Status of the
European Green Crab in Oregon and Washington Estuaries
in 2011

Sylvia Behrens Yamada,
Zoology Department,
Oregon State University
Corvallis, OR 97331-2914
541-754-9891 (home)
yamadas@science.oregonstate.edu

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

Wendy M. Sletton
Oregon Department of Fish and Wildlife
2040 SE Marine Science Drive
Newport, Oregon 97365
wendy.m.sletten@state.or.us

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

Once a non-native species arrives and survives in an area, its long-term persistence depends on its recruitment success. If conditions are not favorable for recruitment it will ultimately disappear. The European green crab (*Carcinus maenas*) has a six-year life span and has persisted at low densities in Oregon and Washington coastal estuaries for the past 14 years. After the arrival of the strong founding year class of 1998, significant self-recruitment to the Oregon and Washington populations occurred only in 2003, 2005, 2006 and 2010. Warm winter water temperatures, high Pacific Decadal Oscillation and Multivariate ENSO (El Niño Southern Oscillation) Indices for March, late spring transitions and weak southward shelf currents in March and April are all correlated with the these strong year classes (Behrens Yamada and Kosro 2010). Cold winter water temperatures, low Pacific Decadal Oscillation Indices, early spring transitions and strong southward (and offshore) currents in March and April are linked to year class failure. Right now, green crabs are still too rare to exert a measurable effect on the native benthic community and on shellfish culture in Oregon and Washington. However, this could change if ocean conditions were to switch to a high PDO and strong El Niño patterns. For example, green crabs were first documented in New England in 1817, but it took warm ocean conditions during the 1950’s for their numbers to build to a level at which they decimated the soft-shelled clam industry.

Extensive surveys by Fisheries and Oceans Canada found green crabs in all the major inlets on the west coast of Vancouver Island, but so far none have been discovered in the inland sea between Vancouver Island and the mainland. Therefore, outreach efforts should continue to prevent the establishment of this invader in the inland waters via ballast water, shellfish transport or other human-mediated vectors.

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 predict the arrival of strong year classes from ocean conditions and alert managers and shellfish growers of possible increases in predation pressure from this invader.
### Professional and Outreach Activities since May of 2010

<table>
<thead>
<tr>
<th>Date</th>
<th>Talks / Activities</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 23.2011</td>
<td>“Status of the European green crab in the Pacific Northwest” Presentation and field sampling exercise</td>
<td>BI 408/508 class: Biological Invasions of Marine Environments. Oregon Institute of Marine Biology, <strong>Charleston, Oregon</strong></td>
</tr>
<tr>
<td>April 4, 2011</td>
<td>“Status of the European green crab in the Pacific Northwest” Presentation and field sampling exercise</td>
<td>Bi 450 class: Marine Biology, Hatfield Marine Science Center, <strong>Newport, Oregon</strong></td>
</tr>
<tr>
<td>March</td>
<td>“Predicting year class strength of crab species from ocean conditions” Talk; “Status of the European green crab in the Pacific Northwest” Poster with Graham Gillespie of DFO, Canada</td>
<td>Pacific Estuarine Research Society, Liberty Theatre, <strong>Astoria, Oregon</strong></td>
</tr>
<tr>
<td>Feb. 12, 2011</td>
<td>“European Green crabs on the Oregon Coast.” Presentation and field sampling exercise</td>
<td>Oregon Coast Aquatic and Marine Science Partnership Colloquium #3 Marine Resources and Human Impacts: Invasive Species. Hatfield Marine Science Center <strong>Newport, Oregon</strong></td>
</tr>
<tr>
<td>Oct. 18-21, 2010</td>
<td>PICES Rapid Assessment Survey of European Green crabs in Yaquina Bay. Comparison of trapping methods used in British Columbia and Oregon.</td>
<td>Coordinated trapping program with Graham Gillespie of DFO Canada. Hatfield Marine Science Center and Yaquina Bay, <strong>Newport, Oregon</strong></td>
</tr>
<tr>
<td>Sept. 21, 2010</td>
<td>“Status of the European green crab in the Pacific Northwest”</td>
<td>Poster with Graham Gillespie given at the Pacific Coast Shellfish Growers Association, <strong>Tacoma, Washington</strong></td>
</tr>
<tr>
<td>August 7-8, 2010</td>
<td>“Status of the European green crab in the Pacific Northwest” Presentation and field sampling exercise</td>
<td>Bi 421 and FW421/521 class: Aquatic Biological Invasions, Hatfield Marine Science Center, <strong>Newport, Oregon</strong></td>
</tr>
<tr>
<td>May 10-12, 2010</td>
<td>Lobbied Oregon Senators and House Representatives to support a bill to screen animal species BEFORE they are imported for the aquarium and pet trade.</td>
<td>Congressional Education Day-sponsored by Union of Concerned Scientists, <strong>Washington, D.C.</strong></td>
</tr>
<tr>
<td>Date</td>
<td>Recent Publications</td>
<td>Journal</td>
</tr>
<tr>
<td>------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>October 2010</td>
<td>Green crab (<em>Carcinus maenas</em>) assessment in Yaquina Bay, Oregon (October 18-21, 2010) and Green crab trapping calibration survey.</td>
<td>Abstract with Graham Gillespie and Katie Marko for PICES Rapid Assessment Survey</td>
</tr>
<tr>
<td>August 2010</td>
<td>“Claw morphology and feeding rates of introduced European green crab (<em>Carcinus maenas</em> L, 1758) and native Dungeness crabs (<em>Cancer magister</em> Dana, 1852)</td>
<td>Manuscript with Tim Davidson and Sarah Fisher published in <em>Journal of Shellfish Research</em> 29 (2):1-7</td>
</tr>
</tbody>
</table>
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 during the 1980’s, most likely via aerial shipment of Atlantic seafood or baitworms. From there, green crabs spread naturally via larvae carried in ocean currents, and by 2000, had dispersed as far north as Port Eliza on the northern west 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, Behrens Yamada et al. 2010). 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, Behrens Yamada et al. 2010).

On the West Coast, the northward range expansion of green crabs during the 1990’s is linked to favorable ocean conditions for larval transport during El Niño events (Behrens Yamada et al. 2005, Behrens Yamada and Kosro 2010). 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). Since then, some localized recruitment has occurred in embayments from Coos Bay to the northern west coast of Vancouver Island. Year classes were more abundant following the warm winters and springs of 2003, 2005, 2006 and 2010 (Behrens Yamada & Gillespie 2008; Behrens Yamada & Kosro 2010).

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:

1. Estimating the size/age structure and relative abundance of green crabs in Oregon and Washington estuaries by using baited Fukui fish traps (Table 2).
2. 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 (Table 3).
3. Estimating year-class strength of 0-age (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 (Figure 2).
4. Comparing patterns in the recruitment strength of 0-age crabs over time and correlating them to ocean conditions: winter surface water temperatures, Pacific Decadal Oscillation Index for March, Day of Spring Transition and alongshore currents for March and April (Appendix 5).
Figure 1. Major sampling sites in Oregon and Washington
Sampling Methods for Green Crabs

Our sampling effort in 2011 focused on one Washington and four Oregon estuaries: Willapa, Tillamook, Netarts, Yaquina and Coos Bay (Figure 1). All estuaries, except Willapa Bay, were sampled at least twice during the 2011 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°-22° 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 0-age green crabs. Green crabs start entering these baited traps when they are around 30 mm in carapace width. Pitfall traps are water-filled 5-gallon buckets buried into the sediment so that their rims are flush with the surface of the sediment. They thus trap actively foraging crabs of any size. Pitfall traps were primarily used at the Stackpole site in Willapa Bay, but one trap was monitored at Sally’s Bend in Yaquina Bay on a weekly basis from throughout the year to document the arrival of 0-age crabs. Typically, we would trap 0-age 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).

<table>
<thead>
<tr>
<th>Trap Type</th>
<th>Description</th>
<th>Dimensions</th>
<th>Tidal Height</th>
<th>Size Selectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Folding Fukui Fish Trap</td>
<td>Plastic mesh (2 cm) with two slit openings (45 cm)</td>
<td>63 x 46 x 23 cm</td>
<td>Subtidal to mid-intertidal</td>
<td>&gt;40 mm</td>
</tr>
<tr>
<td>Minnow/Crayfish</td>
<td>Wire mesh (0.5 cm) cylinder with two openings expanded to 5 cm</td>
<td>21 cm diameter 37 cm long</td>
<td>Medium to high</td>
<td>20-70 mm</td>
</tr>
<tr>
<td>Pit fall</td>
<td>Water-filled 5-gallon bucket embedded into the sediment</td>
<td>31 cm diameter 37 cm high</td>
<td>High</td>
<td>All sizes</td>
</tr>
</tbody>
</table>

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 anterior-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 in 2004, by P. Sean McDonald. Funding constraints did not allow us to sample Grays Harbor every year. Asterisk indicates that all but two crabs trapped in Netarts Bay originated from one “hot-spot”.

<table>
<thead>
<tr>
<th>Estuary</th>
<th>Number of crabs trapped over (number of traps deployed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2002</td>
</tr>
<tr>
<td>Coos Bay</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>(180)</td>
</tr>
<tr>
<td>Yaquina</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>(168)</td>
</tr>
<tr>
<td>Netarts</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(44)</td>
</tr>
<tr>
<td>Tillamook</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>(71)</td>
</tr>
<tr>
<td>Willapa</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>(1640)</td>
</tr>
<tr>
<td>Grays Harbor</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>(1203)</td>
</tr>
<tr>
<td>Total</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>(3306)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estuary</th>
<th>Number of crabs trapped per 100 traps per day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2002</td>
</tr>
<tr>
<td>Coos Bay</td>
<td>5</td>
</tr>
<tr>
<td>Yaquina</td>
<td>15</td>
</tr>
<tr>
<td>Netarts</td>
<td>0</td>
</tr>
<tr>
<td>Tillamook</td>
<td>3</td>
</tr>
<tr>
<td>Willapa</td>
<td>3.5</td>
</tr>
<tr>
<td>Grays Harbor</td>
<td>0.4</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
</tr>
</tbody>
</table>
Table 3. *Carcinus maenas* catch rates (crabs per 100 trap-days) by embayment in the Pacific Northwest, 1997–2011. “P” indicates confirmed presence from public reports. British Columbia data were supplied by Graham Gillespie of the Department of Fisheries and Oceans Canada. Underlined values are still subject to change slightly due to multiple sampling events.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Quatsino Sound</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter Harbor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Klaskino</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kyuquot Sound, BC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amai Inlet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mary Basin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tlupana Inlet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sydney Inlet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nootka/Esperanza</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Queen Cove</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clayoqut Snd. BC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretty Girl Cove</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barkley Sound, BC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipestem Inlet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Esquimalt BC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grays Harbor, WA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Willapa Bay, WA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Necanicum, OR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tillamook Bay, OR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Netarts Bay, OR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nestucca Bay, OR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yaquina Bay, OR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alsea Bay, OR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winchester Bay, OR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coos Bay, OR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coquille River, OR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 shows the catch rates of *Carcinus maenas* (crabs per 100 trap-days) by embayment in the Pacific Northwest from 1997 to 2011. "P" indicates confirmed presence from public reports. British Columbia data were supplied by Graham Gillespie of the Department of Fisheries and Oceans Canada. Underlined values are still subject to change slightly due to multiple sampling events.
Results

_Carcinus maenas Abundance in the Pacific Northwest_

The relative abundances of green crabs trapped in Oregon and Washington estuaries in 2011 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. When green crabs were rare in Oregon, we focused on known “hot spots” to at least catch a few crabs for age class analysis. For example, most of the crabs caught in 2011 came from two hotspots: the intersection in Netarts Bay and from around a cement bridge footing in John Ney Slough in Coos Bay. One thus must use caution in interpreting differences in CPUE between sites and over time. Minor differences in CPUE are not significant but differences of an order of magnitude would be.

Catches of green crabs in Oregon and Washington have decreased an order of magnitude since the 1998 colonization event when CPUE per 100 traps ranged from 65 to 192 (Table 3). Between 2002 and 2004 catches had dropped to 3-6 per 100 traps (Table 2). Averages catches from 2005 to 2008 roughly doubled to 15-18 per 100 traps due to the recruitment of two strong cohorts in 2005 and 2006. For the last three years catches have again decreased to below 10 per 100 traps due to poor recruitment.

Extensive sampling effort by Fisheries and Oceans Canada, starting in 2006 (Gillespie et al. 2007, Gillespie, pers. com.) reveal an interesting distribution pattern in British Columbia. While no green crabs were trapped in the inland sea between Vancouver, 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 in Oregon and Washington, but those in Pipestem Inlet in Barkley Sound average around 20 per trap in 2007, 2008 and 2011 while those in Amai Inlet averaged 27 per trap in 2010. These catches are two orders of magnitude greater than what has been observed in Oregon and Washington in recent years (Table 3).

_Recreation strength of 0-age Carcinus maenas_

Young-of-the-year, or 0-age, green crabs typically enter minnow traps once they reach 30 mm in carapace width. Most years, 0-age crabs of this size, and larger, entered our traps by early September, but in 2010 and 2011 we did not trap them until October. In 2011 we only trapped one 0-age crab class during our fall survey.

As can be seen from Figure 2 and Appendix 4, 0-age green crabs were most abundant in 1998 with average catches for the Oregon and Washington estuaries estimated over 100 per 100 traps. The next highest catches were in 2005 and 2006 with averages of 35 and 27 per 100 traps respectively. For all other years average catches averaged below 11 per 100 traps (Figure 2).
Age Structure of *Carcinus maenas* 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 2011. 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 2010 year class and crabs between 70 to 80 mm, the 2009 year class. Larger crabs would represent by the 2008 to 2005 cohorts. While large crabs were still present during the early summer, it appears that the strong 2005 and 2006 year classes had mostly died of senescence by the end of the summer. The 2010 year class is now the most abundant one, contributing to 80% of the population (Table 4).
Table 4. Estimated age structure of *Carcinus maenas* retrieved from Oregon and Washington estuaries in 2011. Total crabs include trapped crabs recorded in Table 1, as well as other sightings.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Coos Bay</td>
<td>1</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>Yaquina</td>
<td>1</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Netarts</td>
<td>0</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>19</td>
</tr>
<tr>
<td>Tillamook</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Willapa</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2</td>
<td>39</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>49</td>
</tr>
<tr>
<td><strong>Percent</strong></td>
<td>4</td>
<td>80</td>
<td>6</td>
<td>2</td>
<td>8</td>
<td>100</td>
</tr>
</tbody>
</table>

**Ocean Conditions and Recruitment Strength of 0-age *Carcinus maenas***

The European green crab (*Carcinus maenas*) has a six-year life span and has persisted at low densities in Oregon and Washington coastal estuaries for the past 15 years. After the arrival of the strong founding year class of 1998, significant self-recruitment to the Oregon and Washington populations occurred only in 2003, 2005, 2006 and 2010. Warm winter water temperatures, high Pacific Decadal Oscillation and Multivariate ENSO (El Niño Southern Oscillation) Indices for March, late spring transitions and weak southward shelf currents in March and April are all correlated with the these stronger year classes (Behrens Yamada and Kosro 2010, Appendix 5). Cold winter water temperatures, low Pacific Decadal Oscillation Indices, early spring transitions and strong southward (and offshore) currents in March and April are linked to year class failure. Even though spring transition was later than average in 2011 (+25 days), we observed recruitment failure. A cool winter and a negative PDO for March (-0.69) may have depressed the larval supply.

Right now, green crabs are still too rare to exert a measurable effect on the native benthic community and on shellfish culture in Oregon and Washington. The next few years are critical in determining whether green crabs can persist in Oregon and Washington. Continual cold winter ocean temperatures, low PDO indices and La Niña conditions would result in continual recruitment failures. However, a switch to high PDO and strong El Niño patterns in the next few years would predict green crab population growth.

**Discussion**
Only 45 *Carcinus maenas* entered 530 taps in 2011 yielding an average catch rate of 8 crabs per 100 traps for Oregon and Washington estuaries. While green crabs in Oregon and Washington are still rare, they are thriving in some inlets on the west coast of Vancouver between Quatsino Sound and Barkley Sound (Behrens Yamada 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. In 2010, a new hot spot was found in Amai Inlet with an average catch of 27 crabs per trap. 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 microhabitats where larger 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 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.

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 must have produced enough larvae in 2005 to adequately “seed” Oregon and Washington estuaries, thus preventing the population from going extinct (Figures 2; Appendix 4). In 2006, another strong year class was detected in Oregon, but not in Washington, estuaries. These two year classes have dominated the population in recent years as recruitment failure occurred in 2007, 2008, 2009 and 2011 (Figures 2, Appendix 4). Right now the 2010 cohort is the dominant one in Oregon and Washington estuaries. Even though this year class is not very abundant, it could serve a similar function as the 2003 one did in keeping keep green crabs from going extinct in Oregon and Washington estuaries.

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 very rapidly throughout the inland sea as their larvae are retained and not carried out to sea, as appears to be the case on the open Oregon and Washington coasts once the summer upwelling pattern starts.
Acknowledgements

We thank the staff and faculty of the Oregon Institute of Marine Biology for their hospitality while sampling in Coos Bay. Summer Knowlton monitored a pitfall trap and David Beugli reported a green crab sighting in Yaquina Bay. Data for Vancouver Island were provided by Graham Gillespie of Fisheries and Oceans Canada and bait was supplied by Chuck’s Seafood of Charleston, Harry’s Fresh Fish of Corvallis, and David Wagman of Oregon Department of Fish and Wildlife.

Literature Cited


Appendix 1. Physical data for *Carcinus maenas* sampling sites in Oregon and Washington estuaries. Range of values observed includes sampling times from 2002 to 2011.

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Location Description</th>
<th>S ‰</th>
<th>Water Temp.</th>
<th>Air Temp.</th>
<th>Green Crabs Found?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COOS BAY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Jordan Cove</strong></td>
<td></td>
<td>Range of values observed</td>
<td>5-34</td>
<td>14-22</td>
<td>14-24</td>
<td>yes</td>
</tr>
<tr>
<td>N 43° 25.971' W 124° 14.981'</td>
<td>10-19-11</td>
<td></td>
<td>31</td>
<td>15.5</td>
<td>15.6</td>
<td></td>
</tr>
<tr>
<td><strong>Russell Point</strong></td>
<td></td>
<td>Range of values observed</td>
<td>22-33</td>
<td>11-20</td>
<td>9-28</td>
<td>no</td>
</tr>
<tr>
<td>N 43° 25.974' W 124° 13.252'</td>
<td>7-16-11</td>
<td></td>
<td>32</td>
<td>15.5</td>
<td>14.8</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30</td>
<td>16.5</td>
<td>17.1</td>
<td>no</td>
</tr>
<tr>
<td><strong>Trans Pacific N</strong></td>
<td></td>
<td>Range of values observed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N 43° 26.575' W 124° 14.434'</td>
<td>7-18-11</td>
<td></td>
<td>30</td>
<td>16.7</td>
<td>14</td>
<td>no</td>
</tr>
<tr>
<td><strong>Trans Pacific S</strong></td>
<td></td>
<td>Range of values observed</td>
<td>13-33</td>
<td>10-18</td>
<td>9-27</td>
<td></td>
</tr>
<tr>
<td>N 43° 26.571' W 124° 13.388'</td>
<td>7-16-11</td>
<td></td>
<td>13</td>
<td>17.6</td>
<td>14.8</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30</td>
<td>14.4</td>
<td>16</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>31</td>
<td>15.5</td>
<td>15.6</td>
<td>no</td>
</tr>
<tr>
<td><strong>Clausen’s Oysters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N 43° 26.911' W 124° 12.209'</td>
<td>8-18-11</td>
<td></td>
<td>24</td>
<td>19.2</td>
<td>19.3</td>
<td>no</td>
</tr>
<tr>
<td><strong>Kentuck Inlet</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N 43° 25.299' W 124° 11.522'</td>
<td>10-17-11</td>
<td></td>
<td>31</td>
<td>15.6</td>
<td>15.5</td>
<td>no</td>
</tr>
<tr>
<td><strong>Joe Nye Slough</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N 43° 20.343' W 124° 18.590'</td>
<td>7-17-11</td>
<td>Mudflat from <em>Zostera marina</em> to high zone</td>
<td>28</td>
<td>16.3</td>
<td>16</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hotspots = near undercut bridge piling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30</td>
<td>14.8</td>
<td>17.3</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>24</td>
<td>10/7</td>
<td>10</td>
<td>no</td>
</tr>
<tr>
<td><strong>Pony Point</strong></td>
<td></td>
<td>Range of values observed</td>
<td>17-32</td>
<td>11-17</td>
<td>11.5-18</td>
<td></td>
</tr>
<tr>
<td>N. Bend Airport</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7-18-11</td>
<td>Mudflat near rip rap, <em>Zostera marina</em> zone</td>
<td>30</td>
<td>15.2</td>
<td>15.8</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>Range of values observed</td>
<td>Date</td>
<td>Salicornia patches below bridge/along creek bank</td>
<td>Zostera marina zone from gate to Fishing platform</td>
<td>Scirpus patches below intersection</td>
<td>Other observations</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------------------------</td>
<td>----------</td>
<td>-----------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>----------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td><strong>YAQUINA BAY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Johnson Slough</td>
<td>4-32 9-20 16-22</td>
<td>6-23-11</td>
<td>Below bridge/along creek bank, <em>Salicornia</em> patches</td>
<td>16 17.5 16 no</td>
<td>16-11 17 16 yes</td>
<td></td>
</tr>
<tr>
<td>8-31-11</td>
<td>27 16.5 17.4 yes</td>
<td>28-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sally's Bend A</td>
<td>22-33 12-23 12-26</td>
<td>6-23-11</td>
<td><em>Scirpus</em> patches below intersection</td>
<td>28 17.8 17.5 no</td>
<td>16-11 20 14 no</td>
<td></td>
</tr>
<tr>
<td>8-31-11</td>
<td></td>
<td>28-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9-16-11</td>
<td>34 14.3 14.9 no</td>
<td>28-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sally's Bend B</td>
<td>29-33 12-19 12-24</td>
<td>6-23-11</td>
<td><em>Scirpus</em> patches below George Street</td>
<td>28 17.8 17.5 no</td>
<td>16-11 20 14 no</td>
<td></td>
</tr>
<tr>
<td>8-31-11</td>
<td></td>
<td>28-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9-16-11</td>
<td></td>
<td>34-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sally's Bend C</td>
<td>19-32 9-19 9-22</td>
<td>6-23-11</td>
<td><em>Zostera marina</em> zone from gate to Fishing platform</td>
<td>28 17.8 17.5 no</td>
<td>16-11 20 14 no</td>
<td></td>
</tr>
<tr>
<td>8-31-11</td>
<td></td>
<td>28-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hatfield Marine Science Center</td>
<td>16-34 9-21.5 8-23</td>
<td>04-04-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pump house</td>
<td></td>
<td>12-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oregon Coast Aquarium</td>
<td>19-34 9-25 8-23 no</td>
<td>9-16-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idaho Point</td>
<td>16-35 8-27.5 7-23 yes</td>
<td>6-23-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TILLAMOOK BAY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>Range of values observed</td>
<td>0-30</td>
<td>9-19</td>
<td>7-27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>----------------------------------------------------------------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tillamook Spit A</strong></td>
<td>6-09-11, mudflat- eelgrass zone below rip rap and in <em>Scirpus</em></td>
<td>4</td>
<td>15.8</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N 45° 30.843’</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 123° 56.738’</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tillamook Spit B</strong></td>
<td>6-09-11, South of Spit B – mudflat in Japanese eelgrass zone</td>
<td>0</td>
<td>13.8</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N 45° 30.456’</td>
<td></td>
<td>25</td>
<td>15.8</td>
<td>20.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 123° 56.615’</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pitcher Point</strong></td>
<td>6-09-11, South of Spit B – mudflat in Japanese eelgrass zone</td>
<td>15</td>
<td>15.9</td>
<td>13</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>N 45° 30.365’</td>
<td></td>
<td>26</td>
<td>14.4</td>
<td>20.3</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>W 123° 56.508’</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Viewpoint</strong></td>
<td>Viewpoint between Garibaldi and Bay City</td>
<td>7-8-11, 26</td>
<td>14.9</td>
<td>20.5</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>N 45° 32.623’</td>
<td></td>
<td>7-9-11, 27.9</td>
<td>15.1</td>
<td>18.9</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>W 123° 54.183’</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NETARTS BAY</strong></td>
<td><strong>RV Park</strong></td>
<td>06-09-11, mud flat east of bridge</td>
<td>1</td>
<td>14.8</td>
<td>16.2</td>
<td>no</td>
</tr>
<tr>
<td>N 45° 25.____’</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 123° 56____’</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Culvert</strong></td>
<td>06-22-11, 11.6</td>
<td>17.9</td>
<td>18.8</td>
<td>yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N 45° 25’ 03.1”</td>
<td></td>
<td>06-23-11, 12.2</td>
<td>16.6</td>
<td>18.8</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>W 123° 56’09.1”</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Boat Ramp</strong></td>
<td>06-09-11, 23</td>
<td>14</td>
<td>16.2</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N 45° 25.832’</td>
<td></td>
<td>06-10-11</td>
<td>18.9</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 123° 56.827</td>
<td></td>
<td>06-22-11, 28.7</td>
<td>14.1</td>
<td>18.9</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td><strong>Whiskey Creek Salmon hatchery</strong></td>
<td>06-09-11, On mudflat and in creek</td>
<td>0</td>
<td>12.6</td>
<td>15.2</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>N 45° 23.670’</td>
<td></td>
<td>9-29-11, 0</td>
<td>14</td>
<td>20.3</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>W 123° 56.214’</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Intersection of Whiskey Creek & Netarts Bay Roads

<table>
<thead>
<tr>
<th>Date</th>
<th>Range of values observed</th>
<th>0-34</th>
<th>7-20</th>
<th>8-23</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>06-09-11</td>
<td>Pool below culvert draining Freshwater marsh</td>
<td>0</td>
<td>12.6</td>
<td>15.2</td>
<td>yes</td>
</tr>
<tr>
<td>06-10-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>06-22-11</td>
<td></td>
<td>1.9</td>
<td>17.3</td>
<td>18.9</td>
<td>Yes</td>
</tr>
<tr>
<td>06-23-11</td>
<td></td>
<td>2.2</td>
<td>16.9</td>
<td>18.9</td>
<td>yes</td>
</tr>
<tr>
<td>9-29-11</td>
<td></td>
<td>31</td>
<td>16.7</td>
<td>19</td>
<td>no</td>
</tr>
</tbody>
</table>

### WILLAPA BAY

#### Stackpole Leadbetter Pt. State Park

<table>
<thead>
<tr>
<th>Date</th>
<th>Range of Values observed</th>
<th>14-30</th>
<th>9-19</th>
<th>8-28</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-28-11</td>
<td>Edge native vegetation</td>
<td></td>
<td></td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>9-29-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>9-30-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No</td>
</tr>
</tbody>
</table>
Appendix 2. Relative abundance of crab species and sculpins (Numbers/trap/day) in Oregon and Washington estuaries during 2011.

### Coos Bay

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Trap Type</th>
<th>Zone</th>
<th>Carcinus maenas</th>
<th>Hemigrapsus oregonensis</th>
<th>Hemigrapsus nudus</th>
<th>Cancer magister</th>
<th>Cancer magister (Recruits)</th>
<th>Cancer productus</th>
<th>Sculpin</th>
<th>Number Traps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russell Point</td>
<td>7-17-11</td>
<td>Fish</td>
<td>Pools by bridge</td>
<td>18</td>
<td>0.25</td>
<td>5.75</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7-18-11</td>
<td>Fish</td>
<td>Zoster marina</td>
<td>16</td>
<td>0.25</td>
<td>2.5</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pony Point/Airport</td>
<td>7-18-11</td>
<td>Fish</td>
<td>Zostera marina</td>
<td>0.1</td>
<td></td>
<td>4.9</td>
<td>4.8</td>
<td>1.2</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clausen’s Oysters</td>
<td>7-18-11</td>
<td>Fish</td>
<td>Mid</td>
<td>0.7</td>
<td></td>
<td>5.9</td>
<td>0.2</td>
<td>1.2</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kentuck</td>
<td>10-17-11</td>
<td>minnow</td>
<td>High marsh</td>
<td>0.04</td>
<td></td>
<td>1.29</td>
<td></td>
<td>0.07</td>
<td>28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TransPacific Ln. N</td>
<td>7-17-11</td>
<td>Fish</td>
<td>Mid</td>
<td>0.6</td>
<td></td>
<td>4.73</td>
<td>0.27</td>
<td>0.73</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10-17-11</td>
<td>Fish</td>
<td></td>
<td></td>
<td></td>
<td>5.3</td>
<td></td>
<td>0.2</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TransPacific Ln. S</td>
<td>7-16-11</td>
<td>Fish</td>
<td>Mid</td>
<td>0.03</td>
<td>0.9</td>
<td>1.5</td>
<td>0.6</td>
<td>1.53</td>
<td>34</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7-17-11</td>
<td>Fish</td>
<td></td>
<td>0</td>
<td>0.13</td>
<td>2.07</td>
<td>0.47</td>
<td>1.2</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jordan Cove</td>
<td>10-18-11</td>
<td>minnow</td>
<td>Scirpus</td>
<td>0.025</td>
<td>0.025</td>
<td>0.125</td>
<td></td>
<td>0.025</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10-19-11</td>
<td>minnow</td>
<td></td>
<td>0.025</td>
<td>0.025</td>
<td>0.025</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joe Ney Slough</td>
<td>7-18-11</td>
<td>Fish</td>
<td></td>
<td>0.35</td>
<td>0.1</td>
<td>2.05</td>
<td></td>
<td>2.3</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7-19-11</td>
<td>Fish</td>
<td></td>
<td>1.4</td>
<td>0.2</td>
<td>2.4</td>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7-10-11</td>
<td>Fish</td>
<td></td>
<td>0.2</td>
<td></td>
<td>3.2</td>
<td></td>
<td>1.8</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10-18-11</td>
<td>fish</td>
<td></td>
<td>2.3</td>
<td>0.2</td>
<td>2.3</td>
<td></td>
<td>2</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Number</td>
<td></td>
<td></td>
<td></td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Yaquina Bay

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Trap Type</th>
<th>Zone</th>
<th>Carcinus maenas</th>
<th>Hemigrapsus oregonensis</th>
<th>Hemigrapsus nudus</th>
<th>Cancer magister</th>
<th>Cancer magister (Recruits)</th>
<th>Cancer productus</th>
<th>Sculpins</th>
<th>Number Traps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johnson Slough</td>
<td>6-22-11</td>
<td>Fish</td>
<td>Below Bridge</td>
<td>0.5</td>
<td></td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>8-31-11</td>
<td>Fish</td>
<td></td>
<td>0.33</td>
<td></td>
<td>26.7</td>
<td></td>
<td></td>
<td></td>
<td>1.7</td>
<td>3</td>
</tr>
</tbody>
</table>

Mean CPUE (Catch/trap/day)
<table>
<thead>
<tr>
<th>Date</th>
<th>Site</th>
<th>Trap Type</th>
<th>Zone</th>
<th>Carcinus maenas</th>
<th>Hemigrapsus oregonensis</th>
<th>Hemigrapsus nudus</th>
<th>Cancer magister</th>
<th>Cancer magister (Recruits)</th>
<th>Cancer productus</th>
<th>Sculpin</th>
<th>Number Traps</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-31-11</td>
<td>Minnow</td>
<td>Marsh</td>
<td>0.2</td>
<td>1.0</td>
<td>1.6</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-22-11</td>
<td>Minnow</td>
<td>Scirpus</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-31-11</td>
<td>Minnow</td>
<td>Scirpus</td>
<td>1.4</td>
<td>0.2</td>
<td>3.2</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9-17-11</td>
<td>Minnow</td>
<td>Zostera marina</td>
<td>0.83</td>
<td></td>
<td>0.67</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-22-11</td>
<td>Minnow</td>
<td>Scirpus</td>
<td>2.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-31-11</td>
<td>Minnow</td>
<td>Scirpus</td>
<td>0.2</td>
<td>4.8</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-22-11</td>
<td>Fish</td>
<td>Zostera marina</td>
<td>1.3</td>
<td></td>
<td>1.6</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-31-11</td>
<td>Fish</td>
<td>Zostera marina</td>
<td>1.4</td>
<td></td>
<td>1.1</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>04-04-11</td>
<td>Fish</td>
<td>Zostera marina</td>
<td>0.6</td>
<td>0.8</td>
<td>0.4</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>04-04-11</td>
<td>Minnow</td>
<td></td>
<td>1.4</td>
<td>1.4</td>
<td>0.4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9-16-11</td>
<td>Fish</td>
<td>Channels /pools</td>
<td>0.8</td>
<td>0.2</td>
<td>13</td>
<td>0.4</td>
<td>0.2</td>
<td>1.6</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9-16-11</td>
<td>Minnow</td>
<td></td>
<td>0.35</td>
<td>1.05</td>
<td>0.05</td>
<td>0.5</td>
<td>0.5</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-22-11</td>
<td>Fish</td>
<td>Low</td>
<td>0.3</td>
<td>1.2</td>
<td>0.2</td>
<td>0.1</td>
<td>9.8</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Number</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tillamook Bay</th>
<th>Mean CPUE (Catch/trap/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site</td>
<td>Trap Type</td>
</tr>
<tr>
<td>Tillamook Spit A</td>
<td>Fish</td>
</tr>
<tr>
<td>Tillamook Spit B</td>
<td>Fish</td>
</tr>
<tr>
<td>Pitcher Point</td>
<td>Minnow</td>
</tr>
<tr>
<td>Viewpoint North</td>
<td>Fish</td>
</tr>
<tr>
<td>Viewpoint South</td>
<td>Fish</td>
</tr>
<tr>
<td>Site</td>
<td>Trap Type</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Boat Basin</td>
<td>06-09-11</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Culvert</td>
<td>06-22-11</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>RV Park</td>
<td>06-09-11</td>
</tr>
<tr>
<td>Intersection</td>
<td>06-09-11</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Whiskey Creek</td>
<td>9-29-11</td>
</tr>
<tr>
<td>Salmon Hatchery</td>
<td>06-09-11</td>
</tr>
<tr>
<td></td>
<td>06-10-11</td>
</tr>
<tr>
<td>Site</td>
<td>Trap Type</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>Stackpole</td>
<td>9-29-11</td>
</tr>
<tr>
<td></td>
<td>9-28-11</td>
</tr>
<tr>
<td></td>
<td>9-29-11</td>
</tr>
<tr>
<td></td>
<td>9-30-11</td>
</tr>
<tr>
<td>Total Number</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 3. *Carcinus maenas* Catches and Sightings from Oregon and Washington Estuaries in 2011. 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.

<table>
<thead>
<tr>
<th>Estuary</th>
<th>Site</th>
<th>Date</th>
<th>Sex</th>
<th>CW</th>
<th>Color</th>
<th>Estimated Year Class</th>
<th>Condition/Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>COQUILLE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COOS</td>
<td>Transpacific Lane S</td>
<td>7-16-11</td>
<td>M</td>
<td>94.0</td>
<td>Yellow</td>
<td>2006</td>
<td>No # 7, 9, 10</td>
</tr>
<tr>
<td></td>
<td>North Bend Airport</td>
<td>7-19-11</td>
<td>M</td>
<td>88.7</td>
<td>Orange</td>
<td>2006</td>
<td>Good - #7 propus tip missing</td>
</tr>
<tr>
<td></td>
<td>Joe Nye Slough</td>
<td>7-18-11</td>
<td>M</td>
<td>83.4</td>
<td>Yellow</td>
<td>2008/7</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M</td>
<td>68.9</td>
<td>Yellow-green</td>
<td>2010</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>F</td>
<td>56.5</td>
<td>Green</td>
<td>2010</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>F</td>
<td>57.3</td>
<td>Green</td>
<td>2010</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>F</td>
<td>63.4</td>
<td>Green</td>
<td>2010</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M</td>
<td>57.9</td>
<td>Green</td>
<td>2010</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M</td>
<td>63.7</td>
<td>Yellow-green</td>
<td>2010</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>7-19-11</td>
<td>F</td>
<td>81.6</td>
<td>Green</td>
<td>2008/7/6</td>
<td></td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M</td>
<td>57.8</td>
<td>Yellow-green</td>
<td>2010</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>F</td>
<td>58.2</td>
<td>Yellow-green</td>
<td>2010</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M</td>
<td>44.3</td>
<td>Tan beige</td>
<td>2010</td>
<td>Molted in transit to 57.0= 29% increase</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M</td>
<td>62.5</td>
<td>Yellow</td>
<td>2010</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>F</td>
<td>54.8</td>
<td>Yellow-green</td>
<td>2010</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>F</td>
<td>50.0</td>
<td>Yellow-green</td>
<td>2010</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Jordan Cove</td>
<td>10-18-11</td>
<td>M</td>
<td>35.5</td>
<td>green</td>
<td>2011</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10-19-11</td>
<td>M</td>
<td>55.5</td>
<td>orange</td>
<td>2010</td>
<td>Good</td>
</tr>
<tr>
<td>YAQUINA</td>
<td>Johnson Slough</td>
<td>8-31-11</td>
<td>M</td>
<td>69.6</td>
<td>Yellow-green</td>
<td>2010</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Pool Slough</td>
<td>7-20-11</td>
<td>M</td>
<td>72</td>
<td>Yellow Green</td>
<td>2009/10</td>
<td>Good- David Beugli</td>
</tr>
<tr>
<td></td>
<td>Sally’s Bend</td>
<td>5-16-11</td>
<td>F</td>
<td>37</td>
<td>dark green</td>
<td>2010</td>
<td>Good - pitfall trap Summer Knowlton</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9-8-11</td>
<td>M</td>
<td>24.2</td>
<td>Green</td>
<td>2011</td>
<td>Pitfall Summer Knowlton</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9-8-11</td>
<td>M</td>
<td>67.4</td>
<td>Yellow</td>
<td>2010</td>
<td>Pitfall trap Missing # 10 pitfall trap</td>
</tr>
<tr>
<td></td>
<td>Aquarium mud flat</td>
<td>9-17-11</td>
<td>M</td>
<td>77.9</td>
<td>Yellow</td>
<td>2009/10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>F</td>
<td>67.2</td>
<td>Yellow-green</td>
<td>2010</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>F</td>
<td>51.0</td>
<td>Green</td>
<td>2010</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M</td>
<td>66.6</td>
<td>yellow</td>
<td>2010</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Date</td>
<td>Sex</td>
<td>Diameter</td>
<td>Color</td>
<td>Year/Season</td>
<td>Condition</td>
<td>Notes</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------</td>
<td>-----</td>
<td>----------</td>
<td>-----------</td>
<td>-------------</td>
<td>------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Idaho Point</td>
<td>6-23-11</td>
<td>M</td>
<td>79.9</td>
<td>Yellow-green</td>
<td>2009/8</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>74.4</td>
<td>Yellow</td>
<td>2009</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>57.4</td>
<td>Yellow-green</td>
<td>2010</td>
<td>good</td>
<td></td>
</tr>
<tr>
<td>NETARTS Culvert</td>
<td>06-22-11</td>
<td>M</td>
<td>55.61</td>
<td>whitish</td>
<td>2010</td>
<td>Good</td>
<td>Wendy Sletten</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>48.58</td>
<td>green</td>
<td>2010</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Intersection of Netarts Rd.</td>
<td>06-09-11</td>
<td>M</td>
<td>63.1</td>
<td>Yellow-green</td>
<td>2010</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>and Whiskey Creek Rd</td>
<td></td>
<td>M</td>
<td>60.64</td>
<td>Yellow-green</td>
<td>2010</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>63.05</td>
<td>Yellow-green</td>
<td>2010</td>
<td>Good</td>
<td>no eggs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>57.18</td>
<td>Yellow-green</td>
<td>2010</td>
<td>No # 6</td>
<td>no eggs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>52.04</td>
<td>Yellow-green</td>
<td>2010</td>
<td>#6 regenerating</td>
<td>no eggs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>54.03</td>
<td>Yellow-green</td>
<td>2010</td>
<td>Good</td>
<td>no eggs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>56.22</td>
<td>Yellow-green</td>
<td>2010</td>
<td>Good</td>
<td>no eggs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>56.9</td>
<td>Yellow-green</td>
<td>2010</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td></td>
<td>06-10-11</td>
<td>M</td>
<td>69.05</td>
<td>Yellow</td>
<td>2009</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>53.64</td>
<td>Yellow</td>
<td>2010</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>61.13</td>
<td>Yellow</td>
<td>2010</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>58.71</td>
<td>Yellow-orange</td>
<td>2010</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td></td>
<td>06-22-11</td>
<td>M</td>
<td>52.11</td>
<td>yellow</td>
<td>2010</td>
<td>#10 part missing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>06-22-11</td>
<td>M</td>
<td>52.87</td>
<td>yellow</td>
<td>2010</td>
<td>#1 missing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>06-22-11</td>
<td>M</td>
<td>52.14</td>
<td>yellow</td>
<td>2010</td>
<td>#10 part missing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>06-23-11</td>
<td>F</td>
<td>54.44</td>
<td>Red-orange</td>
<td>2010</td>
<td>good</td>
<td></td>
</tr>
<tr>
<td></td>
<td>06-23-11</td>
<td>F</td>
<td>55.76</td>
<td>green</td>
<td>2010</td>
<td>good</td>
<td></td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Year</th>
<th>Class</th>
<th>Estuary</th>
<th># Months &lt;10°C</th>
<th>Mean Winter Temp. °C</th>
<th>N</th>
<th>CPUE Minnow traps</th>
<th>CPUE Pitfall traps</th>
<th>Mean Carapace Width (mm)</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>Coos</td>
<td>4</td>
<td>9.6</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>0</td>
<td>10.9</td>
<td>1</td>
<td>0.01</td>
<td>59.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td></td>
<td>1</td>
<td>10.4</td>
<td>0</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td>2</td>
<td>10.3</td>
<td>2</td>
<td>0.05</td>
<td>45.0</td>
<td>0.32</td>
<td>43.5</td>
<td>4.6</td>
<td>36-52</td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td>2</td>
<td>9.9</td>
<td>17</td>
<td>0.32</td>
<td>43.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td>3</td>
<td>9.8</td>
<td>5</td>
<td>0.08</td>
<td>45.4</td>
<td></td>
<td></td>
<td></td>
<td>43-52</td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td>5</td>
<td>8.8</td>
<td>1</td>
<td>0.01</td>
<td>47.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td>4</td>
<td>9.0</td>
<td>0</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td>1</td>
<td>10.0</td>
<td>2</td>
<td>0.04</td>
<td>40.7</td>
<td></td>
<td></td>
<td></td>
<td>40-41</td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>0.01</td>
<td>35.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>Yaquina</td>
<td>0</td>
<td>10.9</td>
<td>201</td>
<td>5.00</td>
<td>46.9</td>
<td></td>
<td></td>
<td></td>
<td>32-60</td>
</tr>
<tr>
<td>1999</td>
<td></td>
<td>4</td>
<td>9.0</td>
<td>13</td>
<td>0.20</td>
<td>38.0</td>
<td></td>
<td></td>
<td></td>
<td>30-47</td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td>3</td>
<td>9.5</td>
<td>14</td>
<td>0.31</td>
<td>37.5</td>
<td></td>
<td></td>
<td></td>
<td>30-45</td>
</tr>
<tr>
<td>2001</td>
<td></td>
<td>3</td>
<td>9.5</td>
<td>Not sampled</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td></td>
<td>4</td>
<td>9.2</td>
<td>1</td>
<td>0.01</td>
<td>38.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>0</td>
<td>10.5</td>
<td>9</td>
<td>0.07</td>
<td>44.9</td>
<td></td>
<td></td>
<td></td>
<td>41-59</td>
</tr>
<tr>
<td>2004</td>
<td></td>
<td>3</td>
<td>9.9</td>
<td>4</td>
<td>0.07</td>
<td>35.3</td>
<td></td>
<td></td>
<td></td>
<td>32-43</td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td>2</td>
<td>10.3</td>
<td>21</td>
<td>0.75</td>
<td>41.0</td>
<td></td>
<td></td>
<td></td>
<td>28-46</td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td>3</td>
<td>9.8</td>
<td>18</td>
<td>0.20</td>
<td>42.6</td>
<td></td>
<td></td>
<td></td>
<td>34-51</td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td>3</td>
<td>9.5</td>
<td>3</td>
<td>0.03</td>
<td>44.4</td>
<td></td>
<td></td>
<td></td>
<td>36-49</td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td>5</td>
<td>8.4</td>
<td>1</td>
<td>0.02</td>
<td>44.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td>0</td>
<td></td>
<td>0</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td>8</td>
<td>0.05</td>
<td>0.05</td>
<td>40.8</td>
<td>6.7</td>
<td></td>
<td></td>
<td></td>
<td>30-50</td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td>0</td>
<td></td>
<td>0</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>Netarts</td>
<td>0</td>
<td></td>
<td>0</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>6</td>
<td>0.15</td>
<td>49.4</td>
<td>3.7</td>
<td>45-55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td></td>
<td>0</td>
<td></td>
<td>0</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td>25</td>
<td>0.92</td>
<td>42.9</td>
<td>5.3</td>
<td>30-53</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>Location</td>
<td>Specimens</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>---------------</td>
<td>-----------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>Tillamook</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td>31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>Willapa</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>Grays Harbor</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td></td>
<td>24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>Not Sampled</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td></td>
<td>0.65</td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td>0.02</td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td>0.30</td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>2002</td>
<td>Tillamook</td>
<td>0.00</td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>0.17</td>
</tr>
<tr>
<td>2004</td>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td>0.17</td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td>0.32</td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>1998</td>
<td>Willapa</td>
<td>0.778</td>
</tr>
<tr>
<td>1999</td>
<td></td>
<td>0.74</td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td>0.03</td>
</tr>
<tr>
<td>2001</td>
<td></td>
<td>0.02</td>
</tr>
<tr>
<td>2002</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>0.167</td>
</tr>
<tr>
<td>2004</td>
<td></td>
<td>Not Sampled</td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td>0.37</td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td>0.17</td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td>0.04</td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td>0.40</td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>1998</td>
<td>Grays Harbor</td>
<td>1.00</td>
</tr>
<tr>
<td>1999</td>
<td></td>
<td>0.02</td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>2001</td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>2002</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>Not Sampled</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td></td>
<td>38.6</td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td>5.3</td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td>29-50</td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td>47.7</td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td>44.7</td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td>5.6</td>
</tr>
<tr>
<td>2002</td>
<td>Tillamook</td>
<td>46-55</td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>37-45</td>
</tr>
<tr>
<td>2004</td>
<td></td>
<td>42-56</td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td>31-51</td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td>40.7</td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td>4.4</td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td>48.3</td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td>5.1</td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td>43-59</td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>Willapa</td>
<td>45.9</td>
</tr>
<tr>
<td>1999</td>
<td></td>
<td>40.0</td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td>37-55</td>
</tr>
<tr>
<td>2001</td>
<td></td>
<td>45.4</td>
</tr>
<tr>
<td>2002</td>
<td></td>
<td>48.5</td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>43-59</td>
</tr>
<tr>
<td>2004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>Grays Harbor</td>
<td>45.3</td>
</tr>
<tr>
<td>1999</td>
<td></td>
<td>40-50</td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td>37-45</td>
</tr>
<tr>
<td>2001</td>
<td></td>
<td>35-48</td>
</tr>
<tr>
<td>2002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>Not Sampled</td>
</tr>
<tr>
<td>Year</td>
<td>Value</td>
<td>CB</td>
</tr>
<tr>
<td>------</td>
<td>-------</td>
<td>----</td>
</tr>
<tr>
<td>2004</td>
<td>Not Sampled</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>2</td>
<td>0.03</td>
</tr>
<tr>
<td>2006</td>
<td>1</td>
<td>0.02</td>
</tr>
<tr>
<td>2007</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>2008</td>
<td>Not sampled</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>2010</td>
<td>Not sampled</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>Not sampled</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 5. *Carcinus maenas* year class strength as a function of Pacific Decadal Oscillation for March. Average catch data for the six estuaries were log -transformed and regressed against Pacific Decadal Oscillation Index for March. The regression was significant at \( p = 0.001 \) and explained \( 66\% \) of the variability. (This figure is an up-dated version of Figure 2b in Behrens Yamada and Kosro 2010.)