Advances in Fishing Methods to Reduce Bycatch
Pacific Fishery Management Council

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Bycatch, the incidental capture of non-target species (including protected species), occurs when there is spatial and temporal overlap between target and non-target species.

Measured by:
- Rates of interaction
- Survivorship
  - At vessel
  - Post-release
Sea Turtle Bycatch Mitigation in U.S. Longline Fisheries

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Capture of sea turtles in longline fisheries has been implicated in population declines of loggerhead (Caretta caretta) and leatherback (Dermochelys coriacea) turtles. Since 2004, United States (U.S.) longline vessels targeting swordfish and tuna in the Pacific and regions in the Atlantic Ocean have operated under extensive fisheries regulations to reduce the capture and mortality of endangered and threatened sea turtles. We analyzed 20+ years of longline observer data from both ocean basins during periods before and after the regulations to assess the effectiveness of the regulations. Using generalized additive mixed models (GAMMs), we investigated relationships between the probability of expected turtle interactions and operational components such as fishing location, hook type, bait type, sea surface temperature, and use of light sticks. GAMMs identified a two to three-fold lower probability of expected capture of loggerhead and...
Sea Turtles and Longline Gear

Shallow Set  VS  Deep Set

**loggerhead and leatherback**

Higher interaction rates, higher survival rates

**olive ridley**

Lower interaction rates, lower survival rates

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Regulatory Changes

2001: Pacific (HI) & Atlantic shallow set fisheries closed

2004: fisheries re-opened w/ extensive regulations

Hawaii Shallow Set Longline Fishery Regulations

Gear:
• Hook: 18/0 circle
• Bait: Fish

Limits & Observer Coverage:
• Hard caps met = closure
• Increased observer coverage (from 20% to 100%)

Education & Safe Handling:
• Skipper trainings
• Safe handling gear on board
Goals:
- Determine if mandatory use of large circle hooks and finfish bait reduced sea turtle bycatch
- Identify explanatory variables (e.g., SST, location, hook, bait) associated with turtle capture risk by using an ecological model
  - Generalized additive mixed model (GAMM)
20 Years of HI LL Observer Data

Observer program managed by NOAA NMFS PIRO

Years:

- Pre-regulation ‘94-’01
- Post-regulation ‘04-’14

15,472 unique sets

20-100% of total annual effort (100% since 2004)
Hawaii data:

- n=222, caught on <2% of sets
- n=105, caught on <1% of sets

Example of “zero inflated” data
Pacific Sea Turtle Catch: CPUE

CPUE - # of individuals caught per 1,000 hooks

Fishery Closure

Re-opened: circle hooks & fish bait (plus hard caps)
Goals:

- Determine if mandatory use of large circle hooks and finfish bait reduced sea turtle bycatch

- Identify explanatory variables (e.g., SST, location, hook, bait) associated with turtle capture risk by using an ecological model

- Generalized additive mixed model (GAMM)
Regulatory Effects on Bycatch Reduction

-84%  ***
-95%  ***

(Z = -8.124 and -25.645 for leatherback and loggerhead turtles p<0.0001)
Goals:

- Determine if mandatory use of large circle hooks and finfish bait reduced sea turtle bycatch
- Identify explanatory variables (eg., SST, location, hook, bait) associated with turtle capture risk by using an ecological model
- Generalized additive mixed model (GAMM)
Models account for interacting factors that influence sea turtle catch;

Predictive models, such as GAMMs, are used to forecast outcomes, such as risk of capture;

Models confirmed that catching a turtle is not a random event; rather, a capture event is influenced by environment and gear.
Factors associated with lower catch risk for both species are circle hooks, fish bait and factors associated with location, SST and month.
Real Time, Dynamic Management: “TurtleWatch”

- Online map
- real time (3 day avg.) SST & ocean currents
- predicted location of waters preferred by loggerhead turtles
- For fishers and managers to assist with decision making - reduce sea turtle interactions.
- More recent publication specific to leatherback turtles.

Howell et al. Enhancing the TurtleWatch product for leatherback sea turtles, a dynamic habitat model for ecosystem-based Management. 2015. Fish Oceanogr.
doi:10.1111/fog.12092
At vessel survival depends on:

- Gear characteristics
- Severity of injury

Post-release survival depends on:

- Severity of injury
- Safe handling
  - (e.g. use a dip net)
- Amount of gear removed

Sea Turtle Safe-Handling Gear and Techniques
Presentation Overview

- Sea Turtles
- Sharks*
- Seabirds
- Marine Mammals

*Not always bycatch
Blue Sharks (*Prionace glauca*)

- Most commonly caught shark in both the deep and shallow-set longline sectors

- East of the 140°W, blue sharks represent ~80% of total shark catch for both fisheries by species

NOAA observer data
Remember:

- 2004 the HI SSLL fishery re-opened
- shift from J hooks and squid bait to circle hooks and finfish bait
- means to reduce turtle bycatch and mortality.
Impacts of Sea Turtle Regulations on Sharks

Blue sharks


1. Deep-Set*
   - 1995–2000: 10
   - 2004–2006: 2
   - 42% reduction

2. Shallow-Set
   - 1995–2000: 18
   - 29% reduction

* Mostly finfish after 2004, not mandatory

Reduced catch rates: Hooks or bait?

• High variability in catch rates with circle hooks
  – Godin et al. (2012) compared the results from 23 studies, many including blue sharks.

• Results suggest it is the change in bait

*Regardless*: Take home = shift to circle hooks and finfish bait reduced mortality of blue sharks in the HI LL fisheries.

Potential Options to Reduce Shark Catch

Deterrents

• Electro-positive metals
• Magnets

Variable results, expensive, and at current state of technology not a viable option\(^1,2,3\)

Fish where sharks are not

• Vertically
• Geographically (EcoCast)

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Removal of shallow hooks suggest potential to reduce epipelagic shark catch

Circle Hooks and Post-Release Survival
Circle Hooks and Post-Release Survival

At-vessel mortality:

- 35% lower at vessel mortality with circle hooks \(^1\)
- 96% that swallowed hooks were pulled up dead \(^2\)

Post-release mortality: \(^2\)

- 0 healthy sharks died
- \~33\% of injured sharks died
- J hooks cause more injury

Increased at vessel survival with *larger* circle hooks:

- survival 79\% on larger Circle hooks (16/0) vs 67 \% \(^3\)

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Leader Material – Monofilament (instead of wire)

• Sharks can bite through monofilament leaders and facilitate an early release\(^1,2\) - although results across studies are not always consistent\(^3\).

• Regardless, monofilament leaders are mandated in a number of fisheries.

• Some suggestion that Santos et al recently found significant decrease (31%) in blue shark catch with monofilament leaders.

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Handling Options – Increase Post-Release Survival

Condition on release is dependent on handling and gear removal

**Optimal:**

- leave shark in water
- minimize trailing gear (cut line as close to hook as possible)
- remove hook if possible
- work with fishers on hook removal/ line cutters to ensure efficiency and safety

1. Hutchinson unpublished data
Presentation Overview

- Sea Turtles
- Sharks
- Seabirds
- Marine Mammals
Seabird Bycatch Mitigation Measures

Hawaii regulations differ based on:
• deep vs. shallow set fishing
• location of fishing (N or S of 23°)

Fishers are given choices amongst suite of options
Seabird Interactions in HI Fisheries

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.

# Efficacy of Seabird Mitigation Techniques

<table>
<thead>
<tr>
<th>Study</th>
<th>Treatment</th>
<th>Contact rate</th>
<th>Contact reduction (%)</th>
<th>Capture rate</th>
<th>Capture reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>McNamara et al. (1999)</td>
<td>Control</td>
<td>32.8 (265.7)</td>
<td>77</td>
<td>2.23 (18.0)</td>
<td>95</td>
</tr>
<tr>
<td>Hawaii longline swordfish gear</td>
<td>Blue-dyed bait</td>
<td>7.6 (61.6)</td>
<td>77</td>
<td>0.12 (17.5)</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>Towed buoy</td>
<td>16.1 (130.4)</td>
<td>51</td>
<td>0.26 (6.8)</td>
<td>86</td>
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<tr>
<td></td>
<td>Offal discards</td>
<td>15.7 (124.7)</td>
<td>53</td>
<td>0.32 (2.3)</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>Streamer line</td>
<td>15.7 (127.2)</td>
<td>52</td>
<td>0.47 (6.6)</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>Night setting</td>
<td>(0.60)</td>
<td>95</td>
<td></td>
<td>97^4</td>
</tr>
<tr>
<td>Boggs (2001)</td>
<td>Control</td>
<td>7.60 (313.5)</td>
<td>94</td>
<td>0.06 (4.24)</td>
<td>100</td>
</tr>
<tr>
<td>Hawaii longline swordfish gear</td>
<td>Blue-dyed bait</td>
<td>0.43 (20.5)</td>
<td>94</td>
<td>0.00 (0.00)</td>
<td>100</td>
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<tr>
<td></td>
<td>Streamer line</td>
<td>1.82 (93.4)</td>
<td>76</td>
<td>0.058 (2.0)</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>Additional 60 g weight at bait</td>
<td>0.61 (25.0)</td>
<td>92</td>
<td>0.0013 (0.11)</td>
<td>98</td>
</tr>
<tr>
<td>Gilman et al. (2003a)</td>
<td>Control</td>
<td>0.61 (75.93)</td>
<td>95</td>
<td>0.06 (4.24)</td>
<td>100</td>
</tr>
<tr>
<td>Hawaii longline tuna gear</td>
<td>Underwater setting chute 9 m</td>
<td>0.03 (1.85)</td>
<td>95</td>
<td>0.00 (0.00)</td>
<td>100</td>
</tr>
<tr>
<td>Boggs (2003)</td>
<td>Control</td>
<td>0.78 (27.1)</td>
<td>95</td>
<td>0.058 (2.0)</td>
<td>79</td>
</tr>
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<td>Hawaii longline swordfish gear</td>
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<td>93</td>
<td>0.0013 (0.11)</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>Night setting and blue-dyed bait</td>
<td>0.01 (0.98)</td>
<td>99</td>
<td>0.00 (0.00)</td>
<td>100</td>
</tr>
<tr>
<td>Gilman et al. (2003b),</td>
<td>Underwater setting chute 9 m</td>
<td>0.30 (5.0)</td>
<td>95</td>
<td>0.03 (0.6)</td>
<td>86^5</td>
</tr>
<tr>
<td>Hawaii longline swordfish gear</td>
<td>Blue-dyed bait</td>
<td>2.37 (64.9)</td>
<td>95</td>
<td>0.08 (1.8)</td>
<td>86^5</td>
</tr>
<tr>
<td></td>
<td>Side-setting</td>
<td>0.08 (1.9)</td>
<td>99</td>
<td>0.01 (0.2)</td>
<td>86^5</td>
</tr>
<tr>
<td>Gilman et al. (2003b),</td>
<td>Underwater setting chute 9 m</td>
<td>0.28 (10.3)</td>
<td>82^6</td>
<td>0.05 (1.7)</td>
<td>88^6</td>
</tr>
<tr>
<td>Hawaii longline tuna gear</td>
<td>Underwater setting chute 6.5 m</td>
<td>0.20 (5.6)</td>
<td>87^6</td>
<td>0.01 (0.5)</td>
<td>88^6</td>
</tr>
<tr>
<td></td>
<td>Blue-dyed bait</td>
<td>0.61 (23.8)</td>
<td>60^6</td>
<td>0.03 (1.2)</td>
<td>63^6</td>
</tr>
<tr>
<td></td>
<td>Side-setting</td>
<td>0.01 (0.1)</td>
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<td>0.00 (0.0)</td>
<td>100^6</td>
</tr>
</tbody>
</table>

*Gilman et al 2005*
Presentation Overview

Sea Turtles

Sharks

Marine Mammals

Seabirds
Marine Mammal Bycatch Mitigation

- Real time fleet communication (while at sea)
- Weak hooks (exploit different strengths of target and bycatch species)
Weak Hooks

Weak hooks (4.5mm)

• Strong enough to retain target species
• Weak enough to be straightened by a large marine mammal (e.g. FKW)

**Bycatch and Mortality Can Be Managed**

<table>
<thead>
<tr>
<th>All Taxa</th>
</tr>
</thead>
<tbody>
<tr>
<td>safe-handling</td>
</tr>
<tr>
<td>dynamic management</td>
</tr>
</tbody>
</table>

### Sea Turtles
- large circle hooks
- finfish bait
- hook depth

### Sharks
- circle hooks
- finfish bait
- monofilament leaders
- release methods

### Seabirds
- side setting
- night setting
- tori lines / streamers
- weighted branch lines

### Marine Mammals
- weak hooks
- fleet communication