Introduction
The European green crab (*Carcinus maenas*) has been transported around the world during the last century and has colonized many temperate coastlines (Behrens Yamada 2001). Numerous research studies have examined the biology and ecology of green crabs and have generally found the green crab to be an aggressive invader that has the potential to negatively impact native species, important estuarine and marine habitats, and fisheries (Behrens Yamada 2001; Howard et al., 2019; Malyshv & Quijón, 2011; Garbary et al., 2014; Neckles, 2015; Matheson et al., 2016). The green crab is currently invading the west coast of North America. Greens crabs became established in the San Francisco estuary prior to 1989 (Behrens Yamada, 2001). Since then coastal currents have been seeding green crab larvae into estuaries of the Pacific Northwest, including Coos Bay (Behrens Yamada et al., 2015). In the past, this migration appears to be linked to strong northwards currents during El Niño years (Behrens Yamada et al., 2015), as indicated by a mixture of high abundance years, low abundance years, and extinction events. However, since 2016 the abundance of green crabs has been continuously increasing in Coos Bay and is now at levels where negative impacts are expected.

The purpose of this project is to monitor changes in green crab abundance and evaluate the young-of-the-year (YOTY) age class in the Coos Bay Estuary. The project goals are to: 1) examine change in green crab abundance (CPUE) among sites and over time, 2) examine the YOTY age class to assess size structure and determine whether recruitment is occurring from within Coos Bay.
Methods
At each of the 14 sites we set either six Fukui fish traps or six modified minnow traps during morning low tide and retrieved traps at low tide the following morning (24 hours). Fukui and minnow traps were baited with raw tuna enclosed in a plastic bait container and staked in place with a 20 inch steel rod. When traps were retrieved, the number of individuals of each crab species in each trap was recorded. Dungeness crabs (*Metacarcinus magister*), red rock crabs (*Cancer productus*), and shore crabs (*Hemigrapsus oregonensis* and *H. nudis*) were counted but not measured. When possible, we recorded water quality data (salinity, pH, temperature) at the trap site using a YSI hand-held meter. European green crabs (*Carcinus maenas*) were counted in the field and then brought back to the laboratory and measured for size (carapace width, mm), weight (g), and sex (m/f). Abdomen color and missing limbs were also recorded.

Results
We set 184 crab traps (156 Fukui, 24 minnow) at 14 sites in Coos Bay from February through October of 2020. We captured 858 green, 10 Oregon shore, 141 Dungeness, and 99 red rock crabs. Overall catch-per-unit-effort (CPUE) was 4.66 for green, 0.05 for Oregon shore, 0.76 for Dungeness, and 0.54 for red rock crabs. This includes data for all traps at all sites for all sampling dates from February thru October 2020.

Abundance among Coos Bay sites:
To better compare sites, we selected only sites sampled using Fukui traps during the summer months (May-August) (Table 1). The average CPUE was highly dependent on site. Green crabs were found at all sites, but were most common in the mid to upper estuary sites where adult Dungeness and red rock crabs were absent (Coos History Museum, Isthmus Slough). Red rock crabs were present only at sites lower in the estuary (Charleston Boat Basin, Empire Docks) and adult Dungeness crabs were most abundant at low and mid-estuary sites (Empire Docks, Indian Point N, Valino Island).

<table>
<thead>
<tr>
<th>Site</th>
<th>Latitude</th>
<th>Longitude</th>
<th>CPUE Green (mean)</th>
<th>CPUE Red rock (mean)</th>
<th>CPUE Oregon shore (mean)</th>
<th>CPUE Dungeness (mean)</th>
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</thead>
<tbody>
<tr>
<td>Charleston Boat Basin</td>
<td>43.347281</td>
<td>-124.323273</td>
<td>0.78</td>
<td>1.39</td>
<td>0.00</td>
<td>0.67</td>
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<td>Coos History Museum</td>
<td>43.375060</td>
<td>-124.212000</td>
<td>26.50</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Empire Docks</td>
<td>43.393000</td>
<td>-124.280000</td>
<td>0.17</td>
<td>3.83</td>
<td>0.00</td>
<td>2.11</td>
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<tr>
<td>Hinch Bridge</td>
<td>43.276272</td>
<td>-124.319689</td>
<td>0.33</td>
<td>0.00</td>
<td>0.11</td>
<td>0.00</td>
</tr>
<tr>
<td>Indian Point N</td>
<td>43.333042</td>
<td>-124.315089</td>
<td>0.80</td>
<td>0.00</td>
<td>0.00</td>
<td>0.97</td>
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<tr>
<td>Isthmus Slough</td>
<td>43.356350</td>
<td>-124.193000</td>
<td>11.20</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>Joe Ney Slough</td>
<td>43.339290</td>
<td>-124.310000</td>
<td>5.50</td>
<td>0.00</td>
<td>0.28</td>
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<td>Metcalf Marsh</td>
<td>43.333930</td>
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<td>0.00</td>
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<td>0.00</td>
<td>0.00</td>
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<tr>
<td>Valino Island</td>
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<td>-124.321000</td>
<td>0.47</td>
<td>0.47</td>
<td>0.17</td>
<td>3.19</td>
</tr>
</tbody>
</table>
**Abundance over time:**

One objective is to look at changes in green crab abundance over time. If we look at mean green crab CPUE collected at all sites over all years during summer months (May through August) using Fukui traps we see a consistent increase in abundance since 2016 (Figure 1). We also see an increase in variability over that time.

![Figure 1. Mean CPUE for green crabs using Fukui traps for all sites sampled in Coos Bay across all years during summer months (May through August). Errors bars indicate standard deviation. Labels above bars indicate the total number of Fukui traps sampled during that period.](image)

Variability may be caused by habitat differences among sites. We detected this in the 2020 site data. We can also examine temporal trends at each site. We see that the temporal trend matches the 2020 trend with consistently more green crabs at mid to upper estuary sites (Figure 2).
Figure 2. Mean green crab CPUE at 10 sites in Coos Bay over time trapped using Fukui traps from May – September 2004 through 2020. Note varying scale on y-axis. Error bars indicate standard deviation.

It appears that green crabs tend to be more abundant in areas where adult Dungeness crabs are in low abundance. We can look at this directly by comparing the CPUE of the two crab species over time at the same 10 sites (Figure 3).
Figure 3. Mean green crab and Dungeness CPUE at 10 sites in Coos Bay over time trapped using Fukui traps from May – September 2004 through 2020. Note varying scale on y-axis.
Size Structure of the young-of-the-year age class:
Size distribution of YOTY crabs gives some insight into the recruitment source. A single tight bell-curve shaped distribution indicates that the larvae arrived in the estuary at approximately the same time, likely from the same location. Flat or double-humped distributions indicate that larvae may have arrived in more than one cohort, suggesting multiple sources. We examined the frequency distribution of YOTY green crabs using September 2020 minnow trap data. Minnow traps tend to capture smaller crabs, but some larger crabs can enter the traps. We removed data from crabs larger than 60mm carapace width as these are likely from the previous year’s recruitment (Figure 4).

![Crab size frequency distribution for YOTY green crabs sampled at four sites in Coos Bay in September 2020 using modified minnow traps.](image)

Discussion
We found that green crab abundance is generally continuing to increase throughout Coos Bay. However, abundance is highly variable with some sites increasing substantially and other sites changing very little. As green crab populations increase, we will likely see negative impacts on organisms, habitats, and fisheries (Grosholz et al., 2011).

Potential Impact on Eelgrass
Studies along the east coast of North America, where green crabs have been abundant for decades, have found that the increasing green crab populations have caused large declines in eelgrass meadows (Malyshev & Quijón, 2011; Garbary et al., 2014; Neckles, 2015; Matheson et al., 2016). A recent study along the coast of British Columbia found similar results (Howard et al., 2019). These studies found that green crabs destroy eelgrass meadows both directly, by eating eelgrass rhizomes, and indirectly, when digging for food (bioturbation). Observed negative impacts appear to start at
around 20 CPUE (although most studies measured crab abundance as a function of area (number per square meter), so direct comparisons are difficult). Since the Coos History Museum site has increased to 26.5 crabs per trap in 2020 from 11.3 crabs per trap in 2019, it is likely that eelgrass populations in the mid-upper area of Coos Bay are experiencing some negative impact from green crab foraging. Since eelgrass is an important foundational habitat for many marine and estuarine organisms, we expect to see flow-on impacts to these species as their habitat declines. For example, researchers in Newfoundland found a 10-fold decrease in abundance and biomass of fish in beach seines when comparing areas of eelgrass habitat destroyed by green crabs and nearby eelgrass meadows without green crabs (Matheson et al., 2016).

**Potential Impact on Dungeness Crab**
The greatest increase in green crab abundance is at mid to upper estuary sites where adult Dungeness and red rock crabs are absent or in low abundance. However, juvenile Dungeness crabs tend to forage in upper and mid estuary nursery sites. For example, in 2018 we captured over 200 juvenile Dungeness crabs per seine sample in both September and October in the upper reaches of South Slough (Sengstacken arm near Elliot Creek). Previous research has found that green crabs displace juvenile Dungeness crabs from desirable sheltered habitats, which increases their chance of being preyed upon (McDonald et al., 2001). Green crabs also consistently win nocturnal foraging trials over juvenile Dungeness crabs (McDonald et al., 2001). The authors conclude that green crabs could negatively impact the Dungeness crab fishery as green crabs encroach on juvenile Dungeness crab nursery habitat, such as what is currently happening in Coos Bay. In addition, a 2019 study conducted by South Slough National Estuarine Research Reserve researchers found that red rock crabs prefer to predate on juvenile Dungeness crabs over green crabs of the same size, indicating that predation by adult crabs might reduce green crab abundance, but will not necessarily be favorable to Dungeness crab populations (Heller and Schooler, unpublished data). As described above, as green crabs increase in abundance, they will also destroy eelgrass habitat, which is a favored habitat of juvenile Dungeness crabs.

**Potential Impact on Bivalves**
Green crabs are also known to negatively affect populations of clams, oysters, and mussels. Studies on the east coast of North America found that green crabs ate bivalve species including quahogs (*Mercenaria mercenaria*), eastern oysters (*Crassostrea virginica*), blue mussels (*Mytilus edulis*), and soft-shell clams (*Mya arenaria*) (Miron et al., 2005). They found predation on these species across a large range of sizes (0-40mm) with green crabs preferring to feed on mussels and clams.

**Green crab self-recruitment in Coos Bay**
The young-of-the-year size (YOTY) distribution did not indicate the presence of two size cohorts in 2020 indicating no evidence of two different recruitment sources. However, this does not mean self-recruitment in Coos Bay is not occurring as it is possible that the 2020 recruits are just from Coos Bay or that there is considerable size overlap of the YOTY crabs from two sources.
Conclusions

We are finding a consistent increase in green crab abundance in Coos Bay over the past five years. The Coos Bay waterfront appears to be a hotspot for green crabs, perhaps due to habitat structure and food availability. Green crab abundance is now in the range where we expect to observe negative effects. More research is needed to: 1) determine the potential impacts of green crabs on important estuarine fisheries, species, habitats, and food webs, 2) evaluate reasons for high variability in green crab abundance, 3) determine sources of recruitment of green crabs, and 4) identify and study management options.

Acknowledgements:
Numerous researchers, interns, and volunteers have assisted in the collection of these data including: Christine Geierman, Bree Yednock, Angela Doroff, Chris Carlson, Renee Heller, Luke Donaldson, Liam Hunt, Ian Rodger, Colin Williams, Thelonious Schooler, and many others...

References:


Appendix 1. Map of crab sampling sites.

Legend

Green crab sample sites

Trap type
- □ Fukui
- △ both
- ⬜ minnow