The influences of oceanographic and meteorological features on reef fish recruitment in Hawai‘i

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Peak Spawning Months of Hawaiian fishes

~50 spp. – Walsh 1987, Longenecker 2008, Bushnell et al. 2010
Reef Fish Recruitment at Ke'ei - West Hawai'i
1977-2011
Substantial Interannual Variation in Recruitment

Overall changes in Yellow Tang abundance in FRAs, MPAs and Open areas - 1999-2010

Overall changes in Kole abundance in FRAs, MPAs and Open areas - 1999-2010

Substantial Interannual Variation in Recruitment
Basic Larval/Recruit Biology

Larval duration:
- ~54 days
- ~60 days

Size @ Settlement:
- ~32mm
- ~43mm

Growth rate:
- ~0.52mm/day
- ~0.4mm/day
- ~0.4mm/day

Shafer 2004
Christie et. al. 2010. Larval Connectivity in an Effective Network of Marine Protected Areas.
Mesoscale Eddies & Fish Recruitment
Timing of eddy formation

“In general, the peak period of eddy formation and movement appears to coincide with the peak season of reproduction by Hawaiian fishes.” (Lobel and Robinson 1983)

vs.

“the generation of eddies is essentially random” (Flament 1996, The Ocean Atlas of Hawai‘i)
How might eddies influence reef fish recruitment?

**Positive:** Increase-nutrients
nearshore retention
survival
recruitment

**Negative**
increase predators
offshore entrainment
decrease survival
decrease recruitment

GEOS = Geostationary Operations Environmental Satellite
Other possible correlates

Fish recruitment correlated with:

• Chlorophyll-a
• Rainfall
• El Niño?
Methods: Data Sources

• Fish recruitment data (WHAP)
• Eddies: 8-day and monthly averages of SST
  SSH  (NOAA CoastWatch AVHRR, AVISO, MODIS)
  Chl-a
• Rainfall (10 locations NOAA NWS+)
• ONI  (Oceanic Niño Index, NOAA)
Annual Variation

- Fish: YOY totals of 5 most abundant recruiting spp.
- Visual determination of eddy presence, size, location, and intensity based on SST and SSH
- Annual means of Chl-a and rainfall

Eddy in May 2006 as seen by

← SST
and SSH →
Monthly variation

• Fish: recruit data from *Zebrasoma flavescens* and *Ctenochaetus strigosus*, plus all 5 spp.

• Eddy activity
  – Standard deviation (Polovina and Howell 2005)
  – Eddy diameter (M. Brown)
  – Mean monthly SST and SSH

• Mean monthly Chl-a and rainfall

• Oceanic Niño Index
**Analysis**

**Correlations**

**GLM**

**Phase Shifts** (1 mo-1yr)

- Seasonality
  - Patzert’s (1969) data re-analyzed with the inclusion of ship days at sea - not accounted for when calculating the number of eddies per season (Lobel & Robinson 1983, Lobel 1989. Lobel 2011).
Results: Annual variation

Eddy Activity by Year

- Aviso satellite cold core eddies
- Pathfinder satellite eddies
Results: Annual variation

No correlations between YOY & eddy number & intensity or other variables when examined singly.
Negative correlation in GLM w/eddies (SSH) & rainfall.
Results: Monthly variation

- No significant correlation between monthly recruitment of *Z. flavescens* and *C. strigosus* and eddy activity as measured by standard deviation, eddy diameter, or mean monthly SSH
- Positive correlation with Sea Surface Temperature (no surprise, summer=warmer)
- No correlation with Chl-a (excluding winter bloom) or rainfall
Results: Monthly Variation

\[ R^2 = 30.7\% \]
\[ P < 0.001 \]
Results: Monthly Variation

\[ R^2 = 13.5\% \]
\[ P < 0.001 \]
Phase shift: SSH negative 2-5 months

Number of months that data for oceanographic variable precedes fish recruitment data

P-value

SSH
Rainfall
SST anomaly
Chlorophyll a (bloom excluded)
Eddy standard deviation

a=0.05

P-value

0.00001
0.0001
0.001
0.01
1

0.1
1

0.00001
0.0001
0.001
0.01
1

0.1
1

Number of months that data for oceanographic variable precedes fish recruitment data
Mean # eddy weeks per month (±SE)

Timing: No peak in our data

Months:
- Jan
- Feb
- Mar
- Apr
- May
- Jun
- Jul
- Aug
- Sep
- Oct
- Nov
- Dec

SST: Pathfinder eddy presence
Timing: No peak in our data

Mean # eddy weeks per month (±SE)

- SSH: Aviso eddy presence
- SST: Pathfinder eddy presence

Months:
- Jan
- Feb
- Mar
- Apr
- May
- Jun
- Jul
- Aug
- Sep
- Oct
- Nov
- Dec
# Re-analysis of Patzert (1969)

## Seasons

<table>
<thead>
<tr>
<th></th>
<th>Jan-May</th>
<th>June-Aug</th>
<th>Sep-Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td># of eddies</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

### Total # eddies observed

![Graph showing the number of eddies observed across different seasons.](image-url)
No peak in re-analysis of Patzert (1969)

<table>
<thead>
<tr>
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<th>Jan-May</th>
<th>June-Aug</th>
<th>Sep-Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td># of eddies</td>
<td>0</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td># eddies / ship days</td>
<td>0.00</td>
<td>0.05</td>
<td>0.10</td>
</tr>
</tbody>
</table>

χ²=0.12, p=0.94
Conclusions

• No conclusive positive linkages between eddy activity, Chl-a or rainfall and fish recruitment either at annual or monthly time scales
• Some suggestion of a negative relationship between YOY and eddy activity 2-5 months prior to recruitment (i.e. larval phase)
• Positive relationship between ONI and yellow tang recruitment but with relatively low predictive value
• No evidence of a spring/summer peak in eddy occurrence in West Hawai’i
• Confirms findings of the unpredictable and highly variable nature of reef fish recruitment