Clam recruitment across substrates in Willapa Bay

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Focus on two life-history stages -

Settlement

Recruitment
Settlement

Recruitment
Questions

• How is clam settlement or recruitment influenced by *Z. japonica*?
  – Ecological theory suggests complex structure increases diversity and abundance of associated organisms, but particular species may not respond positively

• How is clam settlement or recruitment influenced by amendment by rock or shell substrates?
  – Beach frosting reduced settlement but increased survival in Puget Sound (Thompson 1995)
  – Shell may improve interstitial water chemistry (Green et al. 2009)
Settlement
June – Dec

Blue lines = 0.5 mm clams in monthly samples
Points = 0.2-0.5 mm very recent

Clams per bag

2010

2011

2012

Clams per bag

J J A S O N D J F M A M J
# Methods: 3 experiments

<table>
<thead>
<tr>
<th>Test</th>
<th>Measure</th>
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<tbody>
<tr>
<td>4 substrates added in mesh bags (round rock, crushed gravel, clam</td>
<td>3 wks,</td>
</tr>
<tr>
<td>shell, oyster shell)</td>
<td>6 wks,</td>
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<td></td>
<td>9 months</td>
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<tr>
<td>Tidal elevation</td>
<td>2 months,</td>
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<tr>
<td>Clam bed vs. <em>Z. japonica</em> habitat</td>
<td>9 months</td>
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<tr>
<td>Mechanical removal or addition of <em>Z. japonica</em> in small plots</td>
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<tr>
<td>Chemical removal of <em>Z. japonica</em> in large plots</td>
<td>11 months</td>
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<tr>
<td>3 substrates added in small plots (round rock, crushed gravel,</td>
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<tr>
<td>shell with gravel)</td>
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EXPERIMENT 1

Crushed gravel  
Round rock  
Crushed oyster shell  
Crushed clam shell

X 5 replicates
X 3 sites

50 cm
EXPERIMENT 1
Recruitment of fingernail-sized clams
~70 per bag
~400 per square foot
Crushed gravel – results show expected seasonal pattern of accumulation from summer recruitment, followed by overwinter mortality
Round rock – no advantage for settlement or survival
Shell treatments – weak settlement advantage, no survival benefit
Reference area of fine-grained sediment – lower clam abundance than in bags with rock/shell due to overwinter mortality
EXPERIMENT 2

2 habitats
- Commercial clam bed
- Zostera japonica

3 treatments
- Eelgrass addition
- Disturbance control
- Control

X 7 replicates
X 2 tidal elevations
X 2 sites
Plots sampled by coring

Eelgrass removal
Disturbance control (transplant)
Control
Non-native dwarf eelgrass
Zostera japonica
EXPERIMENT 2
2 months:
Higher settlement at lower elevations

Experiment in clam beds

Experiment in *Z. japonica*

Manila recruits per core

Elevation: Lower                   Higher                          Lower                       Higher
2 months:
Higher settlement at lower elevations in both habitats

**Experiment in clam beds**

- Elevation: Lower
  - 1' 281st: ~45
  - 1' Woody: ~20
  - 3' 281st: ~10
  - 3' Woody: ~5

- Elevation: Higher
  - 1' 281st: ~5
  - 1' Woody: ~3
  - 3' 281st: ~2
  - 3' Woody: ~1

**Experiment in Z. japonica**

- Elevation: Lower
  - 1' 281st: ~15
  - 1' Woody: ~10
  - 3' 281st: ~5
  - 3' Woody: ~1

- Elevation: Higher
  - 1' 281st: ~5
  - 1' Woody: ~3
  - 3' 281st: ~2
  - 3' Woody: ~1
2 months: Plot-level treatments had no effect on settlement.

Experiment in clam beds:
- Add *Z. japonica*
- Disturb sediment

Experiment in *Z. japonica*:
- Elevation: Lower vs. Higher
2 months:
Plot-level treatments had no effect on settlement
After 2 months, Manila clams were less abundant at high than low elevations. No effect of habitat was detectable statistically, but 2 sites provided low power.

Clam beds – recruitment 16/ft²
Z. japonica – recruitment 6/ft²

After 9 months, Manila clams were less abundant in Z. japonica than on clam beds.
EXPERIMENT 3

- No addition
- Crushed gravel
- Round rock
- Gravel + shell

Z. japonica sprayed with imazimox

X 2 plot replicates
X 6 subplot replicates
EXPERIMENT 3
Compare *Z. japonica* and removal, then substrate addition.
EXPERIMENT 3
Removing *Z. japonica* did not markedly improve clam recruitment
EXPERIMENT 3
Removing *Z. japonica* and adding rock or shell substrate dramatically improved clam recruitment
Substrates were equally effective with or without shell

![Graph showing Manilas <20mm per sq ft for No addition, Crushed rock, Round rock, and Rock and Shell with Zj and noZj categories.](image-url)
EXPERIMENT 3

*Z. japonica* reduced the effectiveness of substrate addition.
All the results

• <10% overwinter survival of newly-settled clams, much improved by mesh and substrate

• High settlement across multiple habitats and substrates, accumulating over many months

• Recruitment response relative to generic graveling:
  – No effect of adding crushed shell
  – No effect of adding round rock

• Little effect of *Z. japonica* on recruitment to fine-grained tideflats, but negative effect of *Z. japonica* on recruitment to graveled tideflats (large scale)
Results for Mya arenaria- extra slides
EXPERIMENT 2 – Eastern soft-shell clams

Mya recruits per core - Oct

1' Clam | 1' Zj | 3' Clam | 3' Zj

Mya recruits per core - May

1' Clam | 1' Zj | 3' Clam | 3' Zj
EXPERIMENT 3 – Eastern soft-shell clams