Model-based discard mortality rates of Pacific halibut from covariates in the North Pacific trawl fishery

Geoffrey M. Mayhew & Jennifer A. Cahalan
Pacific States Marine Fisheries Commission

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Background

- **International Pacific Halibut Commission (IPHC)**: assesses Pacific halibut stocks and sets catch limits
  - **North Pacific Fishery Management Council (NPFMC)**: allocates Pacific halibut resource among users in Alaska
    - **National Marine Fisheries Service (NMFS)**: develops, implements, and enforces regulation for management in U.S. waters, and closes fisheries with limits are exceeded

- Ex-vessel value of over $100 million U.S.
- When halibut are discarded (e.g. no quota or bycatch) **post-capture mortality** (kg) must be estimated.

Discard Mortality Rates (DMR)

- Discard mortality rates (DMRs) = estimates of proportion of incidentally captured halibut that do not survive after being returned to water
- Halibut mortality (kg) = DMR * (weight of discarded halibut)

- On **trawl** vessels, on-board observers (**NMFS**) classify the condition of randomly selected halibut prior to discard, each class with an assumed mortality probability[1,2,3]

Condition	Mortality Probability
Excellent	0.20
Poor	0.55
Dead	0.90

1. Clark et al 1992, 2. Williams 1996, and 3. Kaimmer and Trumble 1998

Discard Mortality Rates (DMR)

- DMRs are estimated at the haul level and continued to the trip and fishery operational level (gear, location, vessel type), and use 2 years of data.
- Haul-level DMR = weighted average of individual mortality probabilities
- Example: A vessel discards 100 kg of halibut and observer assesses condition of 5 halibut within the haul:

Individual	Weight (kg)	Condition	Mort Prob	Weight * Mort Prob
1	2.0	Excellent	0.20	0.40
2	1.0	Poor	0.55	0.55
3	4.0	Poor	0.55	2.20
4	2.5	Excellent	0.20	0.50
5	0.5	Dead	0.90	0.45
Total	**10.0**			**4.10**

Haul-level DMR:
4.10 kg / 10.0 kg = 0.41

If we were to apply this haul-level DMR, estimated mortality:
100 kg * 0.41 = **41 kg**

Problems:

- Assessing halibut condition is time-consuming when done properly
- Variability between observers
- Low sample sizes

Solution?

- Predict halibut condition using physiologically relevant covariates
- Use trained model to generate DMR and halibut mortality estimates

Appendix T: Key to Pacific Halibut Viability for Trawl Vessels

Codes: Excellent = E, Poor = P, Dead = D, Unknown = U

1a. Fish is alive ..... Go to 2a

1b. Fish is dead when sorted from the catch ..... code **DEAD**

Fish is in rigor and lifeless, even if no apparent injuries. Gills appear washed out, i.e., dull red, pink, or white in color. Mouth may contain sediment.

2a. Body of fish appears uninjured, or has only minor injuries ..... Go to 3a

2b. Injuries to fish are significant and obvious ..... code **DEAD**

Body cavity is ripped open, exposing internal organs. Body tissue may be torn or ripped in a rough, ragged manner. Red hemorrhaging observed on 25% or more of the white side.

3a. Fish is able to close operculum when stimulated ..... Go to 4a

Operculum is closed strongly or weakly, but pressure is evident. Operculum may not stay closed for long, though pressure may last up to 5 seconds or longer.

3b. Fish cannot close operculum, even when stimulated. ..... code **DEAD**

4a. Fish displays activity and has muscle tone ..... go to 5a

Fish displays a minimal amount of activity, especially when stimulated. May be able to clench jaw tightly.

4b. Fish exhibits no muscle tone ..... code **DEAD**

5a. Fish is not bleeding, or only slightly bleeding, if at all ..... go to 6a

5b. Blood is flowing freely and continuously in large quantity (profusely ..... code **DEAD**

Bleeding is coming from a torn or severed gill arch, or a body injury.

6a. Body injuries are minimal, perhaps difficult to find. ..... go to 7a

May consist of superficial nicks or cuts on body. Less than 10% of dorsal and anal fin area is frayed.

6b. Body injuries are readily apparent ..... code POOR

Skin is damaged with abrasions. Cuts and lacerations in body extend through the skin and just barely into the flesh (not deeply). Dorsal and anal fin area is frayed between 10-50% Fin edges may be bleeding. Roughly 10-25% of the white side of fish shows red hemorrhaging.

7a. Operculum pressure is strong and sustained ..... go to 8a

7b. Operculum pressure is weak and not sustained ..... code **POOR**

8a. Fish is strong and lively, displaying good muscle tone. ..... go to 9a

Fish is flopping around the deck, hard to control. Jaw may be tightly clenched, difficult to open.

8b. Fish appears weak ..... code **POOR**

Movement is intermittent, perhaps occurring when provoked or stimulated. Body is limp.

9a. Fish is bleeding from gills ..... code **POOR**

Blood is flowing continuously, slow and steadily, but not profusely. Gills are deep to bright red in color.

9b. No bleeding observed ..... code **EXCELLENT**

Gills are deep red in color.

What affects halibut condition?

- For each halibut:
  - Time out of water (before discard)
  - Size of halibut (length or weight)
- For each haul:
  - Haul size
  - Tow duration
  - Air temperature

Condition

↓ **Not currently collected**

↑ Currently recorded

↓ Currently recorded

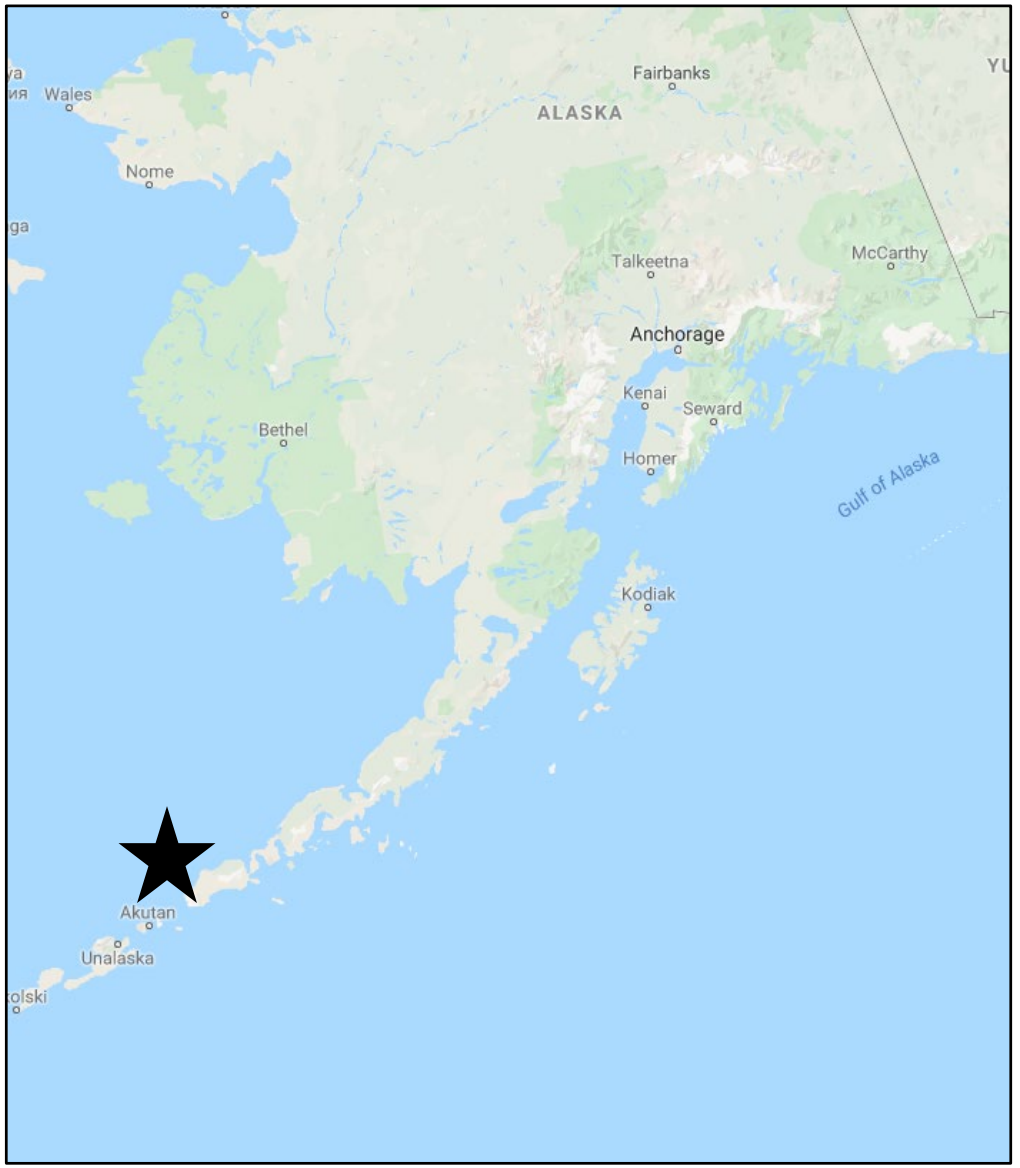
↓ Currently recorded

↓ **Use modeled atmospheric data**

Special Study

- 2016-2017, months Jan – April
- Observers additionally measured **time out of water** prior to discard
- Predominantly on trawl catcher vessels targeting Pacific cod near Unimak Island

- n = 634 halibut
- 102 hauls
- 5 vessels



Predictive Models

- Proportional odds logistic regression, where: **E** → **P** → **D**

- Full model:

  Condition ~
  time out of water +
  haul size +
  halibut kg +
  ~~tow duration +~~ Not useful; correlates with haul size
  air temperature +
  time out of water * haul size +
  ~~time out of water * air temperature~~ Not useful

Predictive Models

- Proportional odds logistic regression, where: **E** → **P** → **D**

- Best model:

  Condition ~
  time out of water +
  haul size +
  halibut kg +
  air temperature +
  time out of water * haul size

For each halibut and its covariates, the model returns:

- **Probability** of each condition category

- **Predicted category** = condition category with the highest probability

Results - Condition Category Prediction

- Model does a fair job of predicting '**Excellent**' and '**Dead**' condition, but has difficulty predicting '**Poor**' condition halibut

		Actual		
		Excellent	**Poor**	**Dead**
Prediction	**Excellent**	**101**	65	39
	Poor	32	**48**	49
	Dead	44	81	**175**

- Can we reliably predict condition category? **Not without more information**

- If the predicted categories from the model are used to calculate haul DMRs, the resulting mortality weight is **overestimated by 9.0%**

Mortality Probability Estimation

- Can we instead **predict each halibut's mortality probability** to generate haul-level DMR estimates?
  - Use the model's condition probabilities as weights in estimation of mortality probability: **Condition probability** x **Mortality probability**
- Example:

Condition	P(Excellent)	P(Poor)	P(Dead)
E	0.78	0.16	0.06
	*** 0.20**	*** 0.55**	*** 0.90**
	= 0.156	**= 0.088**	**= 0.054**

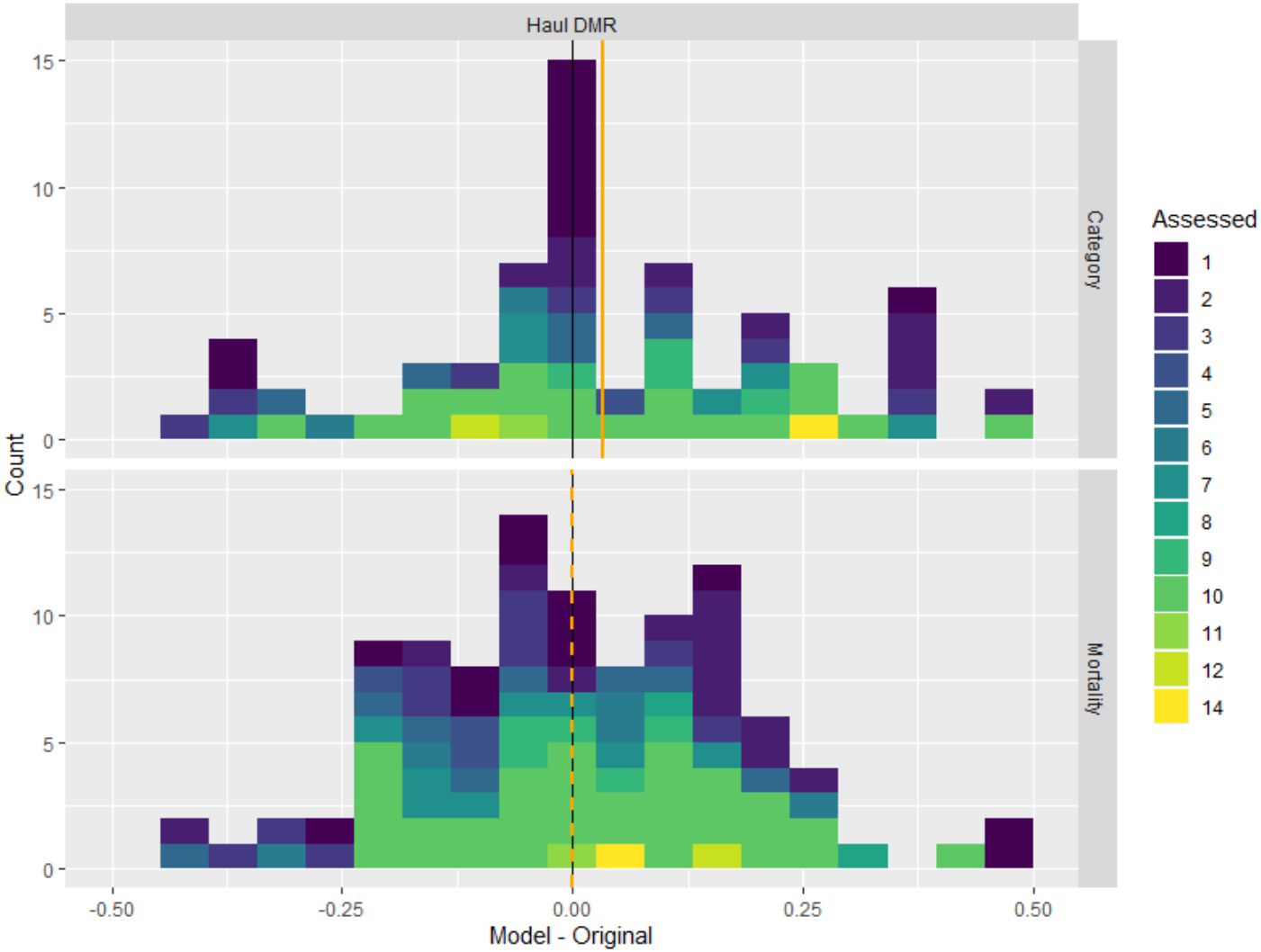
Model-derived mortality probability:
0.156 + 0.088 + 0.054 = **0.298**

- Estimated mortality probabilities are not limited to **0.2**, **0.55** and **0.90**

Model-based DMR and Mortality Estimates

- Estimated based on modeled mortality probabilities are more accurate/less-biased than those based on predicted condition category

Metric	Condition Category	Mortality Probability
DMR Bias	0.0327	0.0006
DMR variance	0.0585	0.0312
Mortality kg bias	+9 %	-3.5%
Mortality kg variance	4533.674	1798.453



Future Work

- **Amendment 80 Halibut Deck Sorting Exempted Fishing Permit**
  - Larger vessels (catcher processors)
  - Greater bycatch weight
  - Pre-sort and discard halibut before moving fish from deck to factory
  - Ability to discard halibut faster sometimes **limited by observer's time-consuming condition assessments**
  - Over **107,000** individual assessments between May 2016 – Nov 2017

Special thanks to:

North Pacific Groundfish Observers

Questions?