Chasing the moving target of sustainability: understanding tradeoffs between fisheries and conservation goals in a changing ocean

Jameal Samhouri, Briana Abrahms, Blake Feist, Mary Fisher, Karin Forney, Elliott Hazen, Dan Lawson, Owen Liu, Jessica Redfern, Lauren Saez, Sam Woodman
We are drowning in information, while starving for wisdom.

- E. O. Wilson
Tropical Storm Laura
Sunday August 23, 2020
8 PM EDT Intermediate Advisory 16A
NWS National Hurricane Center

Current information:
Center location 20.0 N 75.6 W
Maximum sustained wind 60 mph
Movement WNW at 21 mph

Forecast positions:
- Tropical Cyclone
- Post/Potential TC
- Sustained winds:
  - D < 39 mph
  - S 39-73 mph
  - H 74-110 mph
  - M > 110 mph

Potential track area:
- Day 1-3
- Day 4-5

Watches:
- Hurricane
- Trop Storm

Warnings:
- Hurricane
- Trop Storm
Integrated Ecosystem Assessment: a framework for organizing science in order to inform decisions in marine management

IEA to tackle entanglements

What do we want?

↓ entanglements, thriving fisheries
IEA to tackle entanglements

What do we want?

↓ entanglements, thriving fisheries

Where are we right now?

synthesize entanglement, ocean, survey, and fishing data
IEA to tackle entanglements

What do we want?  ↓entanglements, thriving fisheries

What are our threats?

Where are we right now?

synthesize entanglement, ocean, survey, and fishing data

assess risk and impacts eg, ocean/market changes
IEA to tackle entanglements

What do we want?

↓ entanglements, thriving fisheries

What should we do?

evaluate scenarios, analyze tradeoffs

What are our threats?

synthesize entanglement, ocean, survey, and fishing data

Where are we right now?

assess risk and impacts eg, ocean/market changes
Retrospective analysis of whale risk and California Dungeness crab fishery revenue 2009-19
Quantifying whale risk and fishery revenue

**Co-occurrence of whales and fishing**

- Fishing activity
- Species distribution
- Risk

**Fish-ticket informed VMS data**

- Abrahms et al.
- Forney et al.
- Feist et al.
- Liu et al.
Whale risk high from 2014-2018

![Whale Risk Chart](image)

Risk to blue whales

Risk to humpback whales

<table>
<thead>
<tr>
<th>Year</th>
<th>Risk to Blue Whales</th>
<th>Risk to Humpback Whales</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014-2015</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>2015-2016</td>
<td>Very High</td>
<td>Very High</td>
</tr>
<tr>
<td>2016-2017</td>
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<tr>
<td>2017-2018</td>
<td>High</td>
<td>High</td>
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<tr>
<td>2018-2019</td>
<td>High</td>
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Habitat Compression

Shaded regions indicate relative likelihood of compressed habitat heightening entanglement risk

2020/02/01:
Habitat Compression Index (100 km²): 419

 Courtesy Jarrod Santora / CCIEA
Whales more common on Dungeness crab fishing grounds during 2014-18 than before or after

Abrahms et al. 2019

Forney et al. in prep
Also see Santora et al. 2020
Fishery performance mixed 2014-18

Dungeness crab fishery revenue (x$10,000)

Risk to humpback whales (normalized)

Risk to blue whales (normalized)

2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
2015-2016
2016-2017
2017-2018
2018-2019

What is Ocean Acidification?

Today, rampant burning of fossil fuels, including coal, oil, and natural gas, is releasing too much carbon dioxide into the atmosphere. Annually, about 25% of human-caused carbon dioxide emissions is absorbed by the ocean, making the ocean's chemistry more acidic. This decrease in ocean pH over time is called ocean acidification and it makes it harder for calcifying animals like Dungeness crab to thrive.

How will Ocean Acidification Affect Dungeness Crab?

Dungeness crab are an abundant and valuable species throughout national marine sanctuaries along the West Coast of the United States. NOAA research shows that crabs in their early larval stages are vulnerable to low pH seawater.

Life Cycle of the Dungeness Crab

Molting from one stage to the next and carrying fertilized eggs require a lot of energy, as does dealing with stress from global ocean change.

NOAA Research Shows Crabs are Vulnerable

Most vulnerable stages

In lab studies, exposure to lower pH seawater decreases Dungeness crab larval development rates and survival. It also impacts the prey species—such as bivalves—which they depend on. Complex modeling projects a 41% decline in Dungeness crab biomass and 30% loss in economic revenue in the next 50 years due to ocean acidification.
Tradeoff analysis to identify approaches for reducing risk to whales with least cost to the CA Dungeness crab fishery

“His is a thought experiment.”
What might have been?

1. Delayed openings
2. Early closures
3. Spring gear reductions
4. Spring depth restrictions

Whale Risk Reduction

Crab Fishery Revenue

- Management outcomes
- Optimal management outcomes

Efficiency frontier
1. Expected risk reductions greatest and more variable in 2014-18

- Blue whale (Balaenoptera musculus) 88-108 feet
- Humpback whale (Megaptera novaeangliae) 40-60 feet

% risk reduction humpback whales:
- 2009-14: 80%
- 2014-18: 60%

% risk reduction blue whales:
- 2009-14: 60%
- 2014-18: 40%
2. Spring gear and depth restrictions remarkably effective

<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 2</th>
<th>% Risk Reduction</th>
<th>Blue Whales</th>
<th>Humpback Whales</th>
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<td>2009-14</td>
<td>2014-18</td>
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<tr>
<td></td>
<td></td>
<td>% risk reduction</td>
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- Delayed Opening
- Depth and Gear Restrictions
- Depth Restriction
- Early Closure
- Gear Restriction
3. Statewide management actions reduce risk more than those affecting central California only

- **Blue whale (Balaenoptera musculus)**: 88-108 feet
- **Humpback whale (Megaptera novaeangliae)**: 40-60 feet

% risk reduction:
- **Blue whales**: 80%
- **Humpback whales**: 60%
What about the fishery?

- Costs greatest and most variable in 2014-18
- Gear and depth restrictions less costly
- Statewide management actions cost the fishery more than those affecting central California only

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Similar costs for small vessels

- Costs greatest and most variable in 2014-18
- Gear and depth restrictions less costly
- Statewide management actions cost the fishery more than those affecting central California only
Tradeoff to the fleet is most stark in 2014-18

Scenario type
- Status Quo
- Depth Restriction
- Gear Restriction
- Depth and Gear Restriction
- Delayed Opening
- Early Closure
- Delay and Early Closure

Spatial domain
- Status Quo
- BIA
- Central California
- Statewide
- Hybrid

Relative revenue to the Dungeness crab fishery
Take-homes

• Management strategies have different benefits to whales and costs to the fishery under alt. ocean conditions
• Depth and gear restrictions in spring alone provide substantial risk reduction at lower cost

Future work

• Hindsight is 20/20 \(\rightarrow\) forecasting tools
• Consider add’l complexities: fleet heterogeneity, HABs, reactive measures