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Status of the European Green Crab in Oregon and Washington Estuaries in 2008

by

Sylvia Behrens Yamada,
Zoology Department,
Oregon State University
Corvallis, OR 97331-2914
541-737-5345; FAX: 541-737-0501;
yamadas@science.oregonstate.edu

and

Andrea Randall,
PO Box 6
Chinook, Washington 98614
jaos.kemmer@hotmail.com

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

A strong cohort of young European green crabs (*Carcinus maenas*) appeared in North American embayments from Oregon to the west coast of Vancouver Island following the strong *El Niño* of 1997/1998. Unusually strong north-moving coastal currents transported crab larvae from established source populations in California to the Pacific Northwest. Both coastal transport and recruitment of young green crabs have been weaker since. Although it was predicted that green crabs would become extinct in the Pacific Northwest once the original colonists died of senescence at about age six, this has not happened. Age-class analysis and the appearance of young crabs evidence the existence of local recruitment in the Pacific Northwest. Good recruitment in 2003, 2005 and 2006 is linked to warm winters and shore-ward transport in late winter and early spring when larvae are believed to be settling out from the plankton. Recruitment in 2007 and 2008 was poor in Oregon and Washington, but the strong 2005 and 2006 cohorts assure a larval source until 2012 when the last of these crabs will die of old age.

An extensive survey by Fisheries and Oceans Canada found green crabs in all the major inlets on the west coast of Vancouver Island, but none in the inland sea between Vancouver Island and the mainland nor north of Vancouver Island. Therefore, outreach efforts should continue to help prevent the establishment of this invader in the inland waters via ballast water or shellfish transport.

Even though green crab abundance in the Pacific Northwest is still low when compared to Europe, eastern North America, Tasmania and California, it is imperative to continue monitoring efforts for two reasons:

1) to elucidate the process of range expansion and population persistence of this model non-indigenous marine species with planktonic larvae and

2) to understand the role of ocean conditions on recruitment strength in order to predict the next strong recruitment event of green crabs.

Professional and Outreach Activities since Summer 2007

Date	Talks / Activities	Location
November 24, 2008	Can ocean Conditions predict the year class strength of the European green crab?	Hypoxia/Upwelling 2008 end of season meeting. College of Atmospheric and Ocean Sciences, OSU
November 13, 2008	Radio interview with Johan Furlong on green crabs in Newfoundland, Canada	The Fisheries Broadcast, CBC Radio, St John's NFL
November 8, 2008	Can ocean Conditions predict the recruitment of the European green crab?	Western Society of Naturalists Meeting, Vancouver, British Columbia, Canada
July 24, 2008	Status of the European Green Crab in the Pacific Northwest – slide show	Aquatic Biological Invasions – BI 421 and FW 421/521/ Hatfield Marine Science Center, Newport, Oregon
July 24, 2008	Crab Identification and Claw Function	Marine Science Exploration Summer Camp, Hatfield Marine Science Center, Newport, Oregon
July 2008	"Can ocean Conditions predict the recruitment of the European green crab?" Manuscript by Yamada and Kosro	Manuscript submitted to Journal of Limnology and Oceanography
June 28, 2008	Exhibit and poster:"Who eats more baby oysters – introduced green crab or native Dungeness crab?"	Sea Fest, Hatfield Marine Science Center, Newport, Oregon
June 17-21, 2008	Trapped with graduate student, Paul Dunn, and showed four biology teachers from the Coos Bay area how to trap and identify green crabs	Oregon Institute of Marine Biology, Charleston, Oregon
Spring Term 2008	Mentor to undergraduate students comparing feeding rates in green crabs and native Dungeness crabs: Sarah Fisher, Amanda Amstutz, Beth Lenker	Hatfield Marine Science Center, Newport, Oregon
May 16, 2008	Panel member at student research presentations; Mentored 4 students studying the role of water temperature on green crab catch rate.	Jane Goodall Environmental Middle School, Salem, Oregon
April 7, 2008	Can ocean Conditions predict the recruitment of the European green crab? Talk and sampling exercise	Marine Biology 450 class Hatfield Marine Science Center, Newport, Oregon

March 11-13, 2008	Can Ocean Conditions predict the Recruitment of the European green crab? Talk by Sylvia Yamada and Mike Kosro	Green Crab Technical Meeting, Vancouver, British Columbia
February 29, 2008	Status of the European Green crab in the Pacific Northwest – poster by Sylvia Yamada and Graham Gillespie	Pacific Estuarine Research Society meeting, Newport, Oregon
	Ocean Conditions and the Recruitment of the European green crab. Talk by Sylvia Yamada and Mike Kosro	
Dec. 7, 2007	Behrens Yamada, S. and Gillespie, G. E. 2008. Will the European green crab (*Carcinus maenas*) persist in the Pacific Northwest? The Fifth International Conference on Marine Bioinvasions.	International Council for the Exploration of the Sea, Journal of Marine Science, 65: 725-729. doi:10.1093/icesjms/fsm191
October 23, 2007	Trapping demonstration and mentor for students of Jane Goodall Environmental Middle School, Salem.	Yaqina Bay study sites- Monthly green crab sampling over the winter
October 9, 2007	Status of the European Green Crab in Oregon, Washington and B.C. in 2007 Yamada, Gillespie, Randall	Pacific Coast Shellfish Growers Association/National Shellfish Association, Welches, Oregon
July 26, 2007	Will the European green crab persist in Pacific Northwest estuaries? Talk for a general audience	Hatfield Marine Science Center, Newport, Oregon
July 14, 2007	Green Crab Biology and Invasion History. Presentation and sampling exercise for Biological Invasion Class	Oregon Institute of Marine Biology, Charleston, Oregon
June 19 –July 4	Sampled non-native species, including green crabs, around northern Vancouver Island with Fisheries and Oceans Canada biologists	Smith Sound, Rivers Inlet and north-west coast of Vancouver Island, British Columbia
June 14-15, 2007	Ocean Conditions and the Recruitment of the European green crab. Talk by Sylvia Yamada and Mike Kosro	OSU Climate Initiative Workshop, Corvallis, Oregon

Introduction

European green crabs (*Carcinus maenas)* made their way to the east coast of North America in sailing ships in the early 1800's (Say 1817). They arrived in San Francisco by during the 1980's, most likely via aerial shipment of Atlantic seafood or baitworms. From there green crabs spread naturally via larvae in ocean currents, and by 2000, had dispersed as far north as Port Eliza on the northern coast of Vancouver Island, British Columbia. It is estimated that their potential range could include Southeast Alaska (Behrens Yamada 2001, Carlton 2003).

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 and shore crabs for food and shelter (McDonald et al. 2001, Jensen et al. 2002). Larger, more aggressive native crab species such as the red rock crab (*Cancer productus*) and the yellow 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, McDonald and Armstrong 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).

On the West Coast, the northward range expansion of green crabs during the 1990's appears to be linked to favorable ocean conditions for larval transport during El Niño events (Behrens Yamada et al. 2005). Warm temperatures and strong northward moving coastal currents (>50 km/day) during the 1997/1998 El Niño were correlated with the appearance of a strong cohort of young green crabs in Pacific NW estuaries in the summer of 1998 (Behrens Yamada and Hunt 2000, Behrens Yamada et al. 2005). With the loss of this strong cohort to senescence and the absence of favorable currents to transport larvae from California in recent years, it was predicted that green crabs in Northwest estuaries would go extinct. This has not happened. Some localized recruitment has occurred in Oregon estuaries. Following the warm winters and springs of 2003, 2005 and 2006 good green crab recruitment occurred in estuaries from Coos Bay to Quatsino Sound, BC on the northern west coast of Vancouver Island (Gillespie et al. 2007).

Goals

The goal of this study is to document the present and predict the future status of the European green crab in the Pacific Northwest. This is accomplished by:

- Estimating the size/age structure and relative density of green crabs in Oregon and Washington estuaries by using baited traps,
- Estimating year-class strength of young-of-the-year green crabs at the end of their first growing season by setting minnow and pit-fall traps in the high intertidal zone at the end of summer and fall,
- Comparing patterns in recruitment strength over time and correlating them to ocean conditions: winter surface temperatures, currents patterns in March and April and date of the spring transition,
- Collaborating with scientists from Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife and Fisheries and Oceans Canada as well as with shellfish growers and sports fishers in order to compile all existing green crab data for the Pacific Northwest.

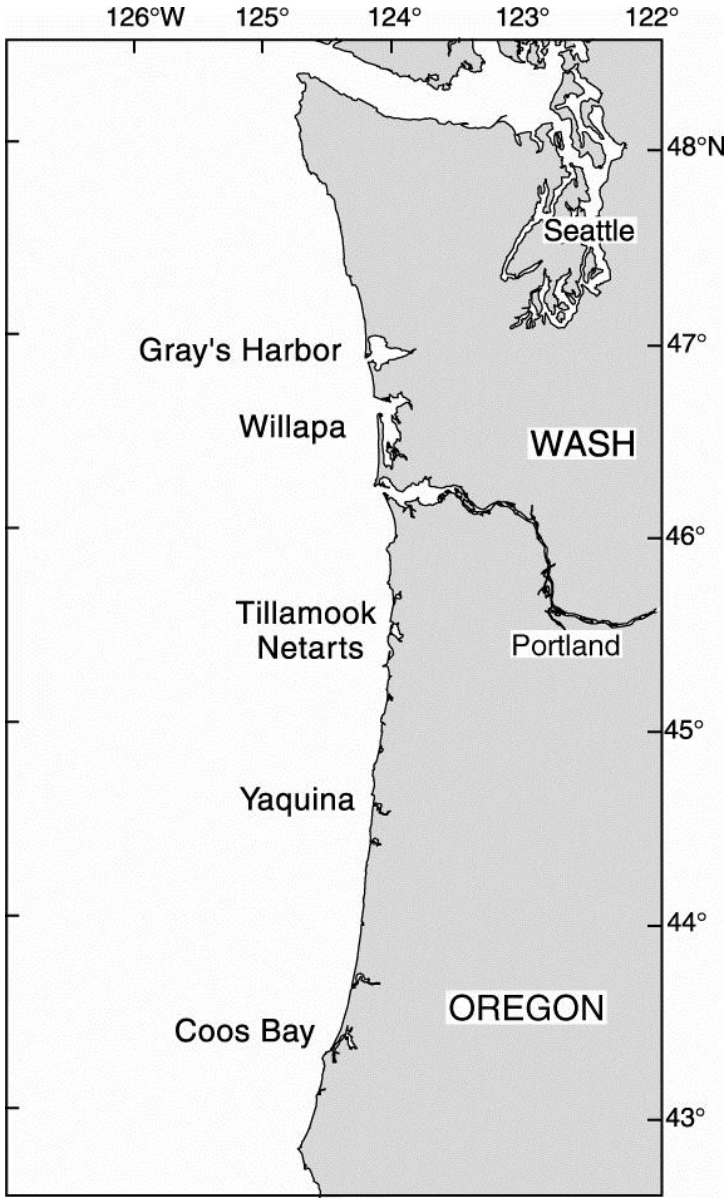


Figure 1. Major sampling sites in Oregon and Washington

Sampling Methods for Green Crabs

Our sampling effort in 2008 focused on one Washington and four Oregon estuaries: Coos, Yaquina, Netarts, Tillamook, and Willapa Bay (Figure 1). These estuaries were sampled at least twice times during the 2008-trapping season (Appendix 2). In each estuary, we selected study sites within various habitat types and tidal levels. Since green crabs are rare and 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^{o}-22^{o} C in the summer (Behrens Yamada and Davidson 2002). Green crabs are noticeably absent 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).

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*. Since traps differ in their sampling efficiency for different sizes of crabs, we used three trap types (Table 1). Folding fish traps, with their wide slit-like openings, work well for adult crabs larger than 40 mm carapace width (CW); while minnow traps with their small mesh size (0.5 cm) retain young-of–the-year green crabs. Green crabs start entering these baited traps when they are around 30 mm CW. Pitfall traps are water-filled 5-gallon buckets buried into the sediment so that their rims are flush with the surface of the sediment. Thus they trap actively foraging crabs of any size. Pitfall traps were only used at the Stackpole site in Willapa Bay where green crabs have been continually sampled by this method since 1998. Typically, we would trap young-of–the-year green crabs in the high intertidal with minnow and pit fall traps and larger adult crabs in the mid to low intertidal and subtidal zones with folding fish traps (Appendix 2).

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 (CW)
Folding Fukui Fish Trap	Plastic mesh (2 cm) with two slit openings (45 cm)	63 x 46 x 23 cm	Subtidal to lower intertidal	Large >40 mm
Minnow/ Crayfish	Wire mesh (0.5 cm) cylinder with two openings expanded to 5 cm	21 cm diameter 37 cm long	Medium to high	Medium-large 20-70 mm
Pit fall	Water-filled 5-gallon bucket embedded into the sediment	31 cm diameter 37 cm high	High	All sizes

On gravel shores, we added rocks to the minnow 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 one tidal cycle (typically 24 hours). We retrieved the traps at low tide, identified all crabs and other by-catch to species and noted the sex, carapace widths (CW) and molt stage of all green crabs (Appendix 3). Green crabs were measured between the tips of their fifth anterio-

lateral spines using digital calipers. Native crabs and other by-catch were released while green crabs were removed from the ecosystem and destroyed.

Table 2. Relative Green Crab abundances (# per 100 trap-days) for study sites in Oregon and Washington estuaries. Data for Grays Harbor 2002 and Willapa Bay 2002-2003 were kindly supplied by Washington Department of Fish and Wildlife and those for Willapa Bay 2004, by P. Sean McDonald.

Estuary	Number of crabs trapped divided by (# trap-days)						
	2002	2003	2004	2005	2006	2007	2008
Coos Bay	9 (180)	14 (203)	18 (137)	9 (242)	22 (273)	52 (246)	65 (276)
Yaquina	26 (168)	63 (1084)	12 (461)	39 (290)	48 (211)	48 (231)	35 (227)
Netarts	0 (44)	11 (44)	12 (39)	52 (106)	47 (82)	35 (103)	17 (89)
Tillamook	2 (71)	6 (70)	4 (51)	12 (102)	41 (147)	15 (93)	1 (100)
Willapa	57 (1640)	13 (409)	6 (195)	113 (449)	19 (245)	4 (318)	0 (98)
Grays Harbor	5 (1203)	--	--	2 (94)	3 (175)	0 (30)	--
Total	99 (3306)	107 (1810)	52 (883)	228 (1283)	180 (1133)	154 (1021)	118 (692)

Estuary		Catch per 100 trap-days					
	2002	2003	2004	2005	2006	2007	2008
Coos Bay	5	7	13	4	8	21	**24**
Yaquina	**15**	6	3	13	23	21	15
Netarts	0	**25**	**31**	**49**	**57**	**34**	19
Tillamook	3	9	8	11	28	16	1
Willapa	3.5	3	3	25	8	1	0
Grays Harbor	0.4	--	--	2	2	0	--
Total	3	6	6	18	16	15	17

Table 3. *Carcinus maenas* catch rates (crabs per 100 trap-days) by embayment in the Pacific Northwest, 1997–2008. P indicates confirmed presence from public reports.

	Number of *Carcinus maenas* per 100 trap-days											
Embayment	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Quatsino Sound											34	
Winter Harbor											1254	
Klaskino											183	
KyuquotSound, BC						P			P	53	38	
Mary Basin											33	
Tlupana Inlet											3	
Sydney Inlet											150	
Esperanza Inlet BC					P	P	P		5	46		
Nootka Sound BC				P						3		
Clayoqout Snd. BC				P						20		
Barkley Sound. BC			P						P	172		120
Pipestem Inlet											2202	2110
Esquimalt BC			P									
Grays Harbor, WA		28	3	3	1	0.4			2	2	0	
Willapa Bay, WA		35	43	4	3	3.5	3	3	25	8	1	<1
Necanicum, OR											P	P
Tillamook Bay, OR	P	128	P	P	2	3	9	8	11	28	16	1
Netarts Bay, OR	P	139			6	0	25	31	49	57	34	19
Nestucca Bay, OR											P	P
Yaquina Bay, OR	P	192	69	63	57	15	6	3	13	23	21	15
Alsea Bay, OR		P				P	P				P	
Winchester Bay, OR		P										
Coos Bay, OR	0.2	65	38	P	63	5	7	13	4	8	21	24
Coquille River, OR		P							5			

Results

Densities in Pacific Northwest

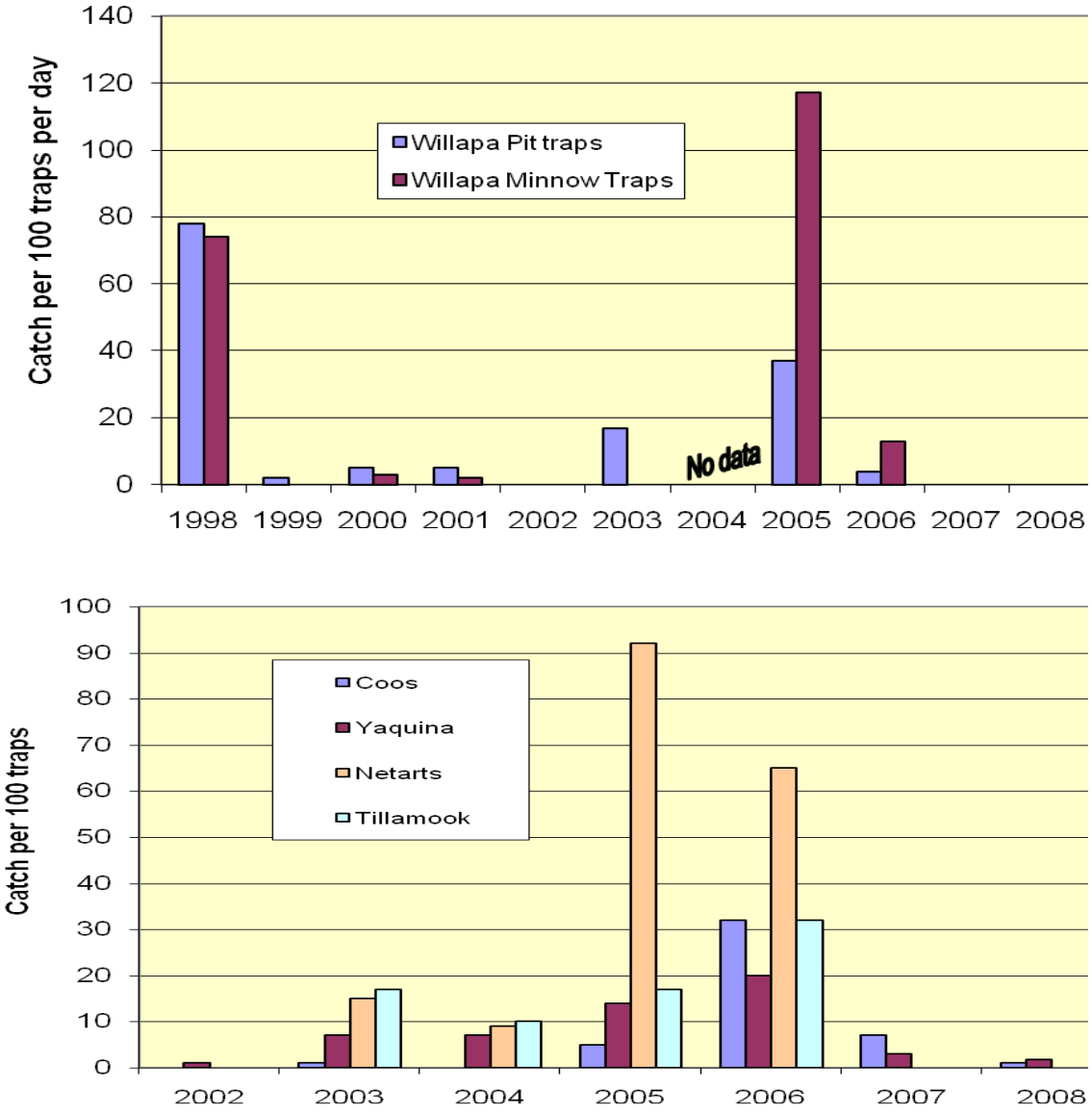
The relative abundances of green crabs trapped in Oregon and Washington estuaries in 2008 are tabulated in Appendix 2 and summarized in Tables 2 and 3. As can be seen from Appendix 2, catch per unit effort (CPUE) is extremely variable. Many factors contribute to this variability, including water temperature, bait type, trap type, tide level, phase in the tidal cycle and the patchy distribution pattern, molt phase, and hunger level of the crabs. Sampling bias also plays a role. For example, when green crabs were rare in Oregon, we focused on known "hot spots" to at least catch a few crabs for age class analysis. One thus must use caution in interpreting differences in CPUE between sites and over time. Minor differences in CPUE are not significant but difference of an order of magnitude would be.

What can be concluded is that catches in Oregon and Washington have decreased an order of magnitude since the 1998 colonization event and have increased slightly after the 2005 recruitment event (Tables 2, 3). While average CPUE per 100 traps ranged from 65 to 192 in 1998, it dropped to 0-15 by 2002. Average catches in both Oregon and Washington averaged less than 7 crabs per 100 traps for 2002, 2003 and 2004. Averages catches from 2006 to 2007 roughly doubled due to good recruitment in 2005 and 2006. The most interesting development over the last three years has been the extensive sampling program for non-native species in Briths Columbia by Fisheries and Oceans Canada. (Gillespie et al. 2006, 2007, 2008). While no green crabs were trapped in the inland sea, east side of Vancouver Island nor north of Vancouver Island, all the inlets sampled on the west coast of Vancouver Island between Quatsino Sound and Barkley Sound yielded green crabs. Densities in many sites were comparable, to those measured in Oregon and Washington. However, catches in Pipestem Inlet in Barkley Sound in 2007 (average of 22 per trap), and Winter Harbor in Quatsino Sound (12 per trap) were an order of magnitude higher than those observed in Oregon and Washington right after the 1997/98 El Niño (Table 3).

Recruitment

Late-stage young-of-the-year (YOTY) green crabs typically enter traps once they reach 30 mm in carapace width by the end of August. Since green crabs live up to 6 years, one good recruitment event is needed at least once every 5 years to keep the population from going extinct. When the last crabs of the 98-cohort died of senescence in the summer of 2004, the 2003 year class became the dominant one in Oregon and Washington estuaries. Even though the 2003 cohort was less abundant than the 1998 one, it produced enough larvae in 2005 to adequately "seed" Oregon and Washington estuaries to keep the population from going extinct. In Willapa Bay, the 2005 recruitment event was the strongest since 1998 (Figure 2; Appendix 4). While recruitment in Oregon estuaries was good in 2006, Washington estuaries showed a decline. 2007 and 2008 were poor recruitment years with no YOTY crabs being caught north of Yaquina Bay (Figure 2, Appendix 4).

Figure 2. Recruitment strength of young-of-the-year green crabs in Willapa Bay, Washington and in four Oregon estuaries. For average sizes of recruits, see Appendix 4.



Age Structure of Green Crabs in Oregon and Washington Estuaries

From previous mark and recapture studies and from shifts in size frequency distributions over time (Behrens Yamada et al. 2005,) we estimated the age of green crabs retrieved from Oregon and Washington estuaries in 2008. We assigned crabs to age classes based on their size and coloration (Table 4; Appendix 3). For example, during the summer crabs between 50 and 70 mm, with green or yellow carapaces would represent the 2007 year class. Larger crabs would primarily represent the 2005 and 2006 cohorts. We estimate that these two cohorts now comprised around 90% of breeding population, and would be able to seed Oregon and Washington estuaries until 2012.

Table 4. Estimated age structure of *Carcinus maenas* retrieved from Oregon and Washington estuaries in 2008. Total crabs include trapped crabs recorded in Table 1, those caught in pheromone trials, sports catches and molts found on the shore. "Older" mostly represent the 2005 and 2006 cohorts.

Estuary	2008	2007	older	Total
Coos Bay	1	4	61	66
Yaquina	1	4	36	41
Netarts	0	1	17	18
Tillamook	0	0	2	2
Willapa	0	0	4	4
Grays Harbor				
Total	2	9	120	131
Percent	1.5	6.9	91.6	100

Conclusions

Population densities of green crabs in Willapa Bay, Washington averaged less than 1 per 100 traps and ranged from 1 to 24 per 100 traps in Oregon estuaries. Lower densities in Washington are attributable to poor recruitment in 2006 and a complete lack of recruitment in 2007 and 2008.

While green crabs in Oregon and Washington are rare, they are thriving in some inlets on the west coast of Vancouver between Quatsino Sound and Barkley Sound (Behrens and Gillespie 2008 and Gillespie et al. 2006, 2007, 2008). Two hot spots were found on our 2007 cruise

around Vancouver Island: Winter Harbor in Quatsino Sound with an average of 12 green crabs per trap and Pipestem Inlet in Barkley Sound with 22 per trap. One trap in Pipestem Inlet yielded 195 green crabs. 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 Yamada (2003) and Jensen, McDonald and Armstrong (2007) found that high densities of green crabs occur primarily in microhabits where larger native crabs are rare or absent. In these two studies and during the 2007 survey around Vancouver Island (Gillespie et al 2007), green crabs occur higher on the shore and in more marginal habitat than larger 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 and high temperatures than green crabs and thus avoid these shallow, warm, low saline microhabitats. In the absence of competition and predation by these larger crabs, green appear to flourish.

Outreach efforts to educate the general public, including boaters and shellfish growers, not to transport 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 crab in the inland sea between Vancouver Island and the mainland, including Puget Sound and Hood Canal. Once green crabs get established in the inland sea, they would spread very quickly as many suitable habitats, devoid of larger crabs and other predators, exist in shallow, warm bays near freshwater outfalls. Other non-native species such as the Japanese oyster, the manila clam and the purple varnish clam spread rapidly throughout the inland sea as their larvae are retained and not carried out to sea.

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Appendix 1. Physical data for *Carcinus maenas* sampling sites in Oregon and Washington estuaries. Range of values observed includes sampling times from 2002 to 2005.

Site	Date	Location Description	S ‰	Water Temp.	Air Temp.	Green Crabs Found?
COOS BAY						
Jordan Cove		***Range of values observed***	***5-34***	***14-22***	***14-24***	
	9-17-08		30	15.1	17	yes
	9-19-08				13	no
Russell Point		***Range of values observed***	***22-33***	***11-20***	***9-28***	
N 43° 25.974'	6-17-08					yes
W 124° 13.252'						
Trans Pacific N	6-17-08		24	19	17	yes
N 43° 26.'	9-18-08		34	14.2	13	no
W 124° 14.'						
Trans PacificS		***Range of values observed***	***22-33***	***11-18***	***10-27***	
N 43° 26.571'	6-17-08		25	16.3	15	yes
W 124° 13.388'	9-18-08		34	14.2	11.4	yes
Haynes Inlet	9-18-08		32	15	16	no
N 43° 27.003'						
W 124° 13.478'						
Clausen's Oysters	6-17-08		21	19	17.3	yes
N 43° 26.911'						
W 124° 12.209'						
Kentuck Inlet	9-16-08		32	17.2	17.5	no
N 43° 25.299'						

W 124° 11.522'						
Isthmus Bridge	9-17-08		30	17.7	11	yes
Joe Nye Slough		Mudflat from Zostera marina to high zone				
N 43° 20.343'		Hotspots = near undercut bridge piling				
W 124° 18.590'	6-19-08		26	17.3	15	yes
Charleston Bridge		Old pier by Fish grotto				
N 43° 20.512'	9-18-08				11	no
W 124° 19.027'						
South Slough		Near data logger across from Valino Island				
N 43° 18.944'	6-19-08					
W 124° 19.251'						
Pony Point		Mudflat near rip rap, *Zostera marina* zone	***17-32***	***11-17***	***11.5-18***	
N. Bend Airport						
N 43° 25.403'	6-19-08		26	12	9.5	yes
W 124° 14.369'	9-17-08		32	13.5	9.2	yes
YAQUINA BAY						
Johnson Slough	***Range of values observed***		***4-32***	***15-20***	***16-22***	
N 44° 34.692'	3-27-08	Below bridge/along creek bank , *Salicornia* patches	10	9.2	8.2	no
W123° 59.333'	9-5-08		26	15.4	14.3	yes
Parker Slough	3-27-08		5	7.7	5	yes
N 44° 35.392'						
W124° 00.957'						
Sally's Bend A		***Range of values observed***	***22-33***	***12-23***	***12-26***	
N 44° 37.699'	8-26-08	*Scirpus* patches below intersection	30	20.5	21.6	no

W124° 01.482'	9-5-08		32	18.2	18.3	no
Sally's Bend B		***Range of values observed***	***29-33***	***12-19***	***12-24***	
N 44° 37.640'	9-5-08	*Scirpus* patches below George Street	32	18.2	18.3	no
W124° 00.790'						
Sally's Bend C		***Range of values observed***	***19-32***	***10-19***	***9-22***	
N 44° 37.419'	1-18-08	*Zostera marina* zone from gate to Fishing platform		9	11	no
W124° 01.463'	2-14-08		20	10	13	no
	3-18-08			14	14	no
	4-30-08		18	14.6	15	yes
	9-5-08		32	18.2	18.3	yes
Hatfield Marine		***Range of values observed***	***22-34***	***11-21.5***	***12-23***	
Science Center	2-14-08		22	9.8	10	no
Pump house	3-27-08		16	8.7	8.8	yes
N 44° 37.408'	4-7-08		23	9.0	8.5	yes
W124° 02.576'	4-30-08		20	13	13	yes
Oregon Coast			***19-34***	***9-25***	***8-23***	
Aquarium	2-14-08		27	10	13	yes
N 44° 37.108'	3-27-08		20	8.8	8	no
W124° 02.165'	8-26-08		31	20.8	19.1	no
Idaho Point		***Range of values observed***	***19-35***	***12-27.5***	***12-23***	
N 44° 36.818'	2-14-08		19	10	13	yes
W 124° 01.582'	3-27-08		16	8.4	7.4	yes
	4-30-08		21	14.3	16.5	yes
	8-8-08		34	12.7	19.5	yes
TILLAMOOK BAY						

Tillamook Spit A			***0-30***	***13-19***	***13-27***	
N 45° 30.843'	4-22-08	mudflat- eelgrass zone below rip rap and in *Scirpus*		8.8	7.7	no
W 123° 56.738'	6-4-08				15	no
	8-27-08					no
	9-21-08		25	10.2	16.8	
Tillamook Spit B	4-22-08		0	8.5	7.2	no
N 45° 30.456'	6-4-08		0	17.1	14.2	no
W 123° 56.615'	8-27-08					no
	9-21-08				16.8	no
Pitcher Point	8-27-08	South of Spit B – mudflat in Japanese eelgrass zone				
N 45° 30.365'	9-21-08				16.8	no
W 123° 56.508'						
NETARTS BAY						
RV Park	6-4-08	mud flat east of bridge	0	17.5	15.5	yes
N 45° 25.___'						
W 123° 56___						
Whiskey Creek						
Salmon hatchery		***Range of values observed***	***0-34***	***13-20***	***14.5-21***	
N 45° 23.670'	4-22-08	On mudflat and in creek	0	6.6	8.2	no
W 123° 56.214'	8-28-08					no
	9-21-08				15	no
Mile 2	9-21-08	*Scirpus* marsh	34	22.5	15	no
N 45° 24.229'						
W 123° 56.694'						
Paddle Creek	6-4-08	Between intersection and Mile 2	20	16.1	17	**yes**

N 45° 24.___' W 123° 56.___'						
Intersection of Whiskey Creek & Netarts Bay Roads N 45° 24.865' W 123° 56.064'	***Range of values observed***		***0-34***	***13.5-20***	***15-23***	
	4-22-08	Pool below culvert draining Freshwater marsh	0	7.4	8.2	**yes**
	6-4-08		20	16.1	17	**yes**
			2	17.7	12.3	**yes**
WILLAPA BAY						
Stackpole Leadbetter Pt. Sate Park N 46° 35.848' W 124° 02.195'		***Range of Values observed***	***14-28***	***11-19***	***9-28***	
	8-19-08	Pit traps in former *Spartina* field	30	15	17	no
	9-15-08		30	22	15	no
	10-15-08		30	9	8	no
Kemmer's sandridge	9-15-08	*Scirpus* field	24	22	23	no
Port of Penisula	10-15-08	Upper edge of jetty, former *Spartina* field	30	10	11	no

Appendix 2. Relative abundance of crab species and sculpins (Numbers/trap/day) in Oregon and Washington estuaries during 2008. An asterisk beside trap number indicates that other traps were either opened or were stolen.

Coos Bay

Site		Trap Type	Zone	*Carcinus maenas*	*Hemigrapsus oregonensis*	*Hemigrapsus nudus*	*Cancer magister*	*Cancer magister* (Recruits)	*Cancer productus*	Sculpin	Number Traps
Russell Point	6-19-08	Fish	Pools by bridge	1.0			5	0		4.25	4
	6-20-08	Fish	*Zoster marina*	0.5			37	0		0.5	4
	6-21-08	Fish		0			3.75	0		1.75	4
Pony Point/Airport	6-20-08	Fish	*Zostera marina*	1.46			4.62	0	1.23	0.54	13
	9-17-08	Fish		0.4	0.07		8.53	0	1.07	3.2	15
Haynes Inlet	9-18-08	Minnow	*Scirpus*		0.2		1.1	0		4.1	10
Clausen's Oysters	6-18-08	Fish	*Mid*	0.08	2.78		4.07	0		6.46	13
		Fish	*Mid*								
Kentuck A	6-19-08	Fish	*Low*	0	0	0	10.87	0		1.5	8
	9-16-08	Minnow	*high*	0	0.1	0	1.2	0	0	1.4	20
Isthmus Bridge	9-17-08	Fish	*Mid*	0.25			9.94	0		0.5	16
TransPacific Ln. N	6-18-08	Fish	*Mid*	0.1	0.2		7.4	0		7.8	10
	6-19-08	Fish		0			1.75	0		3.25	8
	9-18-08	Fish		0	0.1		23.4	0		0.7	10
TransPacific Ln. S	6-18-08	Fish	*Mid*	0.5			17.2	0		2.2	10
	6-19-08	Fish		0.37			17.63	0		1.37	8
	9-18-08	Fish		0.1			22.6	0		0.3	10

Jordan Cove	9-17-08	minnow	*Scirpus*	0.1			0.15	0		2.96	20
	9-19-08	Minnow					0.42	0		0.40	43
Charlston Bridge	9-18-08	Minnow	*Marsh by old pier*			0.4		0		0.2	10
Joe Ney Slough	6-20-08	Fish		1.0	0.31		2.92	0		2.85	13
	7-17-08	Fish		0.17	0.16		0.92	0		2.67	12
South Slough-Valino data logger	6-20-98	Fish		0.13	0.77	0.77	5.38	0		11.61	15
Total Number				65							276

Yaquina Bay

Mean CPUE (Catch/trap/day)

Site	Date	Trap Type	Zone	*Carcinus maenas*	*Hemigrapsus oregonensis*	*Hemigrapsus nudus*	*Cancer magister*	*Cancer magister* (Recruits)	*Cancer productus*	Sculpins	Number Traps
Johnson Slough	3-27-08	Fish	Below Bridge	0	0	0	0.3	0			6
	9-5-08	Fish		0.5			15.5	0.5			2
	9-5-08	Minnow	Marsh	0.07	0.07		0.07	0		0.53	15
Parker Slough	3-27-08	Fish	*Zostera marina*	0.33	0	0.67	0.33	0			3
Sally's Bend A	8-16-08	Minnow	*Scirpus*	0	0.07	0	0	0	0	0.73	15
	9-5-08	minnow		0	0.17			0		1.00	6
Sally's Bend B	9-5-08	minnow	*Scirpus*	0	1.67			0		1.17	6
Sally's Bend C Fishing Platform	1-18- 08	Fish		0	0	0	0.4	0	0	0	10
	2-14-08	Fish	*Zostera marina*	0	0.1	0.1	0	0	0	0	10

	3-18-08	Fish	*Zostera japonica*	0	0.1	0.1	0	0	0	0	10
	5-1-08	Fish		**0.17**		0.5		0			6
	9-5-08	Fish		0.20	0.1		0.30	0		3.10	10
HMSC Pump house	2-14-08	Fish	*Zostera marina*	0	0.86	0	0	0	0		7
	3-26-08	Fish		**0.2**	1.0	0.2	0.6	0	0.2		5
	3-27-08	Fish		0	0.4			0			6
	4-7-08	Fish		**0.15**	0.1	0.1	0.55	0.1	0.45	0.05	20
	5-1-08	Fish		**0.2**	0.05		0.1	0.05	0.8	0.05	20
Oregon Coast Aquarium	2-14-08	Fish	Channels /pools	**0.6**	0.2	0	0.2	0	0.8		5
	3-27-08	Fish	pools	0	0.2			0.4			5
	3-28-08	Fish		0	0.4			1.2			5
	8-26-08	Minnow	*Scirpus*	0	0.33	0.13	0	0	0	0.46	15
Idaho Point	2-14-08	Fish	Low	**0.1**	0.8		0.2	0	0.1	1 hermit	10
	3-27-08	Fish		**0.86**	0.29		0.43	0			7
	3-28-08	Fish		**0.43**	0.29		9.57	0			7
	5-1-08	Fish		**0.2**	0.6		2.8	0.8			10
	6-28-08	Fish	Low	0.5			0.56	0	7.0		4
	8-8-08	Fish	Low	**1.5**			2	0		5.5	2
Total Number				35							227

Tillamook Bay

Mean CPUE (Catch/trap/day)

Site		Trap Type	Zone	*Carcinus maenas*	*Hemigrapsus oregonensis*	*Hemigrapsus nudus*	*Cancer magister*	*Cancer magister* (Recruits)	*Cancer productus*	Sculpin	Number Traps
Tillamook Spit A	4-22-08	Fish	*Z. japonica*	0	0	0	0	0	0	0	9
	6-5-08	Fish		0.01	0.36	0	0	0	0	5	11
	6-6-08	Fish		0	0.64	0	0	0	0	1.45	11
	8-27-08	Minnow	*Scirpus*	0	0.1	0	0.3	0.7	0	2.3	10

	9-21-08	Minnow			0.08			0.69		3.08	13
Tillamook Spit B	4-22-08	Fish	*Zostera japonica*	0	0	0	0	0	0	0.5	2
	6-5-08	Fish	*Scirpus*	0	0	0	0	0	0	3	3
	6-6-08	Fish		0	0	0	0	0	0	4	3
	8-27-08	Minnow	*Scirpus*	0	0.2	0	0	0.5	0	4.8	10
	9-21-08	Minnow						0.1		0.5	10
Pitcher Point	8-27-08	Minnow	*Scirpus*	0	0.5	0	0	0	0	4	8
	9-21-08	Minnow						0.1		1.3	10
Total Number				1							100

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

Site		Trap Type	Zone	*Carcinus maenas*	*Hemigrapsus oregonensis*	*Hemigrapsus nudus*	*Cancer magister*	*Cancer magister* (Recruits)	*Cancer productus*	Sculpin	Number Traps
RV Park	4-22-08	Fish	creek /mudflat	0	0	0	0	0	0	0	4
	6-5-08	Fish		0.17	0	0	0	0	0	5	6
	6-6-08	Fish		0	0.5	0.67	0.33	0	0	1.5	6
		Fish									
Intersection	4-22-08	Fish	pools	0.6	0	0	0	0	0	0.2	5
	6-5-08	Fish		0.33	4	1	0	0	0	1.0	3
	6-6-08	Fish		1.67	23	0.3	0.17	0	0.17	0.33	6
		Fish									
Paddle Creek	6-6-08	Fish		0.5	2	3.5	0	0	0	4	2
Mile 2	9-21-08	Minnow			0.27	0.27		0		1.88	11

Whiskey Creek Salmon Hatchery	4-22-08	Fish	Creek/mudflat	0	0	0	0.1	1.0	0	0.2	9
	6-5-08	Fish		0	8.2	0	0	0	0	9.8	5
	6-6-08	Fish		0.2	6		0.2	0	0	0.6	5
	8-27-08	Minnow	*Fucus*/mudflat	0	0.31	0.06	0	0	0	0.94	16
	9-21-08	Minnow			0.09	0.27		0		0.45	11
Total Number				17							89

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

Site		Trap Type	Zone	*Carcinus maenas*	*Hemigrapsus oregonensis*	*Hemigrapsus nudus*	*Cancer magister*	*Cancer magister* (Recruits)	*Cancer productus*	Sculpin	Number Traps
Stackpole	8/20/08	Pit-fall	*Old Spartina* patch	0	0	0	0.25	0.08	0	0	12
	8/21/08	Pit-fall		0	0	0	0.08	0	0	0	12
	9/21/08	Pit-fall		0	0	0	0.08	0.16	0	0	12
	10/16/08	Pit-fall		0	0	0	0.08	0	0	0	12
	8/20/08	Minnow	*Old Spartina* patch	0	0	0	0.3	0	0	2.3	10
	8/20/08	Minnow		0	0	0	0.2	0	0	1.1	10
	9/12/08	minnow		0	0	0	0.2	0.1	0	2.0	10
	10/16/08	minnow		0	0	0	0.1	0.1	0	3.3	10
Kemmer's sand ridge	9/12/08	Minnow	Scirpus field	0	0	0	0.08	0	0	7.2	5
Port of Peninsula	10/16/08	Minnow	Upper edge of jetty, old *Spartina* field	0	0	0	0.2	0	0	3.8	5
Total Number				0							98

Appendix 3. *Carcinus maenas* Catches and Sightings from Oregon and Washington Estuaries in 2008. Crabs were assigned to year classes based on the size and condition attained by tagged crabs of known age (Behrens Yamada et al. 2005). Crabs that are green have molted recently, while red crabs have not molted for a long time, in some case well over a year. Missing limbs are numbered in sequence: 1= Right claw; 5= last leg on right side, 6= left claw, 10=last leg on left side.

Estuary	Site	Date	Sex	CW	Color	Year Class	Condition/Comments
COOS	Charleston Boat Basis	11-24-08	M		Orange	Older	Found with puncture wounds by Scott Groth
	South Slough by bridge	3-15-08	M	77			Clam harvester
	South Slough by Valino data recorder	6-21-08	M	73.9	Yellow		Good
		7-17-08	M	76.8	Orange		Good
			M	78.9	Yellow-green		Good – Paul Dunn
			M	63.8	Yellow-green	07	Good- Paul Dunn
	Joe Ney Slough Under bridge	6-21-08	M	54.6	Yellow-green	07	No # 1, 3, 6
			M	76.8	Orange-red		good
			M	75.6	Yellow-orange		good
			M	71.3	Yellow		Good
			F	69.5	Yellow-green		Good
			M	62.2	Yellow-green	07	Good
			M	66.3	Yellow		Good
			M	85.9	Yellow-green		Good
			M	85.6	Yellow-orange		No # 1, 6
			M	86.6	Yellow		Good
			M	71.1	Yellow		Good
			F	74.0	Yellow		# 1 regenerating
			M	87.9	Yellow		Good
	Airport /Pony Pt	6-20-08	M	90.0	Yellow		Good

			M	89.16	Yellow		Tips of # 1 worn
			M	90.8	Yellow		# 2 missing
			M	86.5	Yellow		Good
			M	85.5	Yellow		Good, small barnacles
			M	91.3	Yellow		Good
			M	80.5	Yellow		# 1 dactyl worn
			M	84.0	Yellow-orange		No # 7
			M	81.5	Yellow		Left-handed
			M	86.1	yellow		Good
			M	80.0	Yellow		Good
			M	81.4	Yellow		No #1
			F	73.3	Orange		Good
			M	80.2	Orange		Good
			M	77.3	Yellow		# 6 propus worn
			M	89.1	Yellow		No # 6
			F	75.8	Yellow- green		Good
			M	77.3	Orange		Good –small barnacles
			M	62.8	Yellow		good
		9-17-08	M	89.8	Yellow-orange		Good; barnacles
			M	89.0	Yellow		Good
			M	85.9	Yellow-orange		Missing legs # 2, 4, 6,
			M	81.0	Orange		No # 7; claw tips worn on #1
			M	84.0	Yellow-orange		Good
	Jordan Cove	9-18-08	M	66.5	Yellow-green	07	No # 3, 6
			M	47.0	Yellow-green	08	Last spine on carapace missing
	Under 101 Bridge	6-19-08	M	84.5	Orange		Right propus chipped; barnacles
			M	83.4	Orange-red		Missing # 6, #1 propus worn
			M	84.0	Yellow		No # 1, 6, 8
			M	72.9	Yellow		No # 1, 6
		6-20-08	M	91.26	Yellow		No # 1, 6

			M	84.5	Yellow		No #1
	Trans Pacific Blvd North	6-18-08	M	76.0	Yellow		# 6 puncture mark #7, 8 missing
	Trans Pacific Blvd South	6-18-08	M	79.5	Yellow orange joints		#1,2 missing
			M	88.4	Yellow-green		Good
			M	86.1	Yellow		Good
			M	86.4	Yellow		#1,7 missing
			M	74.6	Orange-red		3 barnacles, puncture in carapace
		6-19-08	M	87.0	Yellow		Good
			M	81.2	Yellow-green		Left-handed
			M	84.0	yellow		No #6
		9-18-08	M	84.2	Yellow-orange		good
	Clausen Oysters	6-17-08	M	88.4	Yellow		Good
	Isthmus Slough	9-17-08	F	70.3	Yellow-orange		Good; barnacle
			M	81.5	Orange		Good, barnacle
			M	87.7	Yellow-orange		Good
			F	70.3	orange		Good, barnacle
Winchester Bay	Boat Basin dock #4	4-17-08	M	85	Red joints		Reported by Scott Groth
SIUSLAW	Florence boat ramp	6-28-08	M	75.5	green		Sports catch reported by Scott Growth
		8-16-08	M	82.7	Orange joints		Sports catch reported by Christopher Stephens

YAQUINA	Johnson Creek	9-5-08	M	44.3	Yellow	08	Only recruit for Yaquina
			M	84.6	Yellow-orange		
	Sawyers Landing on top of float	3-13-08	M	81.4	Orange		Mitch Vance No 3,4,5,7,9,10
	Parker Slough	3-27-08	M	82.5	yellow		good
	Sally's Bend A						
	Sally's Bend B						
	Sally's Bend C	5-1-08	M	56.2	Yellow	07	good
	Fishing platform	9-5-08	M	74.3	Yellow-orange		No # 4
		9-5-08	M	83.7			No # 7, 10
		12-08-08	M	77.7	Orange-red		Missing #1 dactyl; Mitch Vance
	HMSC Pump house beach	2-27-08	M	90.14	Orange-yellow		Missing # 6
		4-7-08	M	87.8	Orange		Good
			M	76.2	Yellow-orange		Pinch marks on basal of #1
			M	71.3	red		Left dactyl worn
		5-1-08	M	87.4	Orange		No #1
			M	93.6	Red orange		Barnacles
			M	91.0	Orange		Right propus tip worn/ no # 2,7
			M	84.0	orange		Left propus missing
	Aquarium mud flat	2-14-08	M	92	Yellow		Missing # 7,9,10
			M	88	Yellow		Good
			M	71	yellow		Good
	Idaho Point	2-14-08	M	71	orange		good
		3-27-08	M	88.8	Yellow orange		Good

			M	81.8	Yellow orange		Missing 3,4
			M	85.8	Orange		Missing 8,9
			M	63.5	Yellow		Missing # 6
			M	48.9	Yellow-orange	07	good
			M	56.8	Yellow-green	07	good
		3-28-08	F	58.1	Yellow-green	07	Good
			M	79.2	Orange		Good
			M	76.8	Yellow-orange		Good- worn dactyl
		4-10-08	M	87.6			good
			M	76.8			One claw missing
			F	73.8			One claw missing
		5-1-08	M	83	Red-orange		Missing dactyl on #6
			M	85	Red-orange		good
		6-18-08	M	84.1	Yellow-green		Left dactyl damaged
			M	88.0	Orange		good
		7-13-08	M	91.4	Orange		No # 6, 8; no dactyl on #1(sports)
		7-31-08	M	84	Yellow-orange		No limbs – only claws (sports)
		8-8-08	M	94.2	Yellow-orange		#2 missing
			M	81.4	Orange		Good
			M	81.3	Yellow-orange		Dactyl chipped
TILLAMOOK	Spit	6-5-08	M	76.8	Yellow-orange		good
	Garibaldi dock by TEP	08/30/08	M	80.1	Yellow-orange		
NETARTS	Outside RV Park	2-18-08	M	84.6	Yellow orange		Good-Sports catch – RV Park
		6-5-08	M	86.7	Red orange		Left claw injured @ base
	Intersection	4-22-08	M	92.3	Red		good
	Netarts Road		M	71.65	Yellow		good
	Whiskey Creek Rd		F	72.65	red		# 1 regenerating missing #2
		6-5-08	M	86.7	yellow orange		No #6

		6-6-08	M	84.1	Yellow-green		#1 propus missing
			M	91.8	Yellow-orange		#1 propus missing
			M	76.4	Orange		good
			M	88.1	Orange		#1 dactyl worn
			M	76.8	Yellow-orange		#2 missing
			M	82.2	Yellow-orange		good
			M	78.6	Orange-red		good
			M	93.2	Yellow-green		good
			M	86.7	Yellow		#6 regenerating
			M	82.4	Yellow		#6 regenerating
	Paddle Creek	6-6-08	M	73.8	Yellow-orange		# 1, 2, missing #6 propus missing
	Whiskey Creek Salmon hatchery	6-6-08	F	49.5	Green	07	good
Nestucca		7-11-08	M	82	Yellow		# 6 missing/ sports catch By Don Graber
Necanicum River	12th Ave. bride Seaside	6-9-08	M	70-90	Yellow		Sports catch reported by Matt Hunter
WILLAPA	Stoney Point	2-10-08	M	69		Older?	Dick Wilson/ Bruce Kaufman
	Tokeland	Summer 08	M	84.5	Green	older	P.Sean McDonald
	Bay Center	2-8-08		v. big		Older	Steve Shotwell
		17-10-08				Older	Steve Shotwell barnacles/missing limbs

Appendix 4. Relative abundance (CPUE) and size of young-of-the-year *Carcinus maenas* at the end of their first growing season in Oregon and Washington estuaries. Crabs were typically caught between mid-August to early October. Catch per unit effort (CPUE) is reported as number of crabs per trap per day. N=number of young 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.

Year Class	Estuary	# Months <10°C	Mean Winter Temp. °C	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		
1998	Yaquina	0	10.9	201		5.00	46.9	5.0	32-60
1999		4	9.0	13	0.20		38.0	5.0	30-47
2000		3	9.5	14		0.31	37.5	5.0	30-45
2001		3	9.5	Not sampled					
2002		4	9.2	1		0.01	38.9		
2003		0	10.5	9		0.07	44.9	5.5	41-59
2004		3	9.9	4		0.07	35.3	5.1	32-43
2005		2	10.3	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		
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			
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			
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			
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			
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				