Non-indigenous Macroalgae in Hawaii

- 20 introduced species of macroalgae since 1950’s
- 1st Surveys 1999-2000
- 5 species considered nuisance species:
  - *Acanthophora spicifera*
  - *Avrainvillea amadelpha*
  - *Hypnea musciformis*
  - *Gracilaria salicornia*
  - *Kappaphycus spp.*
Algae Dominated
Project Goals: FY 2003

• Assessment of alien/invasive algae throughout Hawai‘i
  – Resurvey 80+ sites from 1999-2000, quantify herbivore and benthic community structure, identify patterns between various parameters and alien algal abundance, generate alien algae distribution maps

• Management of current alien algae problems on O‘ahu
  – Monitor removal plots, examine coral algal interactions, document distribution and spread, finish experiments from 2002
    • *Gracilaria salicornia*-Waikiki
    • *Kappaphycus*-Kane‘ohe Bay

• Education & Outreach
  – Develop brochures, posters, underwater ID cards, field guide and lesson plans for k-12 teachers, hold workshops

• Other
  – Compile a global database on invasive macroalgae
Statewide Alien Algae Surveys

- Quantitative assessment of benthic reef communities & grazers (urchins, mollusks & fish)
- Temperature & salinity
- Protection? MLCD, NARS, FMA or other
- Horizontal visibility
- Turtles present?
- Coral alien algal interactions?
- Seagrass?
Sites Surveyed as of 8/20/2003
Sites Surveyed as of 8/20/2003

Acanthophora spicifera
- Absent
- Present

600 ft. fathom line
Sites Surveyed as of 8/20/2003

Hypnea musciformis
- Absent
- Present

600 ft. fathom line
## Summary of Alien Algae Statewide Surveys

<table>
<thead>
<tr>
<th></th>
<th>Number of Sites</th>
<th>% of Total</th>
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<tr>
<td>Coral/Algae?</td>
<td>11</td>
<td>20.755</td>
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<td>Turtles</td>
<td>15</td>
<td>28.3</td>
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<td>Seagrass</td>
<td>5</td>
<td>9.43</td>
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<td>49.06</td>
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<tr>
<td>Gracilaria salicornia</td>
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<td>9.43</td>
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<tr>
<td>Hypnea musciformis</td>
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<td>28.3</td>
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<td>Aliens</td>
<td>30</td>
<td>56.6</td>
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<td>Turtles and aliens</td>
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<td>17</td>
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<td>Protected?</td>
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<td>35.8</td>
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<tr>
<td>Protected with Aliens</td>
<td>10</td>
<td>18.9</td>
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<td>Total # Sites</td>
<td>53</td>
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Management of *Gracilaria salicornia* on O‘ahu

- Reconnaissance surveys
- Monitor removal plots
- Examine coral/algal interactions
- Dispersal experiments
- Impacts on diversity
- Grazing
- Volunteer clean-up events & mechanical suction device
Gracilaria salicornia:
Distribution on the south shore of O‘ahu
Gracilaria salicornia
Removal Plots

Removal & Re-growth Experiment

G. salicornia removed 11/14/02
Control Plots

Percent Cover of Gracilaria salicornia

2002-2003


Nov-Before

Nov-After

March-2003
Management of *Kappaphycus* spp. on O’ahu

- Monitor removal plots
- Examine coral/algal interactions: one year of photoquadrat data
- Assess impacts of nutrient enrichment and grazing by fish and urchins on re-growth: one year factorial experiment
- Continue to assess distribution and spread
- Reproductive characteristics
Kappaphycus spp. Removal Plots

2002-2003

Before Removal

June July Aug Oct Nov Dec

3-May

July-03

Percent Cover

0 20 40 60

Kappaphycus

Coral
Kappaphycus spp.
Control Plots

<table>
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<tr>
<th></th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>May</th>
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2002-2003

Percent Cover
Factors Influencing Re-establishment of Alien Algae in Cleared Plots

- Site Identification: 3 sites
- Remove algae in 0.5 m plots
- Factorial experiment-cage, urchin, fertilizer, time, site
- Monitor changes

Experimental Design (one block)

<table>
<thead>
<tr>
<th>Herbivores</th>
<th>Nutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>-</td>
<td>+</td>
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<td>-</td>
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Herbivores +

Herbivores -

Urchins

Urchins +

Urchins -
Factorial Experiment:

Urchin addition, Fish Exclusion, Fertilizer Addition, 3 sites (Patch Reefs 29, 44 & Mark’s Reef), 3 transects on each reef, monthly sampling for 1 year
Results of *Kappaphycus* Factorial Experiment

The graph shows the percentage cover of *Kappaphycus* by month for different treatments:

- **Control**
- **Cage**
- **C/F**
- **Fert**
- **C/U/F**
- **U/F**
- **Urchin**
- **C/U**

The treatments are analyzed from May to October, with data points represented by bars and error bars indicating variability. The graph highlights the effects of different treatments on *Kappaphycus* coverage over the specified months.
### ANOVA Results for Factorial Experiment

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Seq SS</th>
<th>Adj SS</th>
<th>Adj MS</th>
<th>F</th>
<th>P</th>
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<tbody>
<tr>
<td>NUTRIENT</td>
<td>1</td>
<td>633.5</td>
<td>1084.0</td>
<td>1084.0</td>
<td>3.97</td>
<td>0.047</td>
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<td>CAGE</td>
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<td>14935.6</td>
<td>15610.6</td>
<td>15610.6</td>
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<td>URCHIN</td>
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<td>NUTRIENT*CAGE</td>
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<td>85.7</td>
<td>85.7</td>
<td>0.31</td>
<td>0.575</td>
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<td>NUTRIENT*Reef</td>
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Results of Kappaphycus Experiment by Reef

Mark's Reef

Patch Reef # 29

Patch Reef # 44

Percent Cover of Kappaphycus

- Cont: Control
- Cage: Cage Treatment
- C/F: Combined Fertilizer
- Fert: Fertilizer
- C/U/F: Combined Unfertilized
- U/F: Unfertilized
- U: Unfertilized Control

Bar graphs show the percent cover of Kappaphycus for each treatment and month for Mark's Reef and Patch Reef # 29 and # 44.
Results: *Kappaphycus spp.*

**Physical Factors: Nutrient Levels**

A. **DIN** ($\text{NO}_3^+\text{NO}_2^-+\text{NH}_4^+$)

B. **Phosphate** ($\text{PO}_4$)

C. **Silicate** ($\text{Si(OH)}_4$)

<table>
<thead>
<tr>
<th>Month</th>
<th>Patch Reef 29</th>
<th>Patch Reef 44</th>
<th>Mark's Reef</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>DIN</em> (µmol)</td>
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<td></td>
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</tr>
<tr>
<td>June</td>
<td>0.5</td>
<td>0.4</td>
<td>0.3</td>
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<tr>
<td>Aug</td>
<td>1.0</td>
<td>1.2</td>
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</tr>
<tr>
<td>Oct</td>
<td>1.5</td>
<td>1.8</td>
<td>1.7</td>
</tr>
<tr>
<td>Nov</td>
<td>2.0</td>
<td>2.2</td>
<td>2.1</td>
</tr>
</tbody>
</table>

| *PO₄* (µmol) |
| June | 0.00 | 0.00 | 0.00 |
| Aug  | 0.05 | 0.05 | 0.05 |
| Oct  | 0.10 | 0.10 | 0.10 |
| Nov  | 0.15 | 0.15 | 0.15 |

| *Si(OH)₄* (µmol) |
| June | 5.0 | 5.0 | 5.0 |
| Aug  | 10.0 | 10.0 | 10.0 |
| Oct  | 15.0 | 15.0 | 15.0 |
| Nov  | 20.0 | 20.0 | 20.0 |
Results: *Kappaphycus spp.*

Physical Factors: Water & Tissue Nutrient Levels

A. Nitrogen

![Nitrogen Graph](image)

B. Phosphorus

![Phosphorus Graph](image)
Results: *Kappaphycus* spp.

Biological Factors: Herbivore Abundance

**Biomass**

- **Acanthurids**
  - Patch Reef 29
  - Patch Reef 44
  - Mark's Reef

- **Scarids**

**Density**

- **Acanthurids**
  - Patch Reef 29
  - Patch Reef 44
  - Mark's Reef

- **Scarids**
Education & Outreach

- Recently held a workshop with Seagrant and National Park Service on big island
- Developing lesson plan for k-12 students
- Draft underwater ID cards made
- Working on field guide
- Continuing volunteer alien algae removal events—Sept 13, Waikiki Natatorium contact Eric Co for more information eco@tnc.org
Other

- Developing a global database for alien/invasive macroalgae
- Continue research with the Nature Conservancy developing techniques for using a mechanical suction device to remove alien algae
- Attendance at numerous conferences: International Marine Bioninvasions Conference, March (3 papers, 2 posters), Annual Phycological Society of America, June (1 paper w/ award), Global Aquaculture Society Meeting, January (invited paper)
- Publication in peer reviewed journals
- Coastal America Award-Oct
Next Clean-up Event: Sept 13th Waikiki Aquarium
Contact: eco@tnc.org for more information