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Recommendation for future studies

Monitoring the spread and impact of *Carcinus maenas*

The appearance of *Carcinus maenas* on the West Coast of North America offers us the unique opportunity to study an invasion in progress. Invasions are usually studied after the fact, when it is too late to gain an understanding of the process. In our case we are uniquely situated to learn from previous cases of green crab invasions and still have the time to study native communities BEFORE the invasion occurs. We are thus positioned not only to learn how one species can transform the structure and function of marine and estuarine communities, but we could also make a significant contribution to the field of invasion biology by presenting a test case. What is needed is for marine scientists in California, Oregon, Washington, British Columbia and Alaska to work together and to monitor their marine and estuarine communities in a standardized fashion.

While it is desirable to study the impact of the green crab on all members of the marine and estuarine communities, time constraints will only allow us to focus on a few of the most important interactions. For our sampling effort in four Oregon bays, we like to propose the following recommendations for monitoring the spread and impact of the green crab:

- 1. Assess crab predation at various sites.** The arrival of the green crab could result in increased predation pressure on prey populations in some habitats and no change in others. If the green crab displaces the less efficient *Hemigrapsus* sp. on more brackish shores, one might expect a dramatic increase in predation pressure. However, in high saline habitats where the more efficient *Cancer* crabs (e.g. *Cancer productus*) dominate, predation pressure may not change because one efficient crab predator is simply replaced by another. Predation pressure between sites can be assessed by putting out prey organisms and following their survival. Seed oysters, young clams or mussels, newly settled barnacles attached to settlement plates and tethered snails could be used as prey. Half the prey would be protected from predators by covering them with mesh cages. Tethered snails are particularly good for assessing crab predation because crabs break snails shells in a diagnostic "peel" pattern (Behrens Yamada and Boulding 1996).
- 2. Keep sampling the same study sites for native crabs.** Try to estimate year class strength from size frequency distributions and note reproductive status of crabs. The arrival of the green crab most likely will be correlated with decreases in the abundance and changes in the size frequency distributions of native crabs.
- 3. Collect young-of-the-year (YOTY) crabs using collectors.** Try setting out vexar bags filled with fine rock or shell gravel, scrub brushes and Astroturf. If *Carcinus maenas* settles out in great numbers from the plankton, one could make a prediction on the impact this species could have in the future. In no YOTY green crabs are found a site, it is very unlikely that green crabs will present a problem one year hence.
- 4. Keep estimating percent cover of common organisms at key study sites.** In order to reduce variability, we recommend picking permanent transects at designated tidal levels and classifying the slope and substrate into categories.
- 5. Develop an effective technique for sampling infauna.** Due to time constraints, we did not sample infauna on the mudflat nor in marsh banks. These habitats and their occupants could be drastically altered by

the arrival of *Carcinus maenas*.

6. Monitor the population structure of direct developing prey species. As far as we know, the invasion of the green crab has not resulted in any local species extinctions. The species that are most at risk would be those prey species that lack a planktonic dispersal stage. Some of these species to monitor are *Littorina sitkana*, *Littorina subrotundata*, and *Myosotella sp.*

Minimizing the impact of *Carcinus maenas* in Aquaculture

The green crab will be with us. Given that they are ecological and physiological generalists, voracious predators and that ocean currents disperse their larvae, they will not go away. All we can do is adapt to this new reality and try to minimize their impact in aquaculture. We need to invest in research aimed at attacking all phases of their life history.

1. Trap green crab larvae in nets and collectors. When megalopae larvae are ready to settle out from the plankton, they swim in the surface layer of the water column and are strongly attracted to light. If larval development is synchronous, it may be possible to attract the larvae to light sources and then fish them out of the water with nets. Young crabs could be collected by putting out favorable settling substrates and scented bait. Crushed oyster shell, fine rock gravel, Astroturf and brushes could be tested for their suitability as larval collectors. Research would have to be initiated to find a scent that acts as an attractant for green crab megalopae.

2. Add moderate predators to control green crab settlement into oyster trays and oyster grounds. Crabs of the genus *Hemigrapsus* are moderately efficient predators. They may eat newly settled green crabs, but they themselves would not pose any problem to oysters > 10 mm. Field experiments should be conducted to test the efficacy of this technique.

3. Provide alternative food for green crabs. For example, green crabs prefer mussels to oysters. Seed mussels could be added to oyster trays or oyster grounds during a time when oysters are most vulnerable. The interactions between alternative prey, oysters and green crabs should be investigated.

4. Inspect oyster trays and grounds frequently and manually remove large green crabs. Oyster tray modules could be hosed down with fresh water to stress smaller crabs both physically and osmotically.

5. Develop a fishery for large green crabs. Green crabs are eaten in European countries. If large crabs are prized for food, their populations could be kept in check. The following research needs to be addressed:

- ❖ Experiment with different bait and odorants that attract green crabs.
- ❖ Experiment with different trap designs.
- ❖ Check around the world for crab recipes and develop markets for green crabs.

If the fishery catches on, there will be an incentive to maintain sustainable populations. This is not desirable. The goal should be to keep the population as low as possible in order to minimize the effect of this species.

