Status of the European Green Crab, *Carcinus maenas*, (aka 5-spine crab) in Oregon Estuaries. Report for 2022

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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 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). Between the two major El Niños, recruitment of young green crabs 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 is a compilation of trapping data for *Carcinus maenas* from various sources and estuaries. These include the following:

1) Catches of adult crabs in Yaquina Bay using Fukui traps set in the intertidal and in the shallow subtidal. The latter were set at 22 sites along a salinity gradient from South Beach Marina to the Port of Toledo by Mitch Vance of Oregon Department of Fish and Wildlife.
2) Catches of adult crabs at 3 sites in the Salmon estuary using Fukui traps set in intertidal areas by volunteers and by Rebecca Flitcroft from the United Stated Department of Agriculture.
3) Summary of catches of crabs trapped in Coos Bay by Shon Schooler, interns and technicians of South Slough National Estuarine Research Reserve. For detailed data on various sites in Coos Bay see Schooler et al. (2022).
4) Catches of adult crabs in Siuslaw and Umpqua estuaries by Shon Schooler and interns.
5) Average catches of Young-Of-The-Year (YOTY, or Age-0) crabs at the end of their first growing season, from 4 Oregon estuaries and Willapa Bay, Washington. This 25-year data set allows us to compare catches of YOTY crabs between years and between estuaries (Figure 3).

Outreach Activities by Sylvia Behrens Yamada in 2022

Date	Talks / Outreach Activities in 2022	Location
January 19, 2022	Science Pub talk for a general audience: European Green crabs: are they here to stay? Fifty-six viewers attended the virtual seminar.	Virtual, Hatfield Marine Science Center, Newport, Oregon
March 3	Green Crab Webinar – summarized status of green crabs in Oregon	Virtual
March 8, 2022	Oregon Invasive Species Council. Gave slide show on status of green crabs in Oregon.	Virtual
April 4, 2022	Trapping demonstration and talk for 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 25, 2022	Published a paper: Sylvia Behrens Yamada, Alan L. Shanks, Richard E. Thomson 2022. "Can the duration and timing of planktonic larvae contribute to invasion success?" A case study comparing range expansion in *Carcinus maenas* and *Pachygrapsus crassipes*".	Biological Invasions 2022 v.24 no.9 pp. 2917-2932 https://pubag.nal.usda.gov/catalog/7891690
May 23, 2022	Itchung Cheung's Environmental Science 199 Class: Coasts Compared.	Virtual talk via Hatfield Marine Science Center, Newport, Oregon
July 16-17, 2022	Trapping demonstration and talk for Jim Carlton's Bioinvasion Class (Bi 408). Gave guest lecture on the invasion history, biology and status of the European Green crab in Oregon and Washington and current control efforts.	Oregon Institute of Marine Biology, Charleston, Oregon
September 28, 2022	Guest lecture to Scarlett Arbuckle's Coastal Ecology and Resource Management class (FW 426).	Hatfield Marine Science Center, Newport, Oregon
November 9, 2022	Gave talk to Friends of Haystack Rock and the Seaside Aquarium on "European Green crabs, are they here to stay?" Talk included life history, range expansion, abundance patterns and control efforts.	Cannon Beach Library
December 28, 2022	Set up a display of crab identification and feeding rates of green crabs and Dungeness crabs on native oysters.	Oregon Coast Aquarium, Crab Fishing Day, Newport, Oregon

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 via aerial shipment 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), and in the Salish Sea between Vancouver Island and the mainland (Behrens Yamada et al. 2017, 2021a, Grason et al. 2018). This summer, as predicted from temperature data and habitat suitability models, green crabs were discovered by the Metlakatla Indian Community in south-east Alaska (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), polychaetes, 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).

Goals

During the Covid pandemic, sampling was reduced in Oregon estuaries, with the exception of Coos Bay (Schooler et al. 2022, Behrens Yamada et al. 2022). The main goal was to maintain our 25-year long data set of the recruitment of "Young-Of-The-Year" (YOTY, or 0-Age) crabs in Coos, Yaquina, Netarts, Tillamook and Willapa Bay. We documented the abundance and size frequency distribution of YOTY crabs by setting crayfish (minnow) traps and pitfall traps in the high intertidal zone at the end of their first growing season. These YOTY crabs, typically measure ≤ 50 mm in carapace width and weigh ≤ 30 g by late September.

The peaks of size frequency distributions can identify cohorts and shifts in peaks over time can be interpreted as growth. The abundance of YOTY 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 crabs typically reach 30-50 mm in carapace width by the fall. Larvae originating to the north 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. Our ultimate goal is to identify patterns in these size distributions between years and between estuaries and to eventually relate these patterns to possible larval sources. Since 2016 we have been preparing crab samples for genetic analysis and sending them to Carolyn Tepolt of Woods Hole Oceanographic Institute. So far, she has determined that larvae originating from a genetically distinct population on Vancouver Island (Sooke Basin) have been transported to Makah Bay, Willapa Bay, Tillamook Bay and Netarts Bay.

Sampling Methods for Green Crabs

Since *C. maenas* larvae settle high on the shore (Zeng et al. 1999), and crabs move into deeper water as they age (Crothers 1968), we adapted our collecting methods and locations to effectively sample all age classes of *C. maenas.* Traps differ in their sampling efficiency for different sizes of crabs (Table 1). Folding Fukui fish traps, with their wide slit-like openings, work well for adult crabs larger than 40 mm carapace width (CW), while crayfish (minnow) traps with their small mesh sizes (50 mm) retain YOTY green crabs. YOTY green crabs start entering these baited traps when they are ~ 25 mm in carapace width. Typically, we would trap larger adult crabs in the mid to low intertidal zones with folding Fukui fish traps and YOTY green crabs in the high intertidal vegetation with crayfish traps at the end of their first growing season (Appendix 1 and 2).

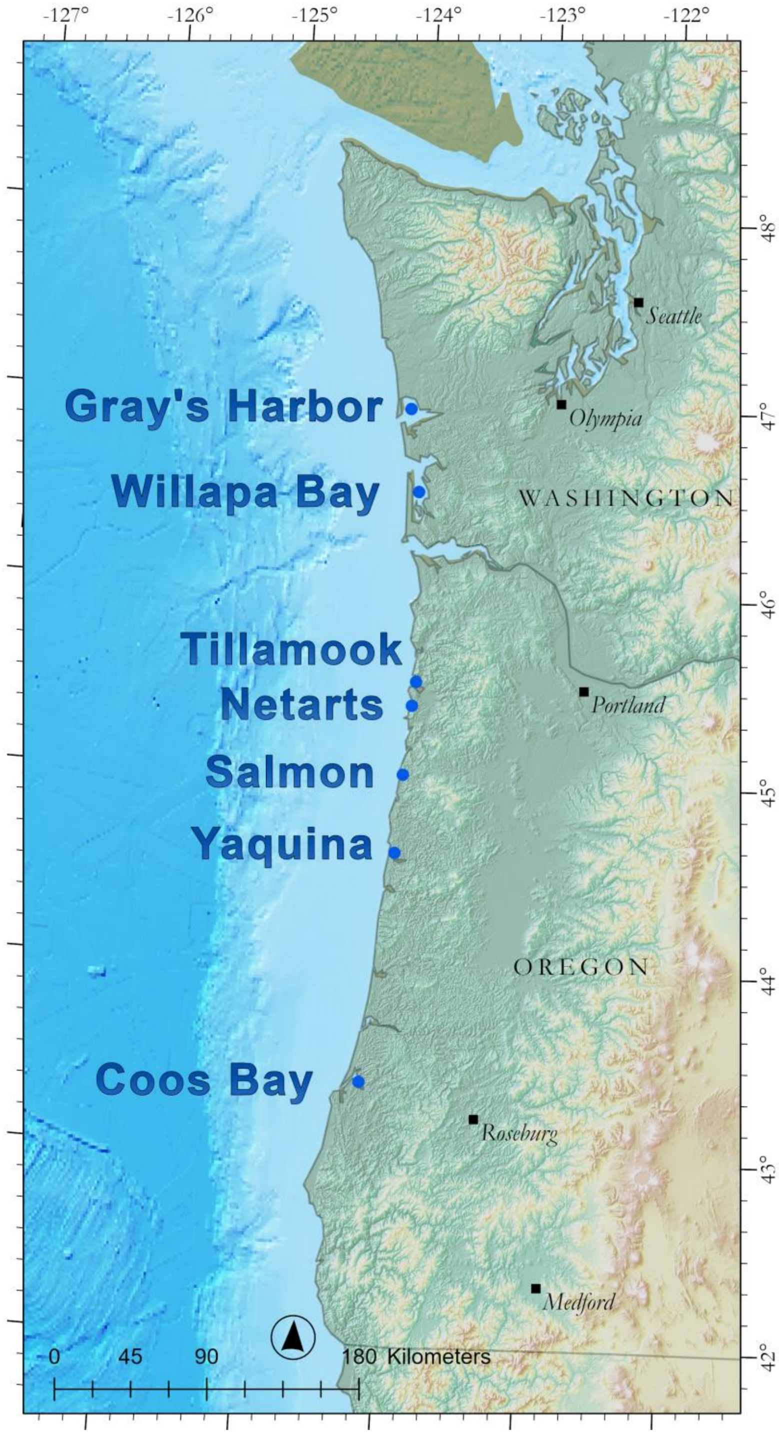


Figure 1. Major sampling sites in Oregon and Washington coastal estuaries.

In addition to these baited traps, we also set pitfall traps in Willapa Bay. These are water-filled 5-gallon buckets buried into the sediment so that their rims are flush with the surface of the sediment. These traps thus catch any actively foraging crabs of any size.

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

Trap Type	**Description**	**Dimensions**	**Tidal Height**	**Size Selectivity**
Fukui Fish trap	Plastic mesh (2 cm) with two slit openings (45 cm)	63 x 46 x 23 cm	Low to subtidal	>40 mm
Frabill Crayfish trap	Wire mesh (0.5 cm) cylinder with two openings expanded to 5 cm	21 cm diameter 37 cm long	Medium to 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
Pitfall trap, Oregon	Large water-filled 1- gallon tin can embedded into the sediment	14.5 cm diameter 16.5 mm high	High	>6 mm

On gravel shores, we added rocks to the crayfish and fish traps to weigh them down and to provide shelter for the crabs. On soft sediment, we pinned the traps down with thin metal stakes. We cut fish carcasses into sections and placed them into egg-shaped commercial bait containers (15 x 8 mm). Holes (0.5 cm) in the sides and lids of the containers allow bait odors to diffuse. One bait container with fresh bait was placed in a trap and left for 24 hours. We retrieved the traps and identified all crabs and other by-catch to species. The sex, carapace widths (CW) and molt stage (color of abdomen) of all green crabs were noted. Green crabs were measured between the outside of their fifth anterior-lateral spines using digital calipers. Native crabs and other by-catch were counted and released while green crabs were removed from the ecosystem, frozen and donated to the Hatfield Marine Science Center aquarium for fish food.

The four Oregon estuaries were sampled at least three times for YOTY crabs with crayfish traps while Willapa Bay was only sampled once in September. 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

***Carcinus maenas* abundance in Oregon estuaries**

The relative abundance of green crabs trapped in Oregon estuaries are tabulated in Appendices 1, 2 and 3, and summarized in Tables 2 and 3. The subtidal Fukui trap surveys of crabs along the salinity gradient in Yaquina Bay showed the same pattern for three crabs for both the 4-hour and the 24-hour soak time, with the 4-hour soak time catching about half as many *C. maenas*. *Carcinus maenas* was most abundant in the mid-estuary, *Cancer magister* was present throughout the estuary, but most abundant in the upper estuary, while *Cancer productus* was only present in the lower, more saline lower estuary (Appendix 2). Maximum catches for *Carcinus maenas* were 53 crabs/trap/day at the Oregon Oyster Farm, for *Cancer magister* were 196 crabs/trap/day at Point Slough, and for *C. productus* were 20 at the Pumphouse. Subtidal traps, on average, tend to catch slightly more *Carcinus maenas* than intertidal traps (Table 2).

Carcinus maenas was the most dominant crab caught at 3 sites in the Salmon River estuary, with average catches ranging from 2.5 to 6.7 crabs/trap/day (Appendix 1). This was the first year of sampling at the Salmon River estuary, which is also the smallest estuary sampled in this report, with an area of 0.8 km^2. Test trapping in the Siuslaw yielded between 2.8 and 5.7crabs/trap/day, and in the Umpqua, 0-0.7 crabs/trap/day (Appendix 3).

For a detailed break-down of *Carcinus maenas* caught in Fukui traps in Coos Bay see Schooler et al. 2022. The 10 sites sampled in Coos Bay were positioned along a salinity gradient. Similar to Yaquina Bay, greater CPUE of *Carcinus maenas* was found in the mid-estuary regions. Coos Bay catches mirrored those in the other estuaries prior to the Covid epidemic (Behrens Yamada et al. 2019). Catches decreased after the arrival of the 1997/1998 El Niño cohort. Between 2002 and 2014 average catches dropped below 1 per trap (Figure 2). Slight increases in catches reflect recruitment events in 2003, 2005, 2006, 2010 (Figure 3). Catches increased steadily after the 2015-2016 El Niño. These increases are directly attributed to the recruitment of eight consecutive strong year classes (Figure 3). In 2022 catches in Fukui traps in Oregon estuaries averaged under 7 crabs/trap/day in the intertidal and up to 9 crabs/trap/day in the subtidal. These catches are not significantly different from 2021 with an average of ~6 crabs/trap/day. (Table 2, Behrens Yamada et al. 2022)

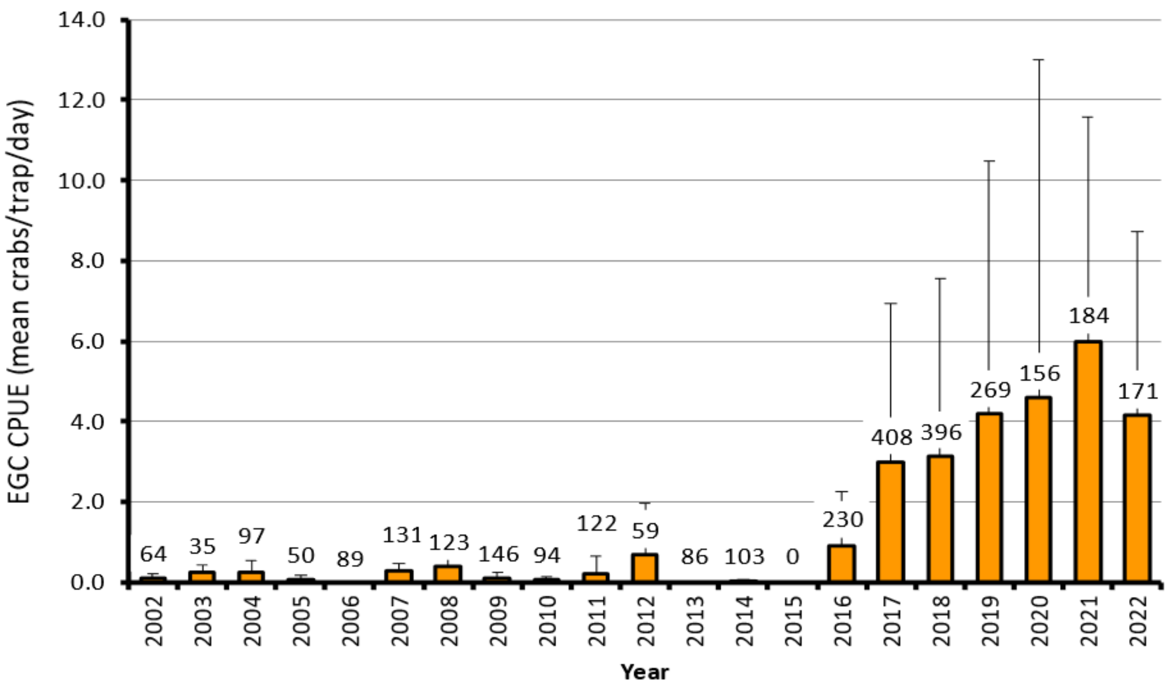


Figure 2. Relative abundance of adult *Carcinus maenas* captured in Fukui fish traps in Coos Bay estuary, expressed as average number of crabs/trap/day. Numbers above bars indicate # of traps. No Fukui traps were deployed in 2015. Error bars represent Standard Deviation. Other Oregon estuaries exhibited similar patterns (Behrens Yamada et al 2019).

Table 2. Summary of Catch per unit effort of *Carcinus maenas* in Oregon estuaries with Fukui traps in 2022. For raw data see Appendix 1, 2 and 3 and Schooler et al. 2022.

Estuary	2022			
	# green crabs	# traps	*Average Catch per trap per day*	*Maximum Catch per trap per day*
Coos Fukui fish traps	710	171	4.15	27
Umpqua Fukui fish traps	5	18	0.28	3
Siuslaw Fukui fish traps	66	16	4.13	10
Yaquina, intertidal Fukui fish traps	134	21	6.38	19
Yaquina, subtidal Fukui fish traps	330	37	8.68	53
Salmon River Fukui fish traps	225	64	3.33	16

3. Summary of Number of *Carcinus maenas* caught per trap per day in Oregon estuaries and Willapa Bay in 2022 using crayfish and 5-gallon pitfall traps. Traps were set monthly during the summer for Coos and Yaquina Bay, three times for Tillamook and Netarts and once for the Salmon estuary and Willapa Bay. For only YOTY crabs caught at the end of their growing season (September-October) see Appendix 4.

Estuary	2022		
	# green crabs	# traps	*Average Catch per trap per day*
Coos, Crayfish traps	75	60	1.25
Yaquina, Crayfish traps	154	181	0.85
Salmon River	4	10	0.4
Netarts, Crayfish traps	54	90	0.6
Tillamook, crayfish traps	89	90	0.99
Willapa, crayfish traps	21	10	2.1
Willapa, 5-gal pitfall traps	47	10	4.7

Recruitment strength of Young-of-the-Year <u>Carcinus maenas</u>

Young-of-the-year (YOTY) 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 3 and Appendix 4, the appearance of YOTY 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. Note that winter water temperatures had to be above 10°C for a new year class to enter the population. In 1998, YOTY green crabs in Oregon and Washington coastal estuaries averaged around 100 per 100 traps. The years between 1999 and 2014 exhibited sporadic recruitment to the population, including years of recruitment failure and moderately recruitment in 2003, 2005, 2006 and 2010. From 2015 to 2022, strong year classes recruited to all the estuaries, with catches of similar size to those of the 1998-year class (Figure 3). Note that in 2020 and 2021 recruitment was good despite cool winter sea surface temperature.

Age Structure of <u>Carcinus maenas</u> in Oregon and Washington Estuaries

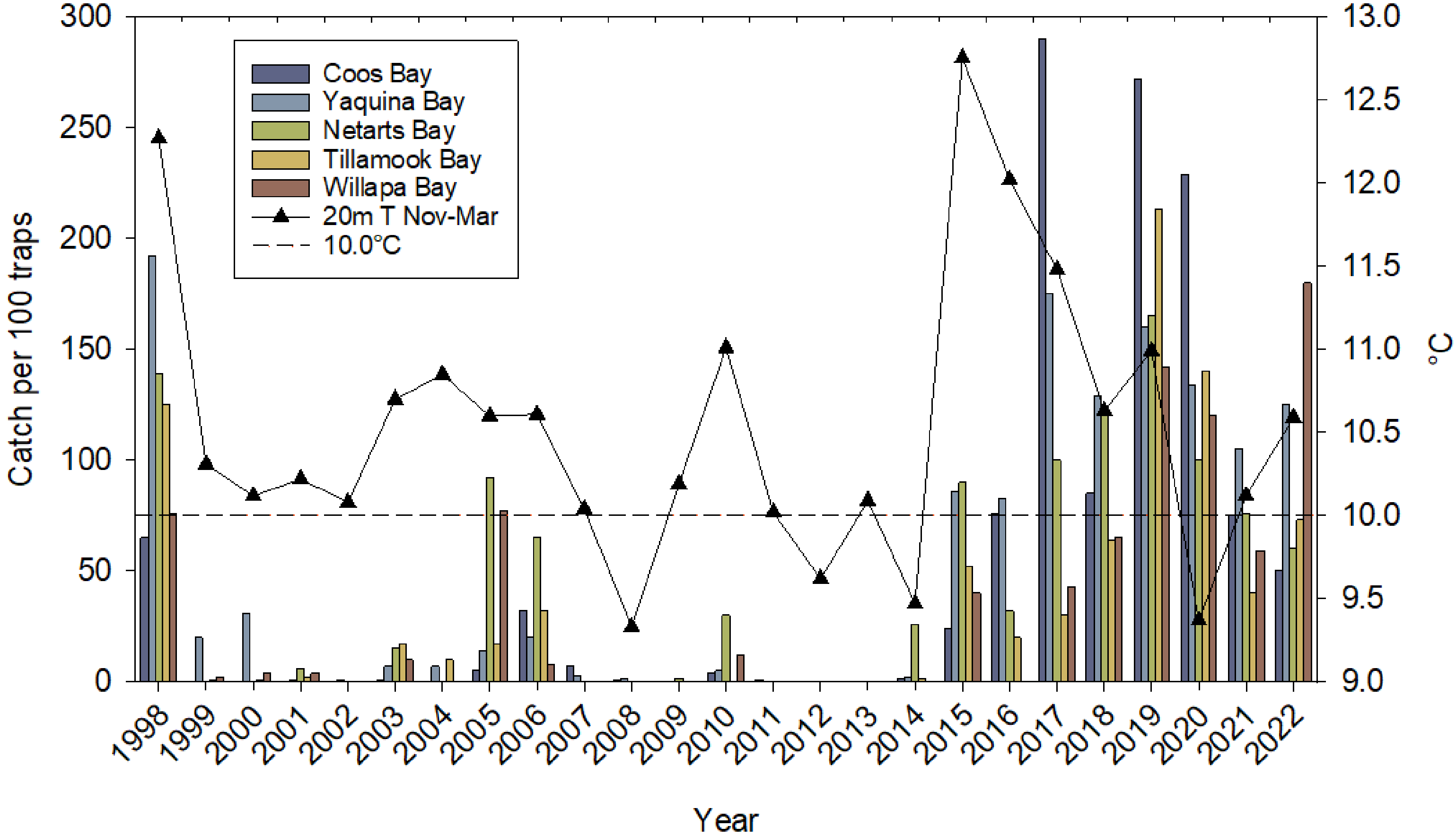
Prior to 2017 we were able to estimate the age structure of crabs in the estuaries, based on their growth from a mark- recapture study, and from shifts in size frequency distributions over time (Behrens Yamada et al. 2005, 2021a.) This was possible because typically only one strong year class appeared every few years and it was easy to follow its size frequency distribution over time. For example, during the summer, male crabs between 50- and 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+. Crabs caught in the fall that were ≤50 mm, and weighing <30 g were classified as Age- YOTY. With the arrival of 8 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 2017-2022 would be present in the population in 2022.

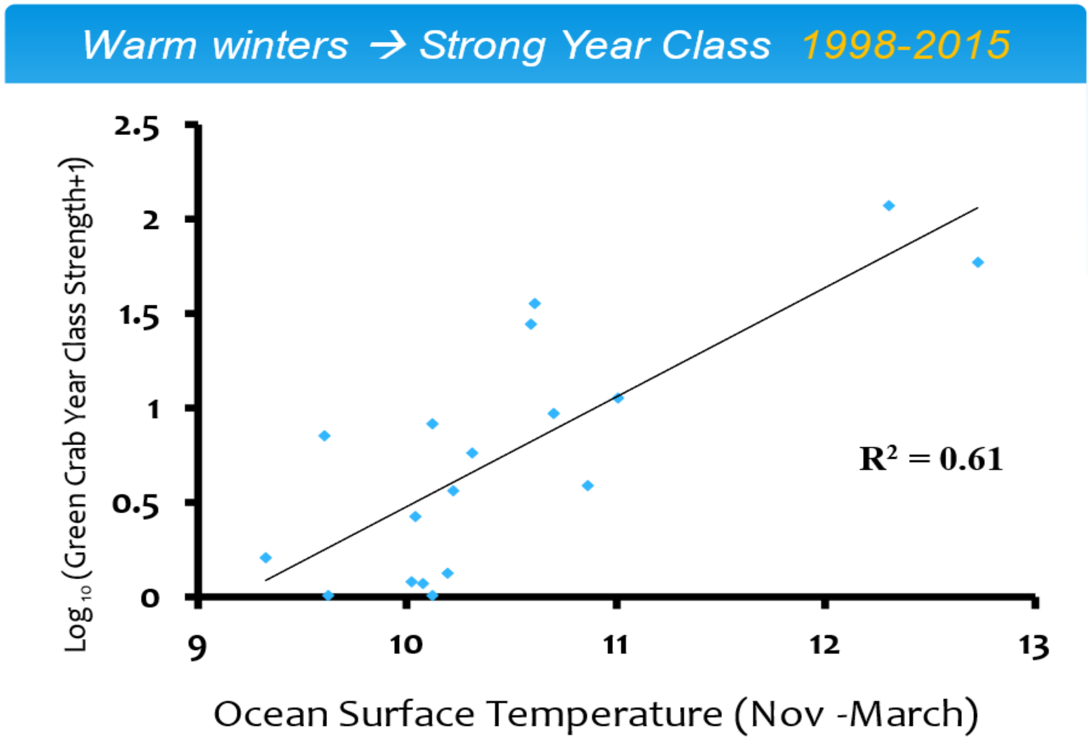
Ocean Conditions and Recruitment Strength of YOTY <u>Carcinus maenas</u>

The European green crab has persisted in Oregon and Washington coastal estuaries for the past 25 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). Regressions of year class strength of young green crabs against winter sea surface temperature and against southern copepod anomaly, (a proxy for northward transport of water masses), showed R^2 values of 0.61 and 0.69 respectively. This suggests that larvae were carried north from California in the warm Davidson Current (top of Figures 4 and 5; Behrens Yamada and Kosro 2010, Behrens Yamada et al. 2015) The predictive power of these ocean indicators, however, is much lower when the recent years 2016-2022 data points are included in the analysis (Behrens Yamada, Fisher and Kosro 2021b). In other words, recruitment of young green crabs in 2018, 2019, 2020, 2021 and 2022 was higher than predicted from winter ocean surface temperature and from the transport of water masses (and larvae) from the south (bottom graphs in Figures 4 and 5).

Recruitment of O-Age Crabs

Figure 3. Relative Abundance of O-Age, 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 10°C below which larvae cannot develop. Note that years 2020 and 2021 have higher recruitment than predicted by winter surface water temperatures.





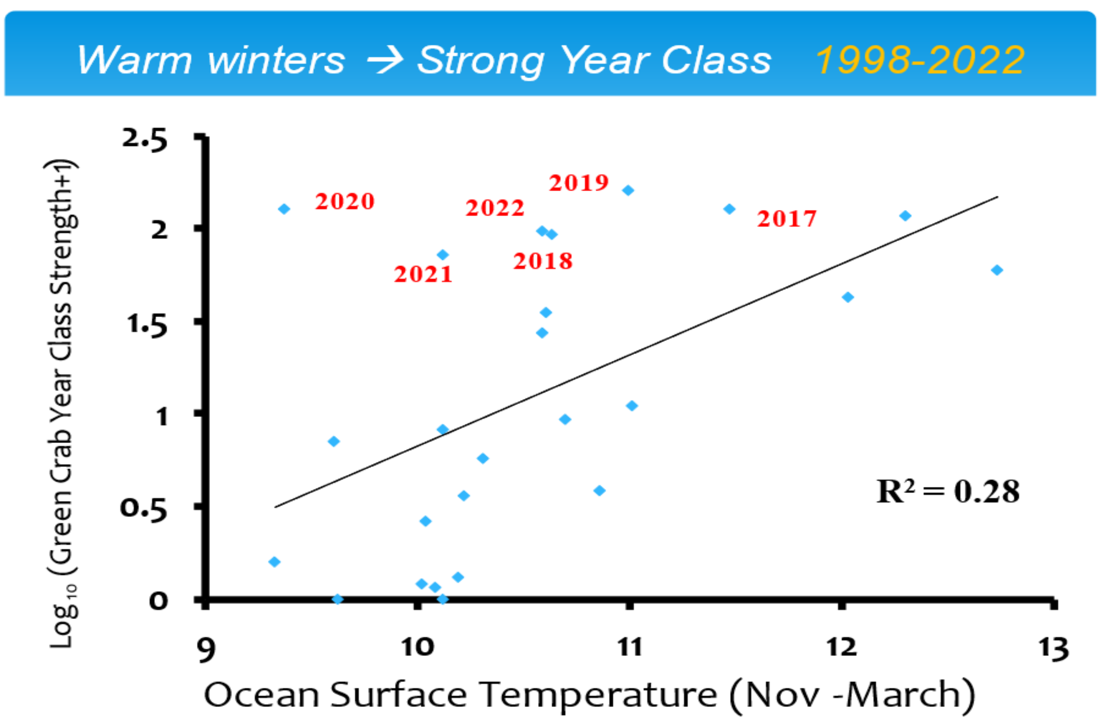


Figure 4. Regression of *Carcinus maenas* year class strength at the end of their first growing season against ocean surface temperature off Newport during the previous winter. From 1998-2015 (top) the R,[2] or % of interannual variability explained by regression, was 61%. The addition of recent years brought the R^2 down to 28%.

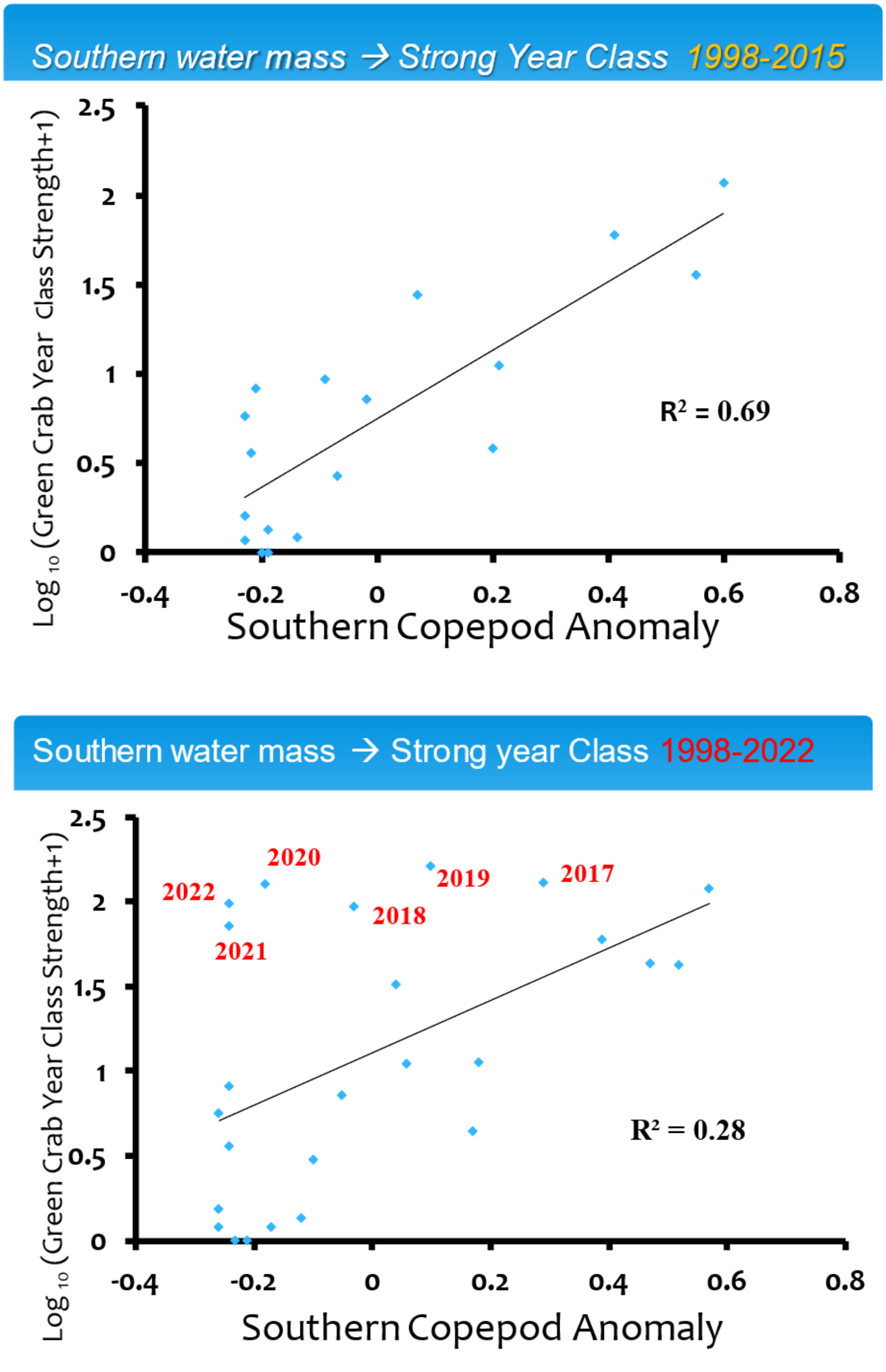


Figure 5. Regressions of *Carcinus maenas* year class strength at the end of their first growing season against southern copepod anomaly (a proxy for southern water sources). From 1998-2015 (top) the $R,^2$ is 69%, but for the period from 1998 – 2022 it is reduced to 0.28%.

Discussion

While green crabs in Oregon and Washington are increasing in abundance, 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.). While these densities are surprisingly high, it should be noted that these hot spots are confined to wave-protected shellfish beaches with freshwater outfall. Hunt and Behrens Yamada (2003), Jensen et al. (2007), and Claudio DiBacco (pers. com.) found that high densities of green crabs occur primarily 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. This year, one *Carcinus maenas* was found at Boiler Bay by the Hatfield Marine Biology class in April and a few gravid female green crabs were documented by a private individual at Cape Kawanda in October. As this species increases in abundance it may also occupy 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 and 2022 more young green crabs were trapped than predicted, supports the view that we now have additional larval sources from Oregon, and, or from the north. During the winter of 2010, Alan Shanks (pers. com.) discovered first instar *Carcinus* zoea in plankton tows at Jordan Cove, Coos Bay. These had to be locally produced. Densities of green crabs in the coastal estuaries may now be large 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, 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 general 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 the establishment of green crabs in locations from which they are still absent, such as Hood Canal and the northern Salish Sea. While green crabs have been discovered at various locations in the Washington Salish Sea (Grason et al. 2018, Behrens Yamada et al. 2017, 2021a) it is not known if this species will establish itself there. Intense trapping efforts are ongoing to reduce the breeding populations in high water retention habitats such as bays, lagoons and the Lummi Nation Sea Pond (Bobbie Buzzell, pers. com.).

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Appendix 1. Relative abundance of crab species and sculpins (Numbers/trap/day) in Oregon and Washington coastal estuaries during **2022**.

Yaquina Bay

Site	Date	Trap Type	Zone	# *Carcinus maenas*	Mean CPUE (Catch/trap/day) *Carcinus maenas*	*Hemigrapsus oregonensis*	*Hemigrapsus nudus*	*Cancer magister*	*Cancer magister* (Recruits)	*Cancer productus*	Sculpins	# Traps
Hatfield MSC pumphouse	4/14/2022	Fukui	mid	27	3.38	0	0	0.25	0	1.25	0	8
Sally's Bend	7/02/2022	Fukui	mid	17	5.17	0	0	0.3	0	0	8	3
Sally's Bend	8/12/2022	Fukui	mid	33	6.6	0	0	0	0.6	0	2.8	5
Sally's Bend	9/27/2022	Fukui	mid	57	11.4	0	0	1.2	0	0	0	5
Total Average CPUE				134	6.38							21
Johnson Slough	5/18/2022	crayfish	high	4	0.4	0.6	0	0	0	0	2.0	10
Sally's Bend A *N 44º 37.699'* *W124º 01.482'*	5/18/2022	crayfish	high	9	0.45	2.75	0	0	0	0	5.0	20
	7/02/2022	crayfish	high	8	0.47	2.12	0	0	0	0	0.88	17
	8/12/2022	crayfish	high	18	0.9	0.85	0	0	0	0	0.8	20
	9/25/2022	crayfish	high	26	1.3	1.0	0.05	0	0	0	1.1	20
Oregon Coast Aquarium Mudflat *N 44º 37.108'* *W124º 02.165'*	4/04/2022	crayfish	high	9	0.6	2.95	0	0	0	0	0.07	15
	5/18/2022	crayfish	high	9	0.47	3.21	0	0	0	0	0.68	19
	7/02/2022	crayfish	high	18	0.9	1.35	0.05	0	0	0	0.55	20
	8/12/2022	crayfish	high	24	1.2	1.05	0	0	0.9	0	0.3	20
	9/25/2022	crayfish	high	29	1.45	0.95	0	0	0	0	0.2	20
Total Average CPUE				154	0.85							181

Salmon River

Site	Date	Trap	Zone	#	Mean CPUE (Catch/trap/day) *Carcinus*	*Hemigrapsus*	*Hemigrapsus*	*Cancer*	*Cancer*	*Cancer*	Sculpins	#

		type		*Carcinus maenas*	*maenas*	*oregonensis*	*nudus*	*magister*	*magister* (Recruits)	*productus*		traps
Road’s End	4/03/2022	Fukui	high	20	6.67	0.67	0	0	0	0	0	3
	6/17/2022	Fukui	high	16	2.67	0.00	1.00	1.00	0.00	0.00	2.00	6
N 45.04752888	7/17/2022	Fukui	high	20	3.33	0.50	0.00	0.50	0.00	0.00	1.50	6
W-124.0023865	8/14/2022	Fukui	high	26	4.33	0.50	0.00	0.33	0.00	0.00	4.17	6
Knight’s Park West	4/03/2022	Fukui	high	15	3.5	6.5	0	0.5	0	0	0	4
	6/17/2022	Fukui	High	23	3.83	0.00	1.50	4.17	0.00	0.00	1.67	6
N 45.04109042	7/17/2022	Fukui	high	16	2.67	0.83	0.00	0.17	0.00	0.00	0.17	6
W -123.994886	8/14/2022	Fukui	High	17	2.83	2.33	0.00	0.17	0.00	0.00	2.17	6
	4/03/2022	Fukui	high	10	3.33	1	0	0	0	0	0	3
Knight’s Park East	6/17/2022	Fukui	high	19	3.17	0.33	0.00	1.00	0.00	0.00	0.67	6
N 45.04020912 *W -123.9916466*	7/17/2022	Fukui	high	15	2.50	0.17	0.00	0.00	0.00	0.00	0.33	6
	8/14/2022	Fukui	high	28	4.67	0.67	0.00	0.33	0.00	0.00	1.50	6
Total Average CPUE				225	3.33							64
Road’s End	4/03/2022	crayfish	high	2	1	3.5						2
Knight’s Park West	4/03/2022	crayfish	high	1	0.25	2.5						4
Knight’s Park East	4/02/2022	crayfish	high	1	0.25	2.75						4
Total Average CPUE				4	0.4							10

Tillamook Bay

Site	Date	Trap Type	Zone	# *Carcinus maenas*	Mean CPUE (Catch/trap/day): *Carcinus maenas*	*Hemigrapsus oregonensis*	*Hemigrapsus nudus*	*Cancer magister*	*Cancer magister* (Recruits)	*Cancer productus*	Sculpins	# Traps
Pitcher Point by	5/21/2022	crayfish	high	18	1.2	1.67	0	0	0	0	5.73	15
45 mph sigh	7/13/2022	crayfish	high	22	1.47	7.87	0	0.33	0	0	0.47	15
N 45° 30.365’	9/11/2022	crayfish	high	11	0.73	4.13	0	0	0	0	1.33	15
W 123° 56.508’												
Tillamook Spit A	5/21/2022	crayfish	high	4	0.27	0.47	0	0	0	0	2.33	15
N 45° 30.456’	7/13/2022	crayfish	high	16	1.07	3	0	0.8	0	0	0.2	15

W 123º 56.615'	9/11/2022	crayfish	high	18	1.2	0.92	0	0	0.07	0	0.8	15
Total Average CPUE				89	0.99							90

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	5/21/2022	crayfish	high	5	0.33	2.07	0.13	0	0	0	0.4	15
	7/13/2022	crayfish	high	23	1.15	1.15	0.10	0	0	0	0.3	20
	9/11/2022	crayfish	high	17	0.85	0.25	0	0	0	0	0.3	20
Whiskey Creek Salmon Hatchery *N 45º 23.670'* *W 123º 56.214'*	5/21/2022	crayfish	high	0	0	0.53	0	0	0	0	0.4	15
	7/13/2022	crayfish	high	3	0.27	0	0	0	0	0	0.6	10
	9/11/2022	crayfish	high	6	0.6	0	0	0	0	0	0	10
Total Average CPUE				54	0.6							90

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'*												
	10/12/2022	Crayfish	High	21	2.1	0	0	0	0	0	0.1	10
	10/12/2022	pitfall	high	47	4.7	0	0	0.3	0	0	0	10
Total Number				68	3.4							20

Appendix 2. Relative abundance of crab species caught with Fukui traps set in the subtidal by Mitch Vance of ODFW in 2022. Soak times were 24 hours for A and 4 hours for B.

A. Yaquina Bay	Approximate River mile	**Number crabs caught per Day**			**Mean CPUE (Catch/trap/day)**			# traps
Site		*Carcinus maenas*	*Cancer magister*	*Cancer productus*	*Carcinus maenas*	*Cancer magister*	*Cancer productus*	
South Beach Marina	1.3	0	14	4	0.0	7.0	2.0	2
Pumphouse	2.0	0	7	47	0.0	2.3	15.7	3
Turning Basin	2.3	7	12	14	2.3	4.0	4.7	3
Kings Slough	3.2	0	19	0	0	19.0	0	1
Coquille Point	3.8	11	2	27	3.7	0.7	9.0	3
Sawyer's Marina	4.0	29	15	14	9.7	5.0	4.7	3
Marker 20	5.1	89	12	3	29.7	4.0	1.0	3
Riverbend Marina	5.3	5	72	0	5.0	72.0	0.0	1
Upper Riverbend	5.5	2	35	0	2.0	35.0	0.0	1
Pooles Slough	6.4	21	93	0	7.0	31.0	0.0	3
Bay Rd., Mile Post 6	6.5	36	207	0	12	69.0	0.0	3
Oregon Oyster	7.2	72	104	0	36.0	52.0	0.0	2
Point Slough	8.8	1	204	0	0.5	102.0	0.0	2
Boone Slough	9.5	9	124	0	4.5	62.0	0.0	2
Craigie Point	9.8	5	367	0	2.5	183.5	0.0	2
Marker 43	10.6	2	97	0	2.0	97.0	0.0	1
Babcock	10.9	3	107	0	3.0	107.0	0.0	1
Airport (north)	11.3	0	16	0	0.0	16.0	0.0	1
Toledo Pilings	12.2	0	0	0	0.0	0.0	0.0	1
TOTAL		292			7.7			38

B. Yaquina Bay		Number crabs caught per 4 Hours			Mean CPUE (Catch/trap/4 hours)			# traps
Site	Approximate Rivermile	*Carcinus maenas*	*Cancer magister*	*Cancer productus*	*Carcinus maenas*	*Cancer magister*	*Cancer productus*	
South Beach Marina	1.3	0	9	9	0.0	9.0	9.0	1
Pumphouse	2.0	1	13	10	0.1	13.0	10.0	1
Turning Basin	2.3	12	8	19	0.6	1.6	3.8	5
Gas Plant	2.9	1	20	13	0.3	5.0	3.3	4
Kings Slough	3.2	0	13	0	0.0	13.0	0.0	1
Coquille Point	3.8	13	11	9	1.9	1.6	1.3	7
Sawyer's Marina	4.0	35	6	4	5.0	0.9	0.6	7
Marker 20	5.1	99	6	11	14.1	0.9	2.4	7
Riverbend Marina	5.3	5	121	0	1.7	40.3	0.0	3
Pooles Slough	6.4	38	67	0	5.4	9.6	0.0	7
Bay Rd., Mile Post 6	6.5	130	65	0	21.7	10.8	0.0	6
Oregon Oyster	7.2	63	103	0	10.5	17.2	0.0	6
Point Slough	8.8	11	34	0	1.8	5.7	0.0	6
Boone Slough	9.5	0	65	0	0.0	16.3	0.0	4
Craigie Point	9.8	14	145	0	2.8	29.0	0.0	5
Marker 43	10.6	3	80	0	0.8	20.0	0.0	4
Babcock	10.9	2	7	0	0.5	1.8	0.0	4
Airport (north)	11.3	1	15	0	0.3	5.0	0.0	3
TOTAL		428			5.28			81

Appendix 3. Relative abundance (CPUE) of *Carcinus maenas* sampled in the Siuslaw and Umpqua estuaries by Shon Schooler of SSNERR in 2022.

Estuary	Site	Latitude. WGS84	Longitude WGS84	Date	Trap type	Number. of.traps	Number.Green. Crab	CPUE.Green. Crabs
Siuslaw	Port.of.Siuslaw Campground	43.968240	-124.099390	06/30/22	Fukui	6	34	5.67
Siuslaw	Port.of.Siuslaw Campground	43.968240	-124.099390	07/28/22	Fukui	4	15	3.75
Siuslaw	Port.of.Siuslaw Campground	43.968240	-124.099390	08/30/22	Fukui	6	17	2.83
Umpqua	Discovery Center	43.704460	-124.093760	06/30/22	Fukui	6	0	0.00
Umpqua	Discovery Center	43.704460	-124.093760	07/28/22	Fukui	6	1	0.17
Umpqua	Discovery Center	43.704460	-124.093760	08/30/22	Fukui	6	4	0.67

Appendix 4. Relative abundance (CPUE) and size of young-of-the-year (YOTY) *Carcinus maenas* at the end of their first growing season in Oregon estuaries and Willapa Bay. YOTY crabs are typically ≤ 50 mm in carapace width and weigh ≤30. Crabs 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 YOTY 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 Minnow 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
1998	Yaquina	**0**	**11.2**	201		**5.00**	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				50		**1.25**	40.7	7.0	39-52
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
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		**0.77**	41.7	5.2	29-50
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
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			