Evaluation of fleet dynamics and oceanography as factors accounting for variations in black-footed albatross interactions in the Hawai‘i-based deep-set longline fishery, 2006-2017

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Black-footed Albatross  
(*Phoebastria nigripes*)

- Nests in Northwestern Hawaiian Islands
  - Incubation – 10-30 day trips
  - Brooding – 1-3 day trips
  - Chick rearing – alternate short and long trips

- Forage in the productive transition areas to the north

*Photo: Brian E. Small*  
*From Thorne et al. 2016*
Changes in albatross foraging behavior

- ENSO was the driver of the steady increase in interactions since 2000 of black-footed and Laysan albatrosses.
- Forage further to the north during La Niña years.

From Thorne et al. 2016
Gilman et al., 2016
Thorne et al. 2016
Longline fishery interactions

- Birds are hooked at the surface and pulled underwater as gear sinks
- Vessels fishing north of 23°N are required to use seabird mitigation measures in 2001
  - Side setting
  - Blue-dyed bait
- Mitigation measures reduced bycatch by 70-90%
- Record all hooked/entangled birds during gear haul
- Fisheries observers conduct bird scans 5 min after the start of the set

Gilman et al., 2015, 2016
Longline fishery interactions

Total Seabird Interactions
Hawaii Longline Fishery (Tuna and Swordfish)

- Black-footed
- Laysan

Seabird measures implemented

Note: Total interactions from 1994 to 2004 are estimates from available bycatch data recorded from a small portion of all trips. Data since 2004 combine estimated interactions from the deep-set (tuna) fishery and actual interactions from the shallow-set (swordfish) fishery.
Increased interactions in the Hawai‘i longline fishery
Sightings vs. Interactions
What cause increase in interactions of BFAL?

- Used observer scan- and interaction data
- 2006-2016 time-series
- Focus on high interaction area 23-30°N and 150-165°W
GLM set up

<table>
<thead>
<tr>
<th>Fleet dynamics</th>
<th>Local Climate Variables</th>
<th>Large-scale Climate Variables</th>
<th>Biological Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonality: Month</td>
<td>Sea surface temperature (SST)</td>
<td>Pacific Decadal Oscillation index (PDO)</td>
<td>Nesting pair counts</td>
</tr>
<tr>
<td>Latitude &amp; Longitude</td>
<td>SST standard deviation</td>
<td>Multivariate ENSO Index (MEI)</td>
<td>Reproductive success</td>
</tr>
<tr>
<td>Effort</td>
<td>Chlorophyll a</td>
<td></td>
<td>Total fish catch</td>
</tr>
<tr>
<td></td>
<td>Wind stress curl</td>
<td></td>
<td>Total Mahimahi catch</td>
</tr>
<tr>
<td></td>
<td>Meridional wind velocity</td>
<td></td>
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<tr>
<td></td>
<td>Zonal wind velocity</td>
<td></td>
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</tr>
</tbody>
</table>
Results: Fleet dynamics

- Strong seasonal pattern
- Sightings increases closer to the breeding colonies
  - North
  - West
Results: Fleet dynamics

Correlation: p-value < 2e-16, r = 0.8
### GLM set up

#### Fleet dynamics
- Seasonality: Month
- Latitude & Longitude

#### Local Climate Variables
- Sea surface temperature (SST)
- SST standard deviation
- Chlorophyll a
- Wind stress curl
- Meridional wind velocity
- Zonal wind velocity

#### Large-scale Climate Variables
- Pacific Decadal Oscillation index (PDO)
- Multivariate ENSO Index (MEI)

#### Biological Variables
- Nesting pair counts
- Reproductive success
- Total fish catch
- Total Mahimahi catch

**Graph:** Map of a region with a grid and coastlines, showing the area of interest.
## Results:
### GLM performance

<table>
<thead>
<tr>
<th>Variable</th>
<th>AIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>U velocity</td>
<td>67049.73</td>
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<tr>
<td>V velocity</td>
<td>67150.43</td>
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<tr>
<td>Wind stress curl</td>
<td>67500.32</td>
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<tr>
<td>PDO</td>
<td>67708.90</td>
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<tr>
<td>MEI</td>
<td>68063.88</td>
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<tr>
<td>Chlorophyll a</td>
<td>68200.24</td>
</tr>
<tr>
<td>Fleet dynamics</td>
<td>68436.97</td>
</tr>
</tbody>
</table>
Local environment
Zonal wind velocity

Wind Speed: 2016, Quarter 1

Wind Speed: 2011-2012 (averaged), Quarter 1
Local environment
Zonal wind velocity

Correlation: p-value < 2e-16, r = 0.87
Large scale climate
Pacific Decadal Oscillation
Large scale climate
Pacific Decadal Oscillation

Correlation: p-value < 2e-16, r = 0.86
Fisheries dependent data limitations

- Problems with fisheries dependent data
  - Only data where fishing happens
  - Fishers and BFAL forage on same resource
- GPS tag black-footed albatross nesting at Tern Island
  - Spend time foraging outside the ‘high interactions’ area
Results:
Tracking data

![Graph](image)
Oceanographic conditions
Pacific Decadal Oscillation

Low sightings and interactions
High sightings and interactions
Negative PDO / La Niña

2011-2012 Q1

Chlorophyll a

Low sightings and interactions

2016 Q1

SST

Positive PDO / El Niño

2011-2012 Q1

Chlorophyll a

High sightings and interactions

2016 Q1

SST
Conclusions

• Increase in BFAL interactions with increase in westerly winds
  • Cold, productive waters move further south
  • Strong Aleutian low during -> strong westerly winds

• Greater overlap between albatross preferred foraging habitat and the longline fishing fleet during +PDO years

• PDO is decadal pattern so increased interactions may persist and not merely a short term anomaly
Conclusions
Thank You!

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