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Status of the European Green Crab in Oregon and Washington Estuaries in 2009

by

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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, 2008 and 2009 has been 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.

Extensive surveys 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 2008

Date	Talks / Activities	Location
Sept. 29, 2009	"Claw Morphology and Feeding Rates of introduced *Carcinus maenas* and native *Cancer magister*" "Linking Ocean Conditions to Year Class Strength of the invasive European green crab, *Carcinus maenas*"	Gave two talks to Pacific Coast Shellfish Growers Association/ National Shellfish Association at Red Lion Inn, Portland, Oregon
Sept. 25, 2009	"Linking Ocean Conditions to Year Class Strength of the invasive European green crab, *Carcinus maenas*"	Manuscript with Mike Kosro accepted by the journal "Biological Invasions".
Aug. 24-27, 2009	"Claw Morphology and Feeding Rates of introduced *Carcinus maenas* and native *Cancer magister*" "Linking Ocean Conditions to Year Class Strength of the invasive European green crab, *Carcinus maenas*"	Gave two talks to 6th International Conference on Marine Bioinvasions at to Portland State University
July 11-12, 2009	"Linking Ocean conditions to year class strength in the European green crab." Presentation and field sampling exercise	Bi 408/508 class: Biological Invasions in the Marine Environment. Oregon Institute of Marine Biology, Charleston, Oregon
April 6, 2009	"Can ocean Conditions predict the recruitment of the European green crab?" Presentation and field sampling exercise	Bi 450 class: Marine Biology Hatfield Marine Science Center, Newport, Oregon
November 24, 2008	"Can ocean Conditions predict the year class strength of the European green crab?"	Talk given to 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?"	Talk given to 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 421/521 and FW 421/521/ Hatfield Marine Science Center, Newport, Oregon

July 24, 2008	Crab Identification and Claw Function	Talk and demonstration at Marine Science Exploration Summer Camp, Hatfield Marine Science Center, Newport, Oregon
June 28, 2008	"Who eats more baby oysters – introduced green crab or native Dungeness crab?"	Exhibit and poster with Sarah Fisher, Amanda Amstutz, at 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 /Summer 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

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 Bay 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 & Cohen 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. 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 (Behrens Yamada & Gillespie 2008; Behrens Yamada & Kosro 2009).

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 Fukui fish 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 early fall,
- Comparing patterns in recruitment strength over time and correlating them to ocean conditions: winter surface water temperatures, Pacific Decadal Oscillation Indices, 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.

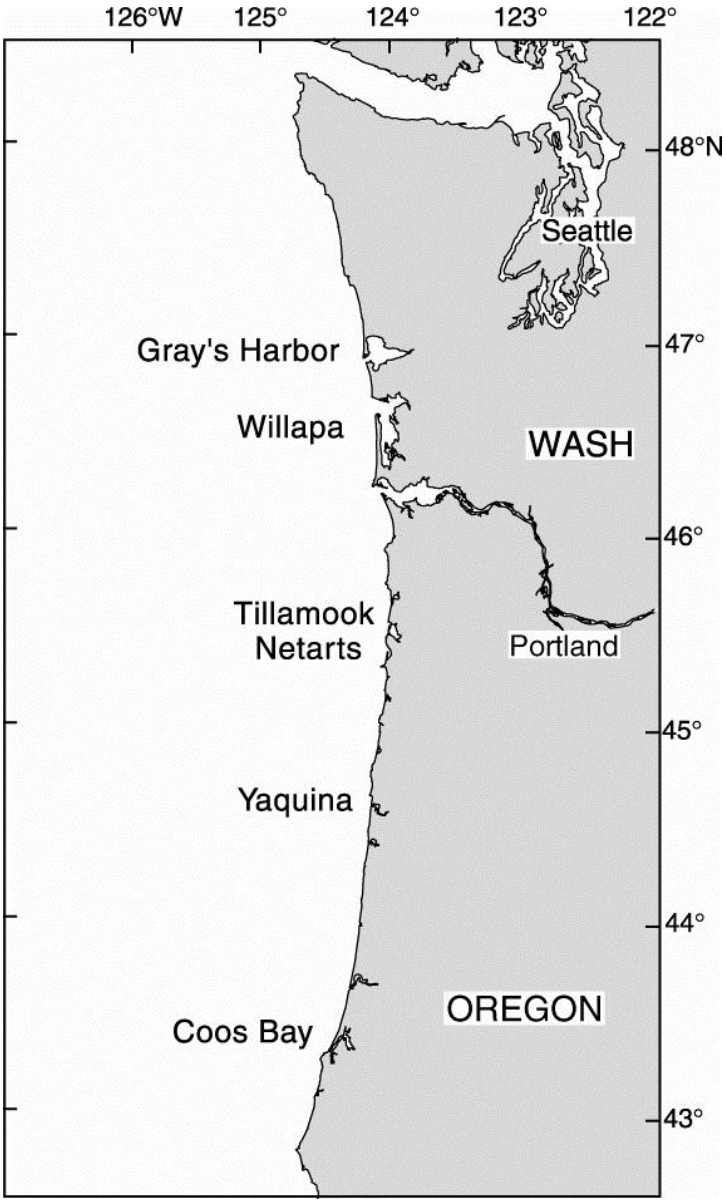


Figure 1. Major sampling sites in Oregon and Washington

Sampling Methods for Green Crabs

Our sampling effort in 2009 focused on two Washington and four Oregon estuaries: Coos, Yaquina, Netarts, Tillamook, and Willapa Bay (Figure 1). Most estuaries were sampled at least twice times during the 2009 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 Fukui 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 Fukui 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*	*2009*
Coos Bay	9 (180)	14 (203)	18 (137)	9 (242)	22 (273)	52 (246)	65 (276)	18 (292)
Yaquina	26 (168)	63 (1084)	12 (461)	39 (290)	48 (211)	48 (231)	35 (227)	19 (162)
Netarts	0 (44)	11 (44)	12 (39)	52 (106)	47 (82)	35 (103)	17 (89)	13 (86)
Tillamook	2 (71)	6 (70)	4 (51)	12 (102)	41 (147)	15 (93)	1 (100)	0 (113)
Willapa	57 (1640)	13 (409)	6 (195)	113 (449)	19 (245)	4 (318)	0 (98)	0 (35)
Grays Harbor	5 (1203)	--	--	2 (94)	3 (175)	0 (30)	--	0 (20)
Total	99 (3306)	107 (1810)	52 (883)	228 (1283)	180 (1133)	154 (1021)	118 (692)	50 (708)

Estuary		*Catch per 100 trap-days*						
	2002	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*
Coos Bay	5	7	13	4	8	21	**24**	6
Yaquina	**15**	6	3	13	23	21	15	12
Netarts	0	**25**	**31**	**49**	**57**	**34**	19	**15**
Tillamook	3	9	8	11	28	16	1	0
Willapa	3.5	3	3	25	8	1	0	0
Grays Harbor	0.4	--	--	2	2	0	--	0
Total	3	6	6	18	16	15	17	7

Table 3. *Carcinus maenas* catch rates (crabs per 100 trap-days) by embayment in the Pacific Northwest, 1997–2009. "P" indicates confirmed presence from public reports. British Columbia data were supplied by Graham Gillespie.

	Number of *Carcinus maenas* per 100 trap-days												
Embayment	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
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		<1
Willapa Bay, WA		35	43	4	3	3.5	3	3	25	8	1	<1	<1
Necanicum, OR											P	P	
Tillamook Bay, OR	P	128	P	P	2	3	9	8	11	28	16	1	<1
Netarts Bay, OR	P	139			6	0	25	31	49	57	34	19	15
Nestucca Bay, OR											P	P	
Yaquina Bay, OR	P	192	69	63	57	15	6	3	13	23	21	15	12
Alsea Bay, OR		P				P	P				P		P
Winchester Bay, OR		P											P
Coos Bay, OR	0.2	65	38	P	63	5	7	13	4	8	21	24	6
Coquille River, OR		P							5				P

Results

Densities in Pacific Northwest

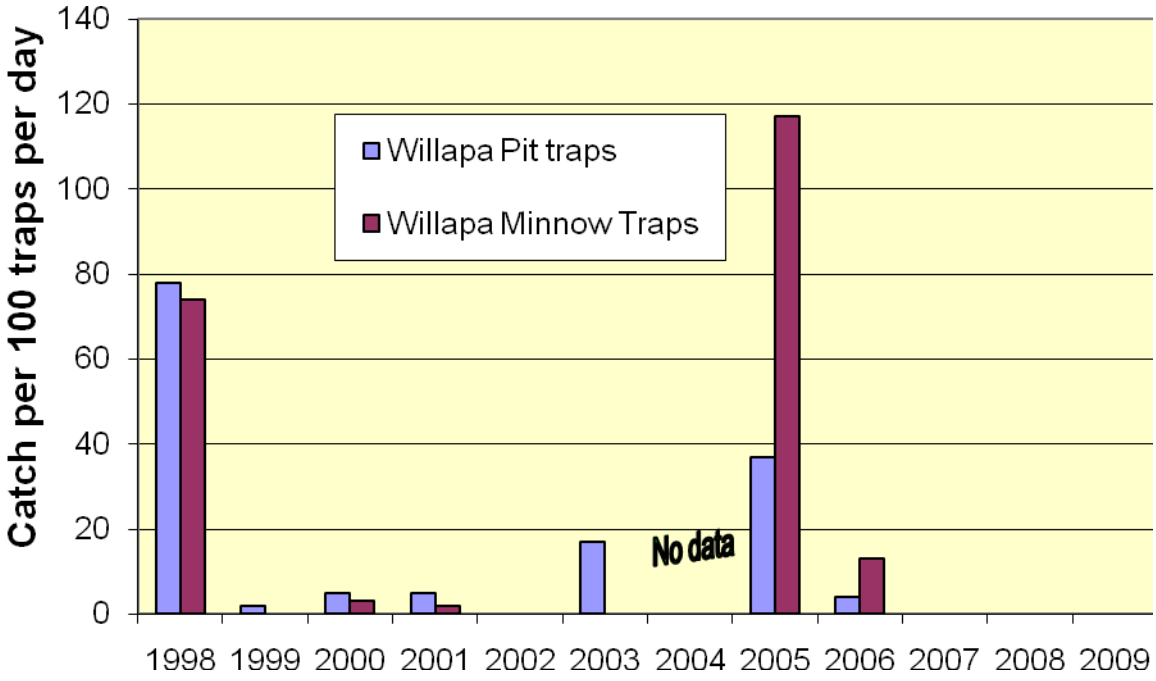
The relative abundances of green crabs trapped in Oregon and Washington estuaries in 2009 are tabulated in Appendix 2 and summarized in Tables 2 and 3. As can be seen from Appendix 2, catch per unit effort (CPUE) is extremely variable. Many factors contribute to this variability, including water temperature, 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.

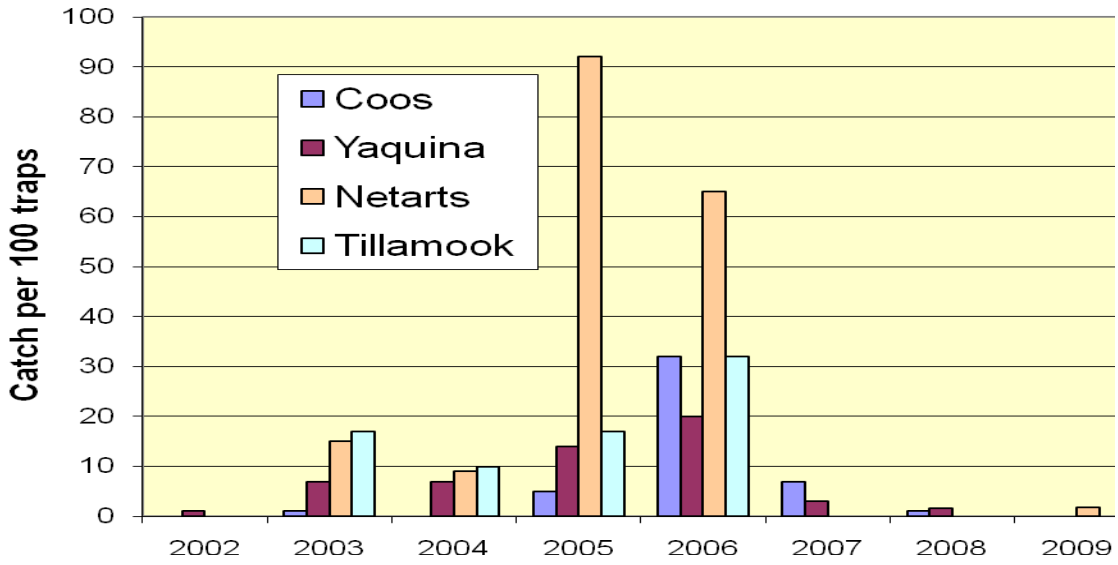
What can be concluded is that catches in Oregon and Washington have decreased an order of magnitude since the 1998 colonization event and increased slightly after the 2005 recruitment event (Tables 2, 3). While average CPUE per 100 traps ranged from 65 to 192 in 1998, it dropped to 0-15 by 2002. Average 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 British Columbia by Fisheries and Oceans Canada. (Gillespie et al. 2007, Gillespie, pers. com.). While no green crabs were trapped in the inland sea between Vancouver Island and the mainland, 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. While densities in many sites were comparable, to those measured in Oregon and Washington, those in Pipestem Inlet in Barkley Sound averaged 22 per trap in 2007 and 2008. These catches are two orders of magnitude greater than what has been observed in Oregon and Washington (Table 3).

Recruitment

Young-of-the-year, or 0-age 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, 2008 and 2009 were poor recruitment years in all estuaries sampled. (Figure 2, Appendix 4).

Figure 2. Recruitment strength 0-age *Carcinus maenas* 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 2009. We assigned crabs to age classes based on their size and coloration (Table 4; Appendix 3). For example, during the summer male crabs between 50 and 70 mm, with green or yellow carapaces would represent the 2008 year class and crabs between 70 to 80 mm, the 2007 year class. Larger crabs would represent by the 2005 and 2006 cohorts. We estimate that crabs in the 2007, 2006 and 2005 year classes represent 96% of the breeding population. While the last 3 year classes have been very week, the strong 2006 cohort would be cable of seeding Oregon and Washington estuaries until 2012.

Table 4. Estimated age structure of *Carcinus maenas* retrieved from Oregon and Washington estuaries in 2009. Total crabs include trapped crabs recorded in Table 1, sports catches and crabs found by shellfish growers.

Estuary	2009	2008	2007	2005/2006	Total
Coquille			1		1
Coos Bay	0	0	1	17	18
Winchester Bay				1	1
Alsea		1	0	2	3
Yaquina	0	0	5	14	19
Netarts	1	0	1	10	12
Tillamook	0	0	0	0	0
Willapa	0	0	0	1	1
Grays Harbor	0	0	0	0	0
Total	1	1	8	45	55
Percent	1.8	1.8	14.5	81.8	100

Conclusions

During 2009, no green crabs were trapped in Grays Harbor, Willapa Bay and Tillamook Bay while densities in Netarts, Yaquina and Coos Bay averaged between 6 to 15 per 100 trap-days. Lower densities in Washington are attributable to poor recruitment in 2006 and a complete lack of recruitment from 2007 to 2009. 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 pers.com.). 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 Behrens Yamada (2003), Jensen et al. (2007) and Claudio DiBacco (pers. com) found that high densities of green crabs occur primarily in microhabits where larger native crabs are rare or absent. In these studies and during the 2007 survey around Vancouver Island (Gillespie et al 2008), 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 of the genus *Cancer* 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 from these larger crabs, green appear to flourish.

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 crab in the inland sea between Vancouver Island and the mainland, including Puget Sound and Hood Canal. Once green crabs get established in this 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 2009.

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***	
	09/23/09		30	20.7	37	no
Russell Point		***Range of values observed***	***22-33***	***11-20***	***9-28***	
N 43° 25.974'	July 8/09		32	18.7	15.3	yes
W 124° 13.252'						
Trans Pacific N	July 8/09		32	17	15.3	yes
N 43° 26.575'						
W 124° 14.434'						
Trans PacificS		***Range of values observed***	***22-33***	***11-18***	***10-27***	
N 43° 26.571'	July 8/09		32	16.2	16.9	yes
W 124° 13.388'						
Trans Pacific Bridge North		In *Scirpus* bed	30	20.7	27	no
N 43° 26.340'						
W 124° 14.199'						
Trans Pacific Bridge South		In *Scirpus* bed	30	20.7	27	no
N 43° 26.195'						
W 124° 14.158'						
Haynes Inlet	09/21/09					no

N 43° 27.003' W 124° 13.478'						
Clausen's Oysters	07/07/09		30	16.1	17.2	no
N 43° 26.911'						
W 124° 12.209'						
Kentuck Inlet	09/22/09		26	16.5	15	no
N 43° 25.299'						
W 124° 11.522'						
Isthmus Bridge						
N 43° 21.595'	07/08/09		26	19.4	16	no
W 124° 11.623'						
Joe Nye Slough		Mudflat from *Zostera marina* to high zone Hotspots = near undercut bridge piling				
N 43° 20.343'						
W 124° 18.590'	07/06/09		30	14.8	11.4	no
Charleston Boat Basin	07/06/09	Old pier by Fish grotto	34	13.1	12	no
N 43° 21.347'						
W 124° 19.706'						
Troller Road W	09/24/09		34	12.6	16.1	no
N 43° 20.114'						
W 124° 19.057'						
Troller Road E	09/24/09		34	16.4	18.7	no
N 43° 20.165'						
W 124° 18.941'						
Pony Point		Mudflat near rip rap, *Zostera marina* zone	***17-32***	***11-17***	***11.5-18***	

N. Bend Airport	07/07/09		30	15.6	14.4	no
N 43° 25.403'	09/22/09		32	15.4	18.2	yes
W 124° 14.369'						
YAQUINA BAY						
Johnson Slough	***Range of values observed***		***4-32***	***9-20***	***16-22***	
N 44° 34.692'	07/ 20/09	Below bridge/along creek bank , *Salicornia* patches	20	19.2	14	yes
W123° 59.333'	08/19/09		28	15.2	14.0	no
	09/10/09		30	16.7	14.8	yes
Sally's Bend A		***Range of values observed***	***22-33***	***12-23***	***12-26***	
N 44° 37.699'		*Scirpus* patches below intersection				
W124° 01.482'	09/10/09		32	18	17.3	no
Sally's Bend B		***Range of values observed***	***29-33***	***12-19***	***12-24***	
N 44° 37.640'		*Scirpus* patches below George Street				
W124° 00.790'	09/10/09		32	18	17.3	no
Sally's Bend C		***Range of values observed***	***19-32***	***9-19***	***9-22***	
N 44° 37.419'	06/10/09	*Zostera marina* zone from gate to Fishing platform	27	15.1	17	yes
W124° 01.463'						
	08/19/09		32	17.6	15	yes
	09/10/09		32	18	17.3	yes
Hatfield Marine		***Range of values observed***	***16-34***	***9-21.5***	***8-23***	
Science Center	04/06/09		20	13.1	18	no
Pump house	06/10/09		27	15.1	15.5	yes
N 44° 37.408'						
W124° 02.576'						
Oregon Coast			***19-34***	***9-25***	***8-23***	
Aquarium	07/21/09		32	18.7	15.5	yes

N 44° 37.108'	08/19/09		34	16.9	16.2	no
W124° 02.165'	09//11/09		32	18.8	24.5	no
Idaho Point		***Range of values observed***	***16-35***	***8-27.5***	***7-23***	
N 44° 36.818'	07/21/09		30	16.8	18.3	yes
W 124° 01.582'						
TILLAMOOK BAY						
Tillamook Spit A		***Range of values observed***	***0-30***	***9-19***	***7-27***	
N 45° 30.843'	07/23/09	mudflat- eelgrass zone below rip rap and in *Scirpus*	30	16	16.3	no
W 123° 56.738'	09/15/09		23	16.3	18.5	no
Tillamook Spit B	07/23/09		27	16	16.3	no
N 45° 30.456'	09/15/09					no
W 123° 56.615'						
Pitcher Point	09/15/09	South of Spit B – mudflat in Japanese eelgrass zone	26		18	no
N 45° 30.365'						
W 123° 56.508'						
Bay City	09/15/09	Mudflat adjacent to boat ramp	30	17.1	18.1	no
Garibaldi	09/15/09	Dock below Tillamook Estuarine Partnership	29	18.2	23.2	no
NETARTS BAY						
RV Park	07/23/09	mud flat east of bridge	0	17.5	15.5	yes
N 45° 25.___'	09/15/09		31	16.2	16.9	yes
W 123° 56___						
Whiskey Creek Salmon hatchery		***Range of values observed***	***0-34***	***7-20***	***8-21***	
N 45° 23.670'	07/23/09	On mudflat and in creek	5	17.8	17.4	no

W 123^{o} 56.214‘	09/16/09					yes
Mile 2	09/17/09	*Scirpus* marsh				no
N 45^{o} 24.229’ W 123^{o} 56.694‘						
Paddle Creek	07/23/09	Between intersection and Mile 2	29	16.3	15.9	yes
N 45^{o} 24.438’ W 123^{o} 55.896‘						
Intersection of	***Range of values observed***		***0-34***	***7-20***	***8-23***	
Whiskey Creek	07/23/09	Pool below culvert draining Freshwater marsh	29	16.3	15.9	yes
& Netarts Bay	09/15/09		34	16.9	17.1	yes
Roads						
N 45^{o} 24.865’						
W 123^{o} 56.064’						
WILLAPA BAY						
Stackpole		***Range of Values observed***	***14-30***	***9-19***	***8-28***	
Leadbetter Pt.	08/19/09	Edge native vegetation				
Sate Park	09/18/09		20	17	22	no
N 46^{o} 35.848’						
W 124^{o} 02.195’						
WDFW Parcel A	09/19/09	*Scirpus* field	20	18	21	no
GRAYS HARBOR						
Grassy Island	9/22/09	Tide fat edge of native grasses	30	22	24	no
N 46^{o} 52.480’						
W 124^{o} 05.904’						
Brady’s Oysters	09/22/09	Tide fat edge of native grasses	30	20	26	no
N 46^{o} 51.723’						
W 124^{o} 04.333’						

Appendix 2. Relative abundance of crab species and sculpins (Numbers/trap/day) in Oregon and Washington estuaries during 2009.

Coos 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
Russell Point	07/08/09	Fish	Pools by bridge	0.17			16.7	0		5.33	6
	07/08 /09	Fish	*Zoster marina*				2.6	0		2.2	5
	07/10/09	Fish		0.2			2.8	0.2		3.4	5
Pony Point/Airport	07/08/09	Fish	*Zostera marina*		0.07		10.2	0.07	0.07	2.2	15
	09/21/09	Fish		0.67			18.17	1	0.67	2.33	6
	09/21/09	minnow	*High marsh*				0.1	0		3.5	10
Haynes Inlet	09/21/09	Minnow	*Scirpus*		0.1		0.4	0		1.0	10
Clausen's Oysters	07/08/09	Fish	*Mid*		0.7		1.3	0.4		3.3	10
Kentuck	09/22/09	minnow	*High marsh*		0.2		0.51	0		1.11	35
Isthmus Bridge	07/08/09	Fish	*Mid*				11.33	0		1.4	15
TransPacific Ln. N	07/08 /09	Fish	*Mid*	0.13			9.88	0		0.38	8
	07/09/09	Fish		0.1	0.2		11.3	0		0.3	10
	07/0/09	Fish		0.1			11.7	0		0.5	10
TransPacific Ln. S	07/08/09	Fish	*Mid*				24.38	0		0.25	8
	07/09/09	Fish		0.1			30.2	0		0.9	10
	07/10/09	Fish		0.4			16.6	0.1		0.5	10
	07/11/09	Fish		0.4			13.1	0		2.7	10

TransPacific Bridge North	09/22/09	minnow	*Scirpus*					0.6		0.4	5
TransPacific BridgeSouth	09/22/09	minnow	*Scirpus*					0.2	0.2		5
Jordan Cove	09/23/09	minnow	*Scirpus*				0.24	0.64		0.92	25
	09.24/09	minnow						0.09		0.14	35
Charleston Boat Basin	07/06/09	Fish	*Below OIMB*		0.1		3.9	0		2.0	10
Troller Road W	09/24/09	minnow	*Scirpus*		1	1.25		0			8
						(Pachy 1.25)					
Troller Road E	09/24/09	minnow	*Scirpus*		0.57	0.4		0			7
Joe Ney Slough	07/06/09	Fish					8.8	0		5.2	9
	07/07/09	Fish			0.4		1.0	0		1.2	5
Total Number				12							292

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	08/20/09	Fish	Below Bridge	0.33			65	0		8.67	3
	08/19/09	Fish		0.33			20	0.67		0.67	3
	09/10/09	Fish		0.5			28	0			2
	08/19/09	Minnow	Marsh				0.17	0		0.17	6
	09/10/09	Minnow	Marsh		1.17		1.17	0		0.5	6
Sally's Bend A	08/19/09	Minnow	*Scirpus*		0.33			0		1.67	6
	09/10/09	minnow			0.92	0.17		0.33		0.75	12

Sally's Bend B	08/19/09	minnow	*Scirpus*		0.17			0.17		2.83	6
	09/10/09	minnow			0.83			0.17		1.5	6
Sally's Bend C Fishing Platform	06/10/09	Fish	*Zostera marina*	0.2	0.29			0.2		0.21	10
	07/20/09	Fish					2.2	0.2		4.8	5
	08/19/09	Fish		0.4	0.3		6.7	0		1.2	10
	09/10/0	Fish		0.2			2.2	0		1.2	5
HMSC Pump house	04/6/09	Fish	*Zostera marina*		0.08		0.23	0.77	0.5		12
	06.19.09	Fish		0.2		0.05	0.8	0.45	0.6	2.15	20
	07/11/09	Fish	*(Ann Eisinger)*	0.33	3.0		0.33	0.33		3.67	3
	07/20/09	Fish					1	3.2		4.8	5
Oregon Coast Aquarium	07/20/09	Fish	Channels /pools	0.2	2.8		4.2	1		13.6	5
	08/19/09	Fish	pools		0.5			2.5		1.5	2
	09/10/09	Fish		0.67				150		1.17	3
	08/19/09	Minnow	*Scirpus*		0.5			2.2		2.4	10
	09/10/09	Minnow						30.58		0.08	12
Idaho Point	07/20/09	Fish	Low	0.1	0.2		10.4	0.1		4.4	10
Total Number				19							162

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	07/23/09	Fish	*Z. japonica*		1.2		0.2	0		2.9	11
	09/17/09	Fish			0.3		6	0		4.7	3
	09/18/09	Fish			0.4		2.2	0		4.1	10
	09/16/09	Minnow	*Scirpus*		0.1		0.5	0.2		0.6	10

	09/07/09	Minnow					0.1	0.2		1.5	10
	09/18/09	Minnow			0.6		0.1	0		2.0	10
Tillamook Spit B	07/23/09	Fish	*Tidal chanel*				0.5	1		16.5	2
	09/17/09	Fish					1	0			1
	09/16/09	Minnow	*Scirpus*					0		1.5	10
	09/17/09	Minnow					0.1	0		0.6	10
Pitcher Point	09/16/09	Minnow	*Scirpus*		0.3			.2		1.7	10
	09/17/09	Minnow			0.1		0.1	0		2.3	10
Hayes Oysters	09/18/09	Minnow					1.6	0		1.6	5
Bay City	09/17/09	Minnow	*Scirpus*					0		0.6	5
Garibaldi TBEP	09/17/09	Fish	*Low tidal- rocks*				11.2	0.2			6
Total Number				0							113

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	07/23/09	Fish	creek /mudflat	0.25	0.75			0		6.75	4
	09/17/09	Fish		0.5			1.25	0.25		3.25	4
	09/18/09	Fish		0.5			0.7	0		0.25	4
Intersection	07/23/09	Fish	pools	1	0.8		7.4	0		1.2	5
	09/17/09	Fish		0.33	13.33		52	0			3
	09/16/09	Fish					71.67	0			3
	09/18/09	Minnow				0.2		0		1.2	5

Paddle Creek	07/23/09	Fish		0.5	5.5	~100		0		1	2
Mile 2	09/17/09	Minnow					0.2	0		0.4	5
Whiskey Creek Salmon Hatchery	07/23/09	Fish	Creek/ mudflat		0.2		6.4	0.2		0.4	5
	09/16/09	Fish				6		0			1
	09/16/09	Minnow	*Fucus*/ mudflat		9.33	0.2	0.67	0		8.67	15
	09/17/09	Minnow		0.07	0.47	0.07		0.07		1.2	15
	09/18/09	Minnow			0.53	0.2		0		2.4	15
Total Number				13							86

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	08/19/09	Minnow	Edge of grass				1.0	0.9		1.3	10
	08/19.09	Minnow	Native grass to dedge				0.4	0		1.0	5
	09/19/09	Minnow	patch Edge of grass					0		0.2	10
	09/19/09	Pit-fall	Tide flat				0.6	0			5
WDFW Pacel A	09/19/09	Minnow	*Scirpus*					0		0.6	5
Total Number				0							35

Grays Harbor **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
Brady's Oysters	09/22/09	Minnow	Edge of grass				0.1	0.1		2.1	10
Grassy Island	09/22/09	Minnow	Edge of grass					0		0.8	10
				0							20

Appendix 3. *Carcinus maenas* Catches and Sightings from Oregon and Washington Estuaries in 2009. 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	Estimated Year Class	Condition/Comments
COQUILLE	Port of Bandon public crab dock	08/03/09	M	72	Orange joints	**2007**	Missing claw and 2 legs reported by Christopher Stephens
COOS	Airport /Pony Pt	09/22/09	M	94.86	Yellow	05/06	Good
		09/22/09	M	80.88	Red	05/06	#6 dactyl missing
		09/22/09	F	77.35	Yellow	05/06	Missing #1/ #2 regenerating
		09/22/09	M	77.56	Green	**2007**	good
	Under 101 Bridge	07/08/09	M	90	yellow	05/06	barnacles
		07/10/09	M	98.6	Orange	05/06	4 large barnacles
	Trans Pacific Blvd	07/08/09	M	90.6		05/06	
		07/09/09	M	81.2		05/06	
		07/09/09	M	89.2		05/06	
		07/10/09	M	86		05/06	
		07/11/09	M	88.8		05/06	
		07/11/09	M	90.8		05/06	
		07/11/09	M	84.8		05/06	
		07/11/09	M	90.3		05/06	
		07/12/09	F	74	Green	05/06	
		07/12/09	M	91	Orange	05/06	#2 tips missing
		07/12/09	M	93.4	Yellow	05/06	
		07/12/09	M	84	Orange	05/06	Propus and dactyl worn
Wincherster Bay	Boat Basin dock #4	July 2009	M	82		05/06	
						05/06	

ALSEA		March 09	M	93.4	Orange/ orange joints	05/06	Missing Limbs 1, 5; barnacles
		Early 2009	M	84.12	Orange	05/06	Left-handed; barnacles
		6/19/09	F	50.49	green	**2008**	#6 missing; Carri Anderson
YAQUINA	Johnson Creek	07/21/09	M	75.94	Yellow/orange	**2007**	
	Johnson Creek	08/16/09	M	75.52	Orange/orange	**2007**	
	Johnson Creek	09/11/09	M	94.64	Orange/orange	05/06	Good,/ lots of barnacles
	Sally's Bend C Fishing platform	06/11/09	M	93.0	Yellow-orange	05/06	#6 dactyl broken & necrotic
		06/11/09	M	86.14	Yellow-orange	05/06	
		08/16/09	M	85.34	yellow	05/06	
		08/16/09	M	83.4	orange	05/06	barnacles
		08/16/09	M	84	orange	05/06	No #3,5; #1 propal tip missing; #6 propus punctured; barnacles
		08/16/09	M	84.3	green	05/06	Abdomen misformed
		09/11/09	F	72.82	Orange/orange	05/06	#1,2 missing #6 propal tip chipped
	HMSC Pump house beach	06/11/09	M	69.6	Yellow-orange	**2007**	#6 regenerating
		06/11/09	M	84.0	Yellow-orange	05/06	Barnacles
		06/11/09	M	90.9	Yellow-orange	05/06	#7 missing
		06/11/09	M	81.6	orange	05/06	
		07/11/09	M	80		05/06	Ann Eislingson
	Aquarium mud flat	07/21/09	M	82.05	Yellow-green	05/06	
		09/11/09	M	76.77	Yellow-orange	**2007**	#5 missing/ #1 propal tip chipped
		09/11/09	F	72.82	Orange	05/06	# 1,2 missing/ #6 propal tip chipped
	Idaho Point	07/21/09	M	74.91	green	**2007**	good
TILLAMOOK							
NETARTS	RV Park mudflat	07/23/09	M	70.45	Yellow green	**2007**	good
		07/23/09	M	83.35	Orange	05/06	

		09/17/09	F	88.1	Orange	05/06	#1propal chipped/No #4/large barnacles
		09/17/09	M	98.4	Yellow/orange	05/06	good
		09/18/09	F	85.0	Orange	05/06	Large barnacles
		09/18/09	F	89.1	Oranage	03/05	Old barnacles – largest female -
	Intersection of Netarts Rd. and Whiskey Creek Rd	07/23/09	M	96.96	Yellow-orange	05/06	Left-handed
		07/23/09	M	85.34	Yellow-orange	05/06	Missing # 3,4; #1 dactyl broken
		07/23/09	M	82.56	Red-orange	05/06	
		07/23/09	M	85.69	Yellow-orange	05/06	
		07/23/09	M	86.7	Yellow-orange	05/06	#1 regenerating
		09/17/09	M	91.8	Yellow-orange	05/06	No dactyl on #1 no #6
	Whiskey Creek Salmon Hatchery	09/17/09	M	47.7	Green	**2009**	good
WILLAPA	Seed bags	~ April 25	M	82.5		05/06	Lots of barnacles –Steve Shotwell – under seed bags

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		
2009				0		0.00			
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		
2009				0		0.00			
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		
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			
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				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				
2009				0		0.00			