Balancing goods and bads: A Bayesian analysis of fishery regulatory decisions

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Why do we need fishery regulations?

Why do we need fishery regulations?

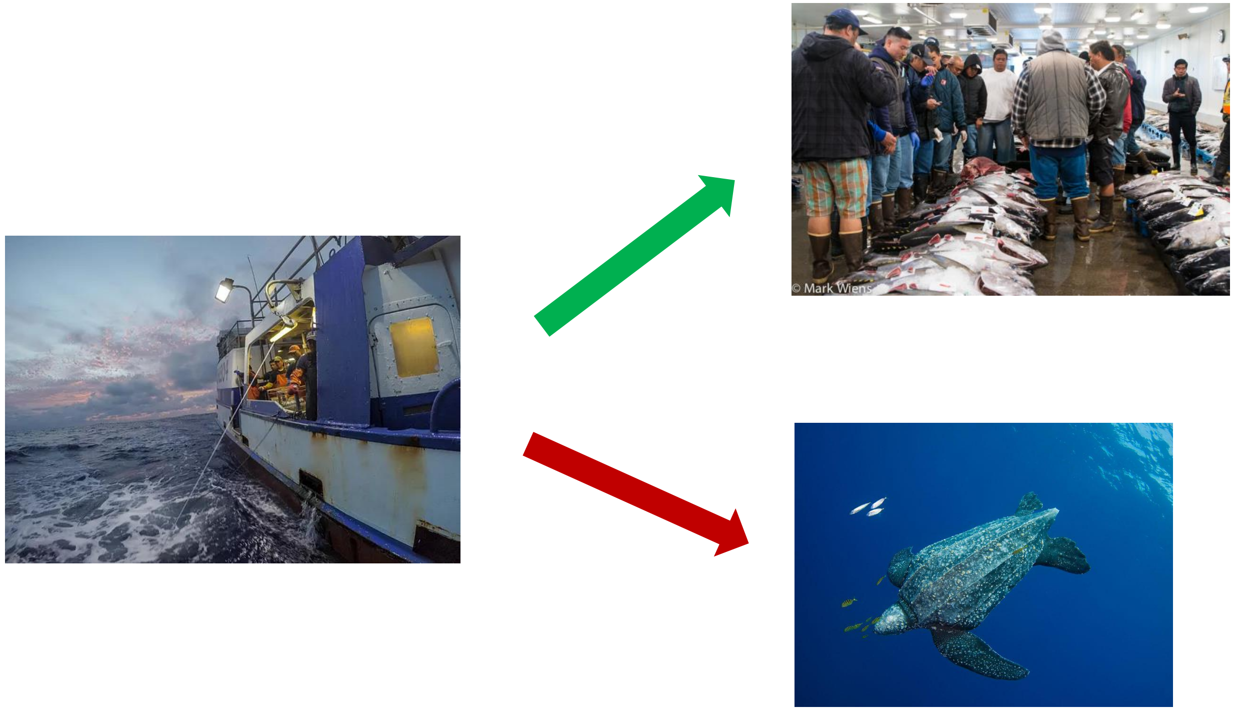
- Many fisheries jointly produce **goods** and **bads**.
  - Goods include desirable fish catch.
  - Bads include undesirable bycatch.

Regulatory trade-off

- How do regulators optimally balance this trade-off?

Regulatory trade-off

- Ronald Coase (1960) described this as **the problem of social cost**.
  - What is the optimal level of regulation of an industry that creates social damages, knowing that regulations will also be costly for the industry.



Bayesian decision analysis

- A framework to help make decisions under uncertainty.
  - List the set of possible decisions
  - Define an expected utility function
  - Maximize utility over the set of decisions.

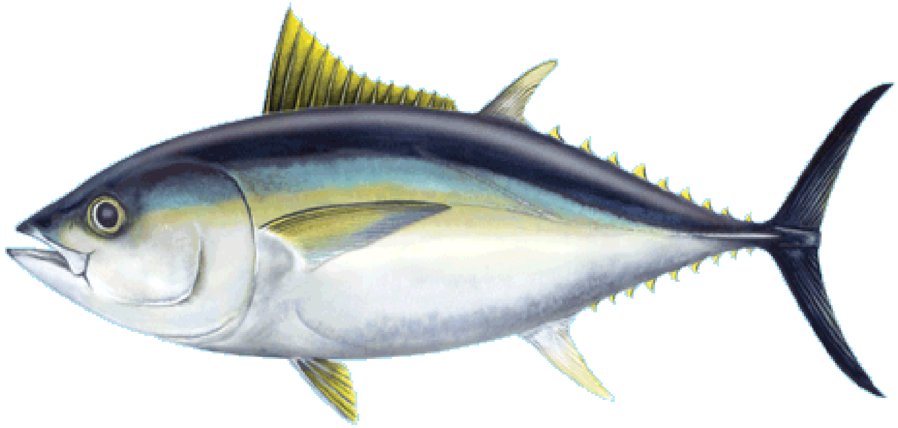
Research objective

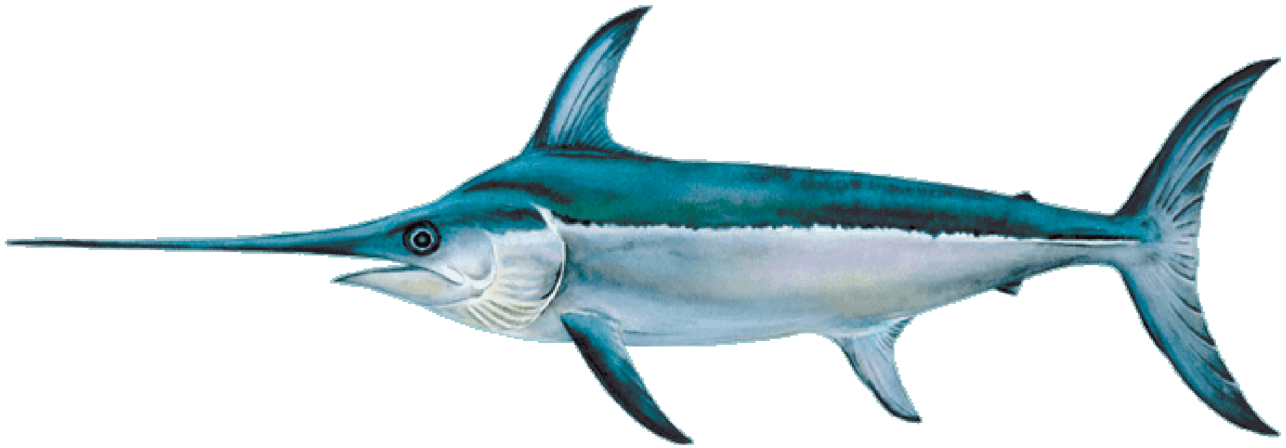
- Apply Bayesian decision analysis to solve the problem of social costs (turtle bycatch) in Hawaii's longline fishery.

  - How much should you restrict sea turtle interactions to maximize social utility?

Hawaii's longline fishery

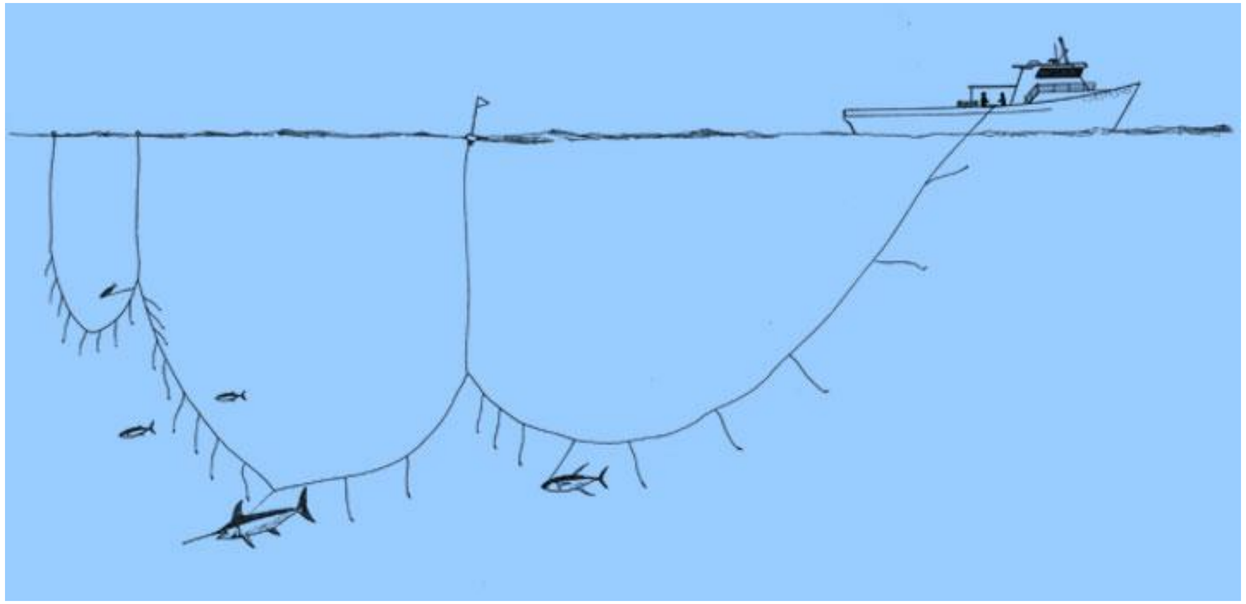
- Pelagic multispecies fishery
  - Bigeye tuna
  - Swordfish
  - Yellowfin tuna
  - Moonfish
  - Mahi-mahi
  - Albacore tuna
  - Skipjack tuna
  - Others…



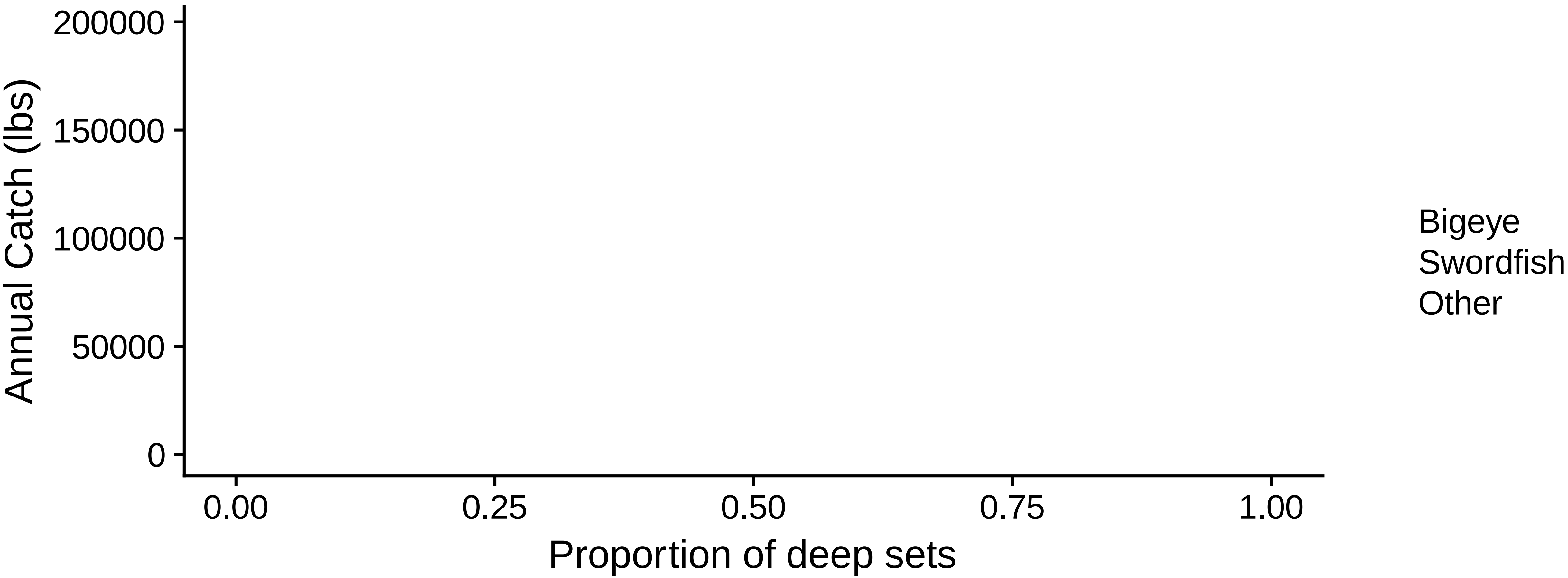


Hawaii's longline fishery

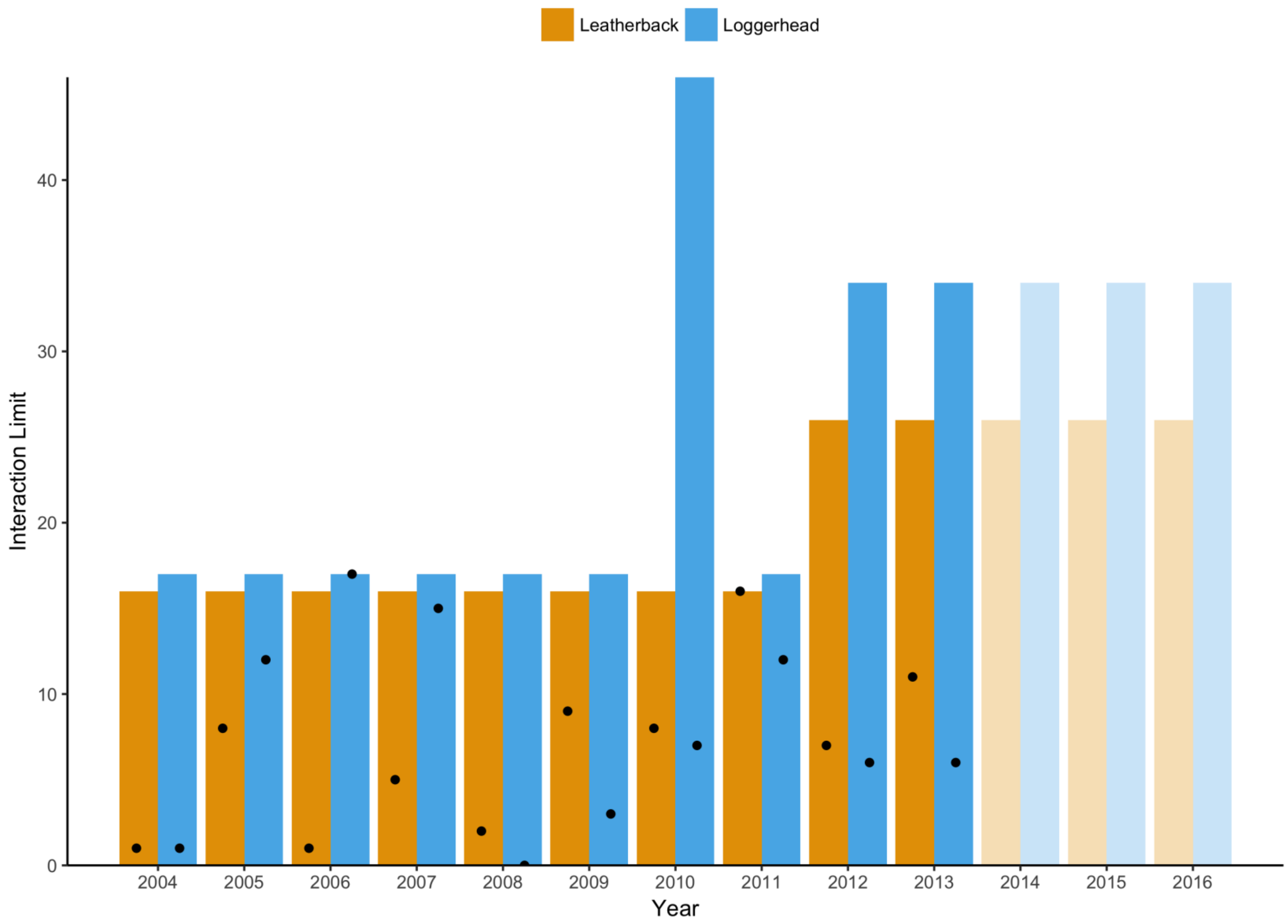
- Shallow sets
- Deep sets



Annual catch composition



Sea turtle interaction limits



Regulators decision problem

$$\max_{d}\left(p_{BE}\mathrm{E}\left(y_{BE}^{rep}\middle|d\right) + p_{SF}\mathrm{E}\left(y_{SF}^{rep}\middle|d\right) + p_{Other}\mathrm{E}\left(y_{Other}^{rep}\middle|d\right)\right) - p_b\, E(b^{rep}|d)$$

Regulators decision problem

$$\max_d \underbrace{\left(p_{BE}\mathrm{E}\left(y_{BE}^{rep}\middle|d\right) + p_{SF}\mathrm{E}\left(y_{SF}^{rep}\middle|d\right) + p_{Other}\mathrm{E}\left(y_{Other}^{rep}\middle|d\right)\right)}_{\text{Benefits}} - \underbrace{p_b\, E(b^{rep}|d)}_{\text{Costs}}$$

- Don't know p_b so I iterate over $p_b = \{1000, 2000, \ldots, 30{,}000{,}000\}$
- Need to calculate the expectations.

Calculate expectations by modeling production

$$y_i \sim \text{Normal}(f(\boldsymbol{x}_i) - \mu_i, \sigma_y^2)$$

$$b \sim \text{Poisson}(\upsilon \sum_i x_i)$$

Data

- Sample period from 2004 to 2013
    - 204 Hawaii longline vessels
    - Annual inputs (count): **deep sets, shallow sets**
    - Annual outputs (pounds): **bigeye, swordfish, other**
    - Annual sea turtle interactions (count): **leatherback** and **loggerheads**

Estimate model using Bayesian inference and simulate expected outcomes

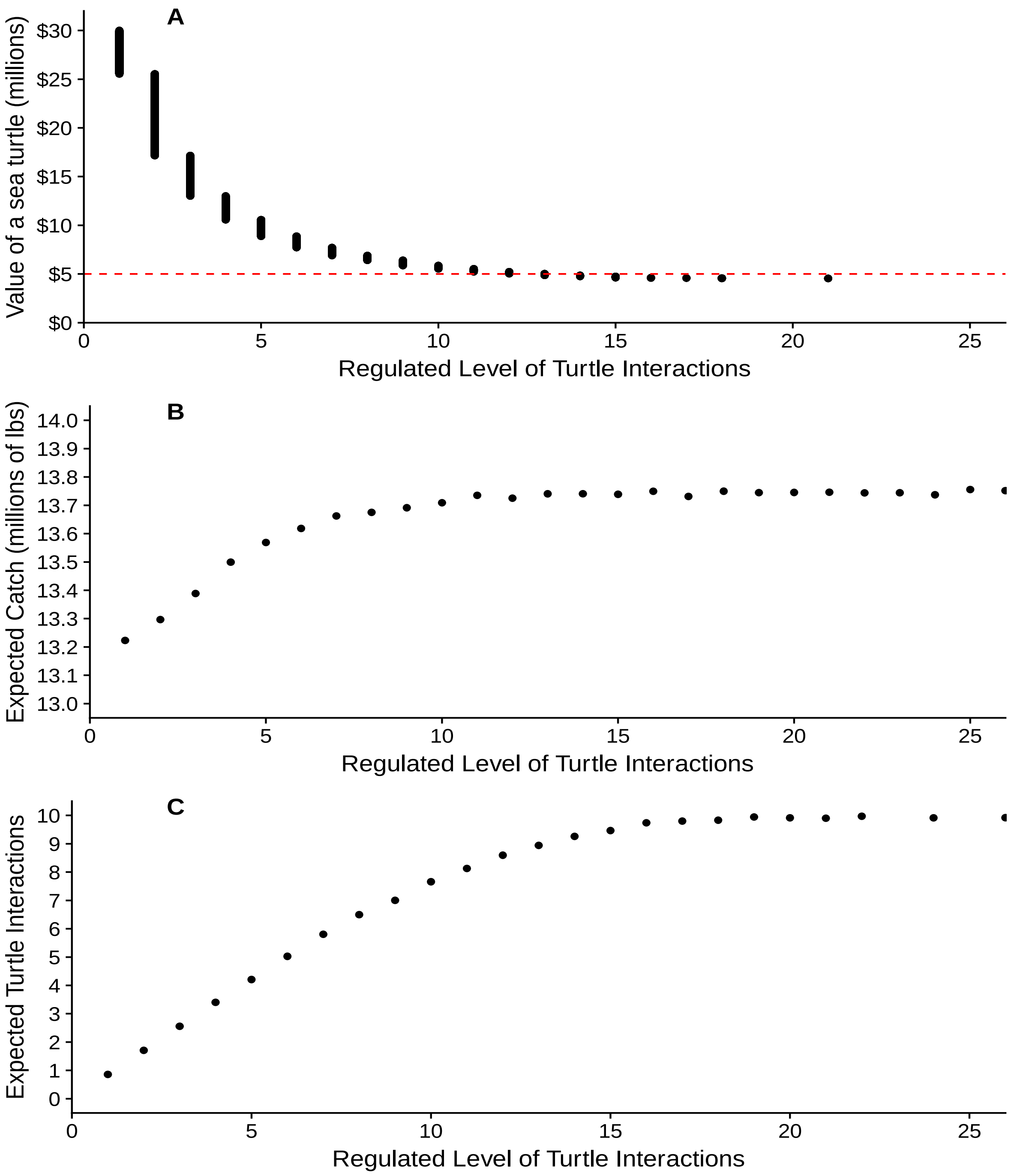
- Use parameter estimates to simulate posterior predictions of production of goods and bads under a set of interaction limits.
- For each interaction limit, calculate the sea turtle value that would make that decision optimal.

Calculate expectations by modeling production

- $E(\cdot\,|d)$ is calculated by randomly drawing inputs for each vessel from their observed input distribution.
- Evaluate if b is greater the d.
- If yes, then redraw inputs.
- If no, then calculate y's.

Regulators decision problem

$$\max_d \left(p_{BE}\mathrm{E}\left(y_{BE}^{rep} \middle| d\right) + p_{SF}\mathrm{E}\left(y_{SF}^{rep} \middle| d\right) + p_{Other}\mathrm{E}\left(y_{Other}^{rep} \middle| d\right)\right) - p_b\, E(b^{rep}|d)$$


A
Value of a sea turtle (millions)
$30
$25
$20
$15
$10
$5
$0
0
5
10
15
20
25
Regulated Level of Turtle Interactions
B
Expected Catch (millions of lbs)
14.0
13.9
13.8
13.7
13.6
13.5
13.4
13.3
13.2
13.1
13.0
0
5
10
15
20
25
Regulated Level of Turtle Interactions
C
Expected Turtle Interactions
10
9
8
7
6
5
4
3
2
1
0
0
5
10
15
20
25
Regulated Level of Turtle Interactions

Summary

- Deciding how much to restrict fishing effort to protect sea turtles depends on the social value of sea turtles.
- Under initial interaction limits, the implicit value of sea turtles is estimated to be close to $5 million.
- The decision analysis framework provides a transparent tool to align fishery regulations with social values.