Green Crab Control: A Removal Effort in a Shallow Central California Estuary

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Green Crab Control: A removal effort in a shallow central California estuary.

Larson, A.A., de Rivera, C.E., Ruiz, G.M., Grosholz, E.D., Sytsma, M.D.
Goal

To test the feasibility and effects of locally removing a well-established population of a marine organism with pelagic larvae.

Removal of adult European green crabs (*Carcinus maenas*) from Bodega Harbor as a **model system** to develop and inform management options for eradication, rapid response, and control of marine invaders.
Bodega Harbor, California

- *C. maenas* since 1993
- Well studied over time
- Knowledge of native community pre-invasion and early invasion (since 1980s)
- Rebound to natural conditions
Project Timeline

• Evaluate initial conditions in Bodega Harbor June 2006 (before *C. maenas* removal)
  – Population estimates (Mark-Release-Recapture)
  – Relative abundance measures (Standardized trapping)
  – Mapping of *C. m.* in Bodega Harbor

• Intensive Removal Period (July 06-Oct 07)
  – Focused on core sites in Bodega Harbor

• Assessment of progress and impacts (Aug 06, Jan, May, June 07, May, August 08):
  – Relative abundance measures (Standardized trapping)
  – Through all sites in Bodega Harbor and in reference bays

• Re-initiation of removal effort May 2008
Removal Methods: Intertidal/shallow subtidal

Baited Traps

Hand Capture

Seine

Habitat Traps (with Ulva, eelgrass and pipe traps)

Open Coast trapping & Snorkeling
Removal Methods: Deep channels, neap tides

Trapping (Baited and Pipe Traps) via Kayak

Trawled main Channel Winter 2006
<table>
<thead>
<tr>
<th>Trap Type</th>
<th>CPUE</th>
<th>% Female</th>
<th>% Gravid</th>
<th>% &lt;35mm</th>
<th>mean size (mm)</th>
<th>*Total removed</th>
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<td>0.2</td>
<td>60</td>
<td>13.33</td>
<td>13.33</td>
<td>51</td>
<td>15</td>
<td>167 traps</td>
</tr>
<tr>
<td>Seine (per 25m)</td>
<td>61.14</td>
<td>56.56</td>
<td>0.23</td>
<td>78.67</td>
<td>29.2</td>
<td>1327</td>
<td>26 transects (8 days)</td>
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<tr>
<td>Hand caught</td>
<td>43.10</td>
<td>0.19</td>
<td>66.27</td>
<td>31.44</td>
<td>503</td>
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<td>3 trawled transects at 1174,902,1275 meters each</td>
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</table>

Year-around removal

Seasonally targeted / opportunistic

*additional crabs removed by similar methods
Assessment:
Standardized Trapping

20 meters
C. m. caught in 10 traps
June 2006

- 0-1
- 2-5
- 6-10
- 11-25
- 26-50
Adult Crabs caught by trapping

- June 2006: 0
- October 2006: 100
- February 2007: 200
- June 2007: 300
- October 2007: 400

Date: Jun 06  Oct 06  Feb 07  Jun 07  Oct 07

Total Crabs Removed

Date: Jun 06  Oct 06  Feb 07  Jun 07  Oct 07

- July 2006
- August 2006
- May 2007
- July 2007
- Jan 2007
Crabs per trap (baited)
Abundance of *C. maenas* at assessment

Hatched area = small crabs (<=35mm)
Assessment of *C. maenas* at Bodega and in Reference Bays

![Graph showing assessment results]

- Bodega: 51% (Jul-06), 85% (Aug-06)
- Tomales: 39% (May-07), 53% (Jul-07)
- Bolinas: 22% (Jul-07)
- Elkhorn: 59% (Jul-07)
Abundance of Cancer crabs at assessment

avg # crabs / day (4 sites)

<table>
<thead>
<tr>
<th>Month</th>
<th>Avg # Crabs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jul-06</td>
<td>8.0</td>
</tr>
<tr>
<td>Aug-06</td>
<td>5.5</td>
</tr>
<tr>
<td>Jan-07</td>
<td>7.0</td>
</tr>
<tr>
<td>May-07</td>
<td>3.0</td>
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<td>Jul-07</td>
<td>7.5</td>
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Abundance of *Hemigrapsus oregonensis* at assessment
Carapace width of *H. oregonensis*

- **June 2006**
  - CW (mm): 20
- **June 2007**
  - CW (mm): 24

2-tailed t-test

*P* < 0.001
Population Estimate:
Mark-Release-Recapture (MRR)

Total Marked: 2,106
Carcinus
Recapture: 67% of marked
Mark IV wire tags

• Pros:
  – Crabs are fully mobile, do not attract predators
  – Efficient; quickly mark many crabs
  – Detectable through molts
  – Effective; easy to detect marks

• Cons:
  – Expensive
  – Cannot differentiate between more than two sites or dates
Mark Release Recapture

\[
\frac{\text{Population size}}{\text{# crabs marked}} = \frac{\text{# crabs caught}}{\text{# crabs recaptured}} \Rightarrow \frac{\hat{N}}{\text{Mt}} = \frac{\text{Ct}}{\text{Rt}}
\]

1. marked individuals are a random sample of the population
2. they disperse at random through the entire population
3. the marking procedure does not damage them
4. none of the marks are eradicated or lost
5. the likelihood of marked individuals being captured again is independent of having once been captured,
6. mortality is negligible between the time of original release of marked individuals and the time of recapture
Mark Release Recapture

\[
\frac{\text{Population size}}{\text{Total Marked}} = \frac{\text{Total Recapture}}{\text{Estimated Population Size}}
\]

Total Marked: 2,106
Total Recapture: 1411
Total crabs caught 7/15-8/31/2006: 7791
Estimated Population Size: 11,629 adults

Current number of \textit{C. maenas} (all sizes) removed from Bodega Harbor: 12,794
Current number of \textit{C. maenas} adults (>35mm) removed from Bodega Harbor: 11,884
Mark Release Recapture

\[ \frac{\text{Population size}}{\text{# crabs marked}} = \frac{\text{# crabs caught}}{\text{# crabs recaptured}} \rightarrow \frac{\hat{N}}{\text{Mt}} = \frac{\text{Ct}}{\text{Rt}} \]

**Total Marked:** 2,106  
**Total Recapture:** 1411  
**Total crabs caught 7/15-8/31/2006:** 7791  
**Estimated Population Size:** 11,629 adults

- This calculation assumes that there was a single episode of marking and a single episode of recapture.

- Although we assume the harbor wide adult population was closed over this time period, this is a harbor wide estimate, and movement throughout the harbor is not random (very little movement between sites).

- More appropriate calculations for our methods could be used if we had been able to distinguish our crabs by date marked (Jolly-Seber)
MRR Methods
Elastomer

• Pros:
  – Mark individuals by date and site
  – Inexpensive

• Cons:
  – ephemeral; visibility after >1 molt is possible not very strong
Recommendations

• For best population size estimates using MRR:
  – Need daily and site release information for best population estimates
  – Wire tags + elastomer can give you this information for all size crabs without altering mortality (due to predation or tagging method)
Conclusions

• Population of *C. maenas* is 85% smaller a year after removal began

• Since removal effort, size and abundance of *H. oregonensis* has increased

• To estimate total population size with MRR: use wire tags and elastomer

• To measure impact, use relative change in abundance (standard trapping measures)
Further removal and assessment

• >3 summers to see effects on
  – Recruitment of *C. maenas*
  – native populations

• Focus removals during summer and fall with highest abundances

• Use of multiple methods to target populations at different times
Future directions

• Implement removals in new embayment
  – volunteer effort for removals

• Continue removals and assessment of impacts of population control

• We are coordinating efforts to examine recruitment strength and sources
Acknowledgements

Caitlin Coleman-Hulbert, Becca Kordas, Celeste Dodge, India Clarke, Lindsey Budd, Brian Steves, Amanda Newsom, Jennifer Panlilio, Val Brenneis, Christina Simkanin, Chris Brown, Jelle Faber, Monaca Noble, David Kimbro, Anna Deck, Chris Bell, Basma Mohamad, Jeff Diez, Kate Huxter, Jarrett Byrnes, Josh Haakensen, Anna Coleman-Hulbert
Sex ratios

- Jul-2006
- 1-Aug
- Jan-07
- May-07
- Jul-07
Date: Jun 06 Oct 06 Feb 07 Jun 07 Oct 07

Total Crabs Removed: 0 100 200 300 400 500

C or M, All sizes
C or M  >=35mm

Date
Jun 06  Oct 06  Feb 07  Jun 07  Oct 07

Total Crabs Removed

C or M  >=35mm

Date
Jun 06  Oct 06  Feb 07  Jun 07  Oct 07

Total Crabs Removed
C or M, all sizes

- MID
- LOW
- SUB

crabs per trap

Jun-06  Oct-06  Feb-07  Jun-07  Oct-07  Mid-07
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