oregonensis*	*Hemigrapsus nudus*	*Cancer magister*	*Cancer magister* (Recruits)	*Cancer productus*	Sculpins	
Sally’s Bend By parking lot	5/10/23	Fukui	Mid	21	3.5	0.17						6
	6/19/203	Fukui	mid	87	8.7						14.3	10
Total Average CPUE				108	6.75							16
Sally’s Bend *N 44° 37.699’* *W124° 01.482’*												
	5/10/23	crayfish	high	21	1.05	1.1					2.7	20
	6/20/23	crayfish	high	22	1.1	2.7					3.4	20
	8/1/23	crayfish	high	38	1.9	0.75			0.1		0.65	20
	8/31/23	crayfish	high	32	2.28	0.12					0.4	25
	10/1/23	crayfish	high	67	2.23	0.1					0.13	30
Total Average CPUE				180	1.56							115

Hatfield MSC pumphouse	4/10/23	Fukui	Mid	27	2.7	0.1		0.1	0.2	0.5		10
Total Average CPUE				27	2.7							10
Oregon Coast Aquarium Mudflat *N 44° 37.108'* *W124° 02.165'*	4/10/23	crayfish	high	11	0.73	0.6			0.6			15
	5/10/23	crayfish	high	18	0.86	1.33					4.33	21
	6/20/23	crayfish	high	12	0.6	1.0					3.2	20
	8/1/23	crayfish	high	20	1.0	1.15					1.05	20
	8/31/23	crayfish	high	23	0.92	0.08					0.08	25
	10/1/23	crayfish	high	37	1.23	0.03			0.2		0.1	30
Total Average CPUE				121	0.924							131

Tillamook Bay					**Mean CPUE (Catch/trap/day)**							# Traps
Site	Date	Trap Type	Zone	# *Carcinus maenas*	*Carcinus maenas*	*Hemigrapsus oregonensis*	*Hemigrapsus nudus*	*Cancer magister*	*Cancer magister* (Recruits)	*Cancer productus*	Sculpins	
Pitcher Point below 45 mph sigh *N 45° 30.365'* *W 123° 56.508'*	5/13/23	Crayfish	High	3	0.2	0.93					2.47	15
	6/17/23	Crayfish	High	5	0.33	9.930			0.13		1.47	15
	10/14/23	Crayfish	high	10	0.67	2.33			0.53			15
Tillamook Spit A *N 45° 30.456'* *W 123° 56.615'*	5/13/23	Crayfish	High	6	0.4	0.87					1.7	14
	6/17/22	Crayfish	High	4	0.27	4.93					1.53	15
	10/14/23	crayfish	high	3	0.2	2.13			5.33			15
Total Average CPUE				31	0.35							89

Netarts Bay	**Mean CPUE (Catch/trap/day)**

Site		Trap Type	Zone	# *Carcinus maenas*	*Carcinus maenas*	*Hemigrapsus oregonensis*	*Hemigrapsus nudus*	*Cancer magister*	*Cancer magister* (Recruits)	*Cancer productus*	Sculpin	# Traps
Boat Ramp Marsh N 45.4306 W 123.9473	5/13/23	crayfish	high	19	1.05	1.67					1.22	18
	7/17/23	crayfish	high	10	0.5	0.45					0.9	20
	10/14/23	crayfish	high	30	1.0	0.1					0.13	30
Whiskey Creek Salmon Hatchery *N 45º 23.670’* *W 123º 56.214‘*												
	5/13/23	crayfish	high	4	0.4	1.6					0.3	10
	7/17/23	crayfish	high	6	0.6						1.0	10
Total Average CPUE				69	0.78							88

Willapa Bay					**Mean CPUE (Catch/trap/day)**							# Traps
Site		Trap Type	Zone	# *Carcinus maenas*	*Carcinus maenas*	*Hemigrapsus oregonensis*	*Hemigrapsus nudus*	*Cancer magister*	*Cancer magister* (Recruits)	*Cancer productus*	Sculpins	
Stackpole *N 46º 35.848’* *W 124º 02.195’*	10/2/23	Frabill	High	4	1	2.25	0	0	0	0	0.25	4
	10/13/23	Frabill	High	5	0.62	4.25	0	0.12	0.62	0	0	8
	10/2/23	Gee	High	14	1.4	2.8	0	0	0.1	0	0.4	10
	10/13/23	Gee	High	16	2	2.75	0	0	0.5	0	0	8
	10/2/23	Pitfall	High/mid	15	1.87	0.5	0	0.37	0	0	0	8
	10/13/23	pitfall	High/mid	6	0.54	0.27	0	1,0	0.09	0	0	11
Total Number				60	1.22							49

Appendix 2. Relative abundance (CPUE) and size of Age-0 (young-of-the-year or YOTY) *Carcinus maenas* at the end of their first growing season in Oregon estuaries and Willapa Bay. Age-0 crabs are typically ≤ 50 mm in carapace width and weigh ≤30. Crabs from all estuaries were sampled within the same week of September or early October. Catch per unit effort (CPUE) is reported as number of crabs per trap per day. N=number of Age-0 crabs sampled; SD=Standard Deviation, Water temperatures for December-March for the Hatfield Marine Science Center Pump Dock in Yaquina Bay were provided by David Specht of the Newport EPA; those for Willapa Bay, by Jan Newton and Judah Goldberg of the DOE. The Grays Harbor site was discontinued after 2009.

Year Class	**Estuary**	**# Months <10ºC**	**Mean Winter Temp. ºC**	**N**	**CPUE Pitfall traps**	**CPUE Crayfish traps**	**Mean Carapace Width (mm)**	**SD**	**Range**
2002	**Coos**	4	9.6	0		0.00			
2003		**0**	**10.9**	1		0.01	59.4		
2004		**1**	**10.4**	0		0.00			
2005		**2**	**10.3**	2		0.05	45.0		44-46
2006		2	9.9	17		**0.32**	43.5	4.6	36-52
2007		3	9.8	5		0.08	45.4	4.0	43-52
2008		5	8.8	1		0.01	47.0		
2009		4	9.0	0		0.00			
2010		**1**	**10.0**	2		0.04	40.7		40-41
2011		1	9.8	1		0.01	35.5		
2012		4	8.7	0		0.00			
2013		3	9.6			Not Sampled			
2014				2		0.015	46.5		45-47
2015				26		**0.24**	47.9	4.9	32-54
2016				52		**0.76**	37.1	4.9	26-52
2017				87		**2.90**	35.7	5.4	22-52
2018				24		**0.85**	35.8	8.8	23-51
2019				75		**2.08**	45.0	4.5	32-50
2020				45		**1.88**	47.6	3.0	37-50
2021				53		**0.75**	45.8	3.5	31-50
2022				31		**0.52**	40.6	7.8	16-50
2023				45		**1.25**	46.0	3.14	38-50
1998	**Yaquina**	**0**	**11.2**	201		**1.92**	46.9	5.0	32-60
1999		4	8.8	13	**0.20**		38.0	5.0	30-47
2000		3	9.7	14		**0.31**	37.5	5.0	30-45

2001		3	9.6	Not sampled					
2002		4	9.4	1		0.01	38.9		
2003		**0**	**11.0**	9		0.07	44.9	5.5	41-59
2004		**3**	**10.1**	4		0.07	35.3	5.1	32-43
2005		**2**	**10.1**	21	**0.75**	0.14	41.0	8.4	28-46
2006		3	9.8	18		**0.20**	42.6	5.9	34-51
2007		3	9.5	3		0.03	44.4	7.0	36-49
2008		5	8.4	1		0.02	44.3		
2009		5	8.9	0		0.00			
2010		**1**	**10.1**	8	0.05	0.05	40.8	6.7	30-50
2011		4	9.3	0		0.00			
2012		4	8.7	0		0.00			
2013			9.6	0		0.00			
2014			9.2	2		0.02	45.9		42-50
2015				43		**0.86**	44.6	4.8	35-54
2016				30		**0.83**	36.9	7.4	26-53
2017				70		**1.75**	39.1	11.8	17-56
2018				37		**1.29**	46.4	7.2	16-54
2019				64		**1.60**	38.0	6.0	25-51
2020				51		**1.42**	41.9	5.1	31-50
2021				42		**1.05**	39.4	4.9	29-48
2022				49		**1.25**	40.5	6.9	39-52
2023				75		**1.25**	45.2	4.3	23-51
2002	**Netarts**			0		0.00			
2003				6		0.15	49.4	3.7	45-55
2004				0		0.00			
2005				25		**0.92**	42.9	5.3	30-53
2006				21		**0.65**	38.6	5.3	29-50
2007				0		0.00			
2008				0		0.00			
2009				1		0.02	47.7		
2010				6		**0.30**	44.7	5.6	37-51
2011				0		0.00			
2012				0		0.00			
2013				0		0.00			

2014				18		0.257	43.6	3.9	33-50
2015				36		**0.90**	46.3	5.4	38-56
2016				16		**0.32**	34.5	5.2	24-44
2017				33		**1.00**	36.7	5.4	25-50
2018				23		**1.24**	33.6	6.5	23-50
2019				15		**1.36**	38.9	7.2	27-50
2020				45		**1.14**	34.2	8.5	11-50
2021				19		**0.76**	35.9	3.9	31-50
2022				18		**0.60**	37.2	10.2	17-50
2023				23		**0.77**	43.2	6.39	24-51
2002	Tillamook			0		0.00			
2003				5		0.17	50.0	3.1	46-55
2004				2		0.10	41.0		37-45
2005				10		0.17	47.8	4.5	42-56
2006				31		**0.32**	40.7	4.4	31-51
2007				0		0.00			
2008				0		0.00			
2009				0		0.00			
2010				0		0.00			
2011				0		0.00			
2012				0		0.00			
2013				0		0.00			
2014				1		0.015			
2015				26		**0.52**	49.2	4.1	44-60
2016				8		**0.20**	45.3	5.3	36-52
2017				11		**0.30**	45.2	7.9	27-57
2018				12		**0.64**	40.1	4.2	35-50
2019				56		**1.90**	42.7	4.7	30-50
2020				51		**1.42**	43.7	4.8	23-51
2021				10		**0.40**	46.8	3.2	40-50
2022				23		**0.73**	41.7	5.2	29-50
2023				9		**0.30**	47.5	2.24	42-50
1998	Willapa	3	8.9	47	**0.778**	**0.74**	45.9	4.0	37-55
1999		4	7.6	3	0.023	0.00	38.2	7.5	32-47

2000		4	8.0	9	0.046	0.03	43.4	12.0	19-58
2001		5	8.0	7	0.046	0.02	51.3	2.7	48-56
2002		4	7.6	0	0.00	0.00			
2003		3	9.0	10	0.167	0.00	48.3	5.1	43-59
2004		5	8.6		Not sampled				
2005		3	9.0	106	**0.37**	**1.17**	46.1	3.3	34-52
2006		5	8.3	5	0.04	0.13	42.5	5.1	35-49
2007		5	8.4est	0	0.00	0.00			
2008		5	7.7est	0	0.00	0.00			
2009		5	7.2	0	0.00	0.00			
2010		3	8.9	2	**0.40**	0.00	43.8		43- 44
2011		5	7.8	0	0.00	0.00			
2012		5	7.7	0	0.00	0.00			
2013		5	8.1	0	0.00	0.00			
2014				0	0.00	0.00			
2015				8	**1.00**	0.20	43.1	4.5	35-47
2016				0	0	0			
2017				9	0	**0.43**	41.3	6.1	32-50
2018				10		**0.64**	46.5	7.8	37-56
2019				22		**1.16**	44.2	5.4	33-50
2020				9		**0.45**	40.4	5.9	30-47
2021				10		**0.59**	46.0	4.3	36-50
2022				37		**1.85**	45.2	3.6	37.50
2023				33		**67**	43.95	5.5	30-50
1998	Grays Harbor			3		**1.00**	45.3	5.0	40-50
1999				24		0.02	37.4	7.7	34-51
2000				3		0.01	41.3	6.5	35-48
2001				1		0.01	47.9		
2002				0		0.00	40.		
2003							Not sampled		
2004							Not sampled		
2005				2		0.03	47.3		44-50
2006				1		0.02	49.0		
2007				0		0.00			

2008							Not sampled		
2009				0		0.00			