Integrating multiple information types to improve estimates of large whale entanglement mortality and serious injury

NOAA Fisheries

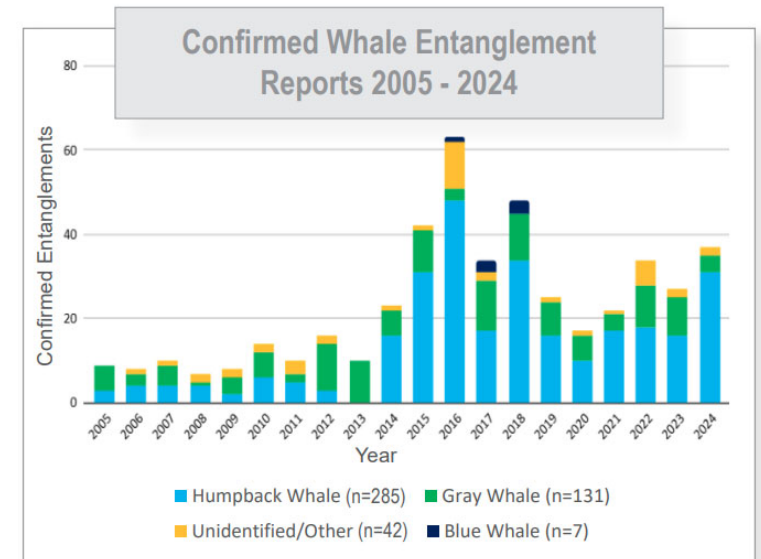Southwest Fisheries Science Center

Jeff Moore, Justin Greenman

Marine Mammal Commission Meeting, Sept 2025

Context

- Increasing whale entanglements in fixed fishing gear during the past decade along the US West Coast

- Relevant fishing gears: various trap/pot gear, mostly in State-managed fisheries (CA, OR, WA), especially for Dungeness crab (plus spot prawn, sablefish)

Confirmed Whale Entanglement Reports 2005 - 2024

Humpback Whale (n=285) Gray Whale (n=131)
Unidentified/Other (n=42) Blue Whale (n=7)

NOAA FISHERIES

Context

- Fisheries are not observed/observable, so it has been difficult to estimate true MSI.

- Opportunistic reports of MSI (i.e., minimum known) have been used as the MSI values in Stock Assessment Reports, for comparison with PBR

2024 West Coast Whale Entanglements
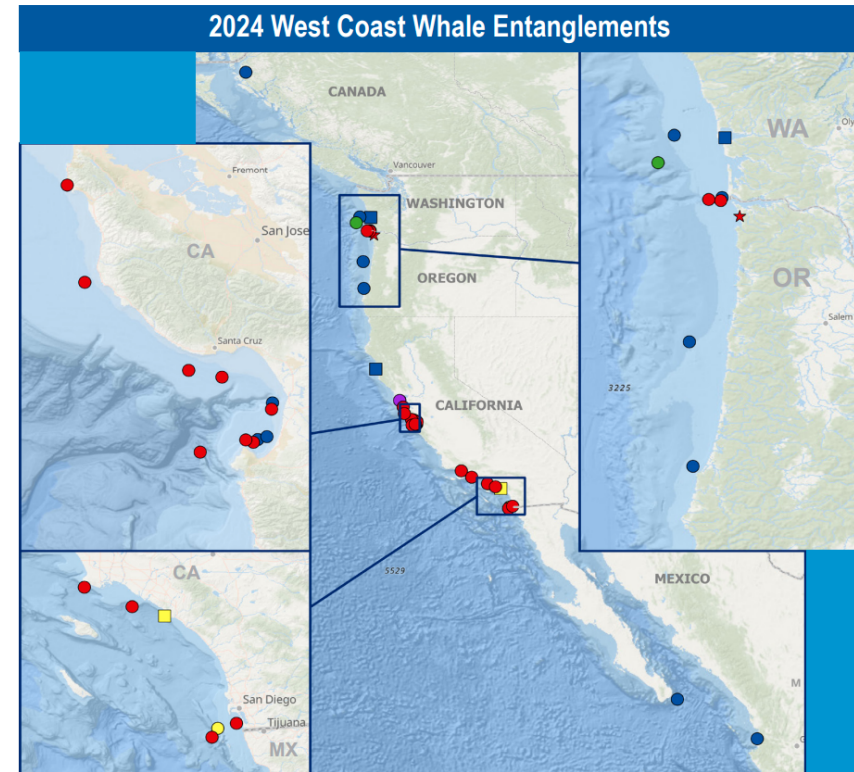
Context

PBR and average annual Mortality and Serious Injury, 2016 – 2020, based on 2022 Stock Assessments (Carretta et al. 2023)

	PBR	MSI (fisheries)	MSI total
Central America	3.5	8.1	14.9
Mexico	43	11.4	22.11

Obsd MSI > PBR

True MSI > PBR?

Central America = "Central America/Southern Mexico – CA/OR/WA" stock (also an Endangered DPS)

Mexico = "Mainland Mexico – CA/OR/WA" stock (part of a Threatened DPS)

NOAA FISHERIES

Research question

- Can we obtain an accurate estimate of actual MSI for large whales affected by fixed gear off the US West Coast?

Research question

- General framework:

$$\hat{C} = \frac{c}{\hat{p}}$$

$\hat{C}$ = total entanglement
c = observed entanglements
$\hat{p}$ = detection rate

- Multiple approaches are being explored for for finding $\hat{p}$, based on different data types

Research question

- Approach 1: Use photo ID data from HappyWhale catalog.

  Assumption: probability of an entangled animal (e.g., in a year) is the same as the probability of observing any given animal within the same time period

NOAA FISHERIES

Research question

- Approach 2: Use repeat sighting reports for entangled individuals

   Remainder of presentation is based on this approach.

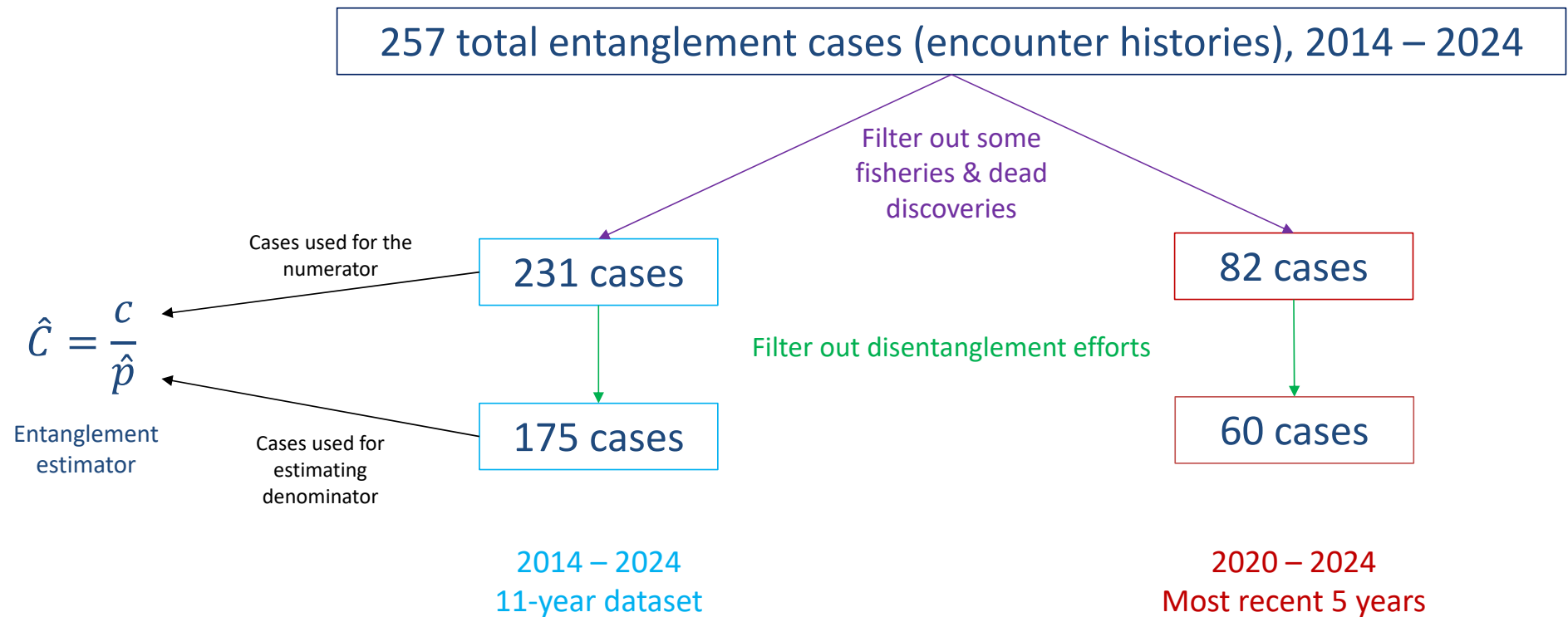|	Entanglement Case Identifi	Entanglement Encounter Da	Entanglement Case Species	Entanglement Case Confirmation	Collection Event Ty	Entanglement Encounter Count	Entanglement Encounter Sta	Entanglement Encounter County	Entanglement Case Last Known Outcome	Entangleme nt Type_(	Entangleme nt Type_(	Entanglement Fishery Type_01
142	20160604Mn	2016-06-04	Whale, humpback	Confirmed Entangled	Report	USA	California	Monterey County, CA		Fishery		Commercial Dungeness Crab
144	20160609Mn	2016-06-09	Whale, humpback	Confirmed Entangled	Report	USA	California	Monterey County, CA	Presumed Still Entangled	Fishery		Gillnet
146	20160612Mn_2	2016-06-12	Whale, humpback	Confirmed Entangled	Report	CAN			Fully Disentangled	Fishery		Commercial Dungeness Crab
148	20160617Mn	2016-06-17	Whale, humpback	Confirmed Entangled	Report	USA	California	Monterey County, CA	Presumed Still Entangled	Fishery		Commercial Dungeness Crab
150	20160624Mn	2016-06-24	Whale, humpback	Confirmed Entangled	Report	USA	California	San Mateo County, CA	Presumed Still Entangled	Unknown		
151	20160705Mn	2016-07-05	Whale, humpback	Confirmed Entangled	Report	USA	California	Monterey County, CA	Presumed Still Entangled	Fishery		Commercial Dungeness Crab
153	20160801Mn	2016-08-01	Whale, humpback	Confirmed Entangled	Report	USA	California	San Luis Obispo County, CA	Presumed Still Entangled	Unknown		
154	20160806Mn	2016-08-06	Whale, humpback	Confirmed Entangled	Report	USA	California	Orange County, CA	Partially Disentangled	Fishery		Commercial Dungeness Crab
155	20160806Mn	2016-08-07	Whale, humpback	Confirmed Entangled	Report	USA	California	Ventura County, CA	Partially Disentangled	Fishery		Commercial Dungeness Crab
156	20160806Mn	2016-08-12	Whale, humpback	Confirmed Entangled	Report	USA	California	San Luis Obispo County, CA	Partially Disentangled	Fishery		Commercial Dungeness Crab
157	20160806Mn	2016-08-13	Whale, humpback	Confirmed Entangled	Report	USA	California	San Luis Obispo County, CA	Partially Disentangled	Fishery		Commercial Dungeness Crab
158	20160806Mn	2016-09-05	Whale, humpback	Confirmed Entangled	Report	USA	California	Los Angeles County, CA	Partially Disentangled	Fishery		Commercial Dungeness Crab
160	20160806Mn	2016-09-14	Whale, humpback	Confirmed Entangled	Report	USA	California	Orange County, CA	Partially Disentangled	Fishery		Commercial Dungeness Crab
161	20160806Mn	2016-09-15	Whale, humpback	Confirmed Entangled	Report	USA	California	Orange County, CA	Partially Disentangled	Fishery		Commercial Dungeness Crab
162	20160806Mn	2016-12-08	Whale, humpback	Confirmed Entangled	Report	USA	California		Partially Disentangled	Fishery		Commercial Dungeness Crab
163	20160806Mn	2017-04-20	Whale, humpback	Confirmed Entangled	Report	USA	California	Orange County, CA	Partially Disentangled	Fishery		Commercial Dungeness Crab
164	20160809Mn	2016-08-09	Whale, humpback	Confirmed Entangled	Report	USA	California	Monterey County, CA	Presumed Still Entangled	Fishery		Commercial Dungeness Crab
165	20160812Mn	2016-08-12	Whale, humpback	Confirmed Entangled	Report	USA	California	Monterey County, CA	Presumed Still Entangled	Unknown		
166	20160816Mn	2016-08-16	Whale, humpback	Confirmed Entangled	Report	USA	California	Monterey County, CA	Presumed Still Entangled	Fishery		Commercial Dungeness Crab
167	20160816Mn_2	2016-08-16	Whale, humpback	Confirmed Entangled	Report	USA	California	San Francisco County, CA	Presumed Still Entangled	Unknown		
168	20160824Mn_1	2016-08-24	Whale, humpback	Confirmed Entangled	Report	USA	California	San Luis Obispo County, CA	Presumed Still Entangled	Unknown		
169	20160824Mn_1	2016-08-25	Whale, humpback	Confirmed Entangled	Report	USA	California	San Luis Obispo County, CA	Presumed Still Entangled	Unknown		
170	20160824Mn_1	2016-08-26	Whale, humpback	Confirmed Entangled	Report	USA	California	San Luis Obispo County, CA	Presumed Still Entangled	Unknown		
171	20160824Mn_2	2016-08-24	Whale, humpback	Confirmed Entangled	Report	USA	California	Monterey County, CA	Presumed Still Entangled	Fishery		Commercial Dungeness Crab
173	20160827Mn	2016-08-27	Whale, humpback	Confirmed Entangled	Report	USA	California	San Francisco County, CA	Presumed Still Entangled	Unknown		
174	20160828Mn_1	2016-08-28	Whale, humpback	Confirmed Entangled	Report	USA	California	San Luis Obispo County, CA	Presumed Still Entangled	Unknown		
175	20160828Mn_2	2016-08-28	Whale, humpback	Confirmed Entangled	Report	USA	California	Monterey County, CA	Presumed Still Entangled	Unknown		

Mark-resight analysis of entanglement report data

- Repeat reports of entanglement individuals = encounter histories
- Occasion duration = 1 week

```
A    100000000000000000000000000000000000000000000000000
B    100011000000000000000000000000000000000000000000000
C    100010011000000000000000000000000000000000000000000
D    100000000000000000000000000000000000000000000000000
E    100000000000000000000000000000000000000000000000000
F    101000000000000000000000000000000000000000000000000
```

Example encounter histories from 6 whales

NOAA FISHERIES

Mark-resight analysis of entanglement report data

Mark-resight analysis of entanglement report data

- Cormack-Jolly-Seber survival model
- Parameters φ ("availability") and q ("conditional detectability")

$s_k = \varphi^k q$ *probability of being seen in week k*

$u_k = 1 - s_k$ *probability of not being seen in week k*

$U = \prod_K u_k$ *probability of never being seen (over a 52-week period)*

$p = 1 - U$ *probability of being detected at least once*

Results

- 18 (10.3%) of 175 cases involved >1 sighting
- 27 resightings total
- Max number of resightings = 4
- Latest resighting = 15th week

Number resightings after initial detection

Number resights

Week
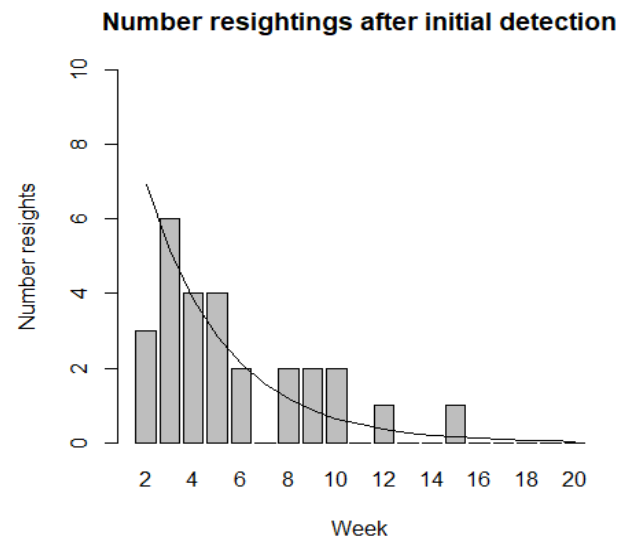
Results (Preliminary), 2020 - 2024

φ = 0.743 (0.042), q = 0.053 (0.015)

p = 0.190 (0.036); 0.131 − 0.273

$C_{2020 - 2024}$ = 430.3 (81.6); 296 − 614

C_{annual} = 86.05 (16.3); 84 - 123

$$\hat{C} = \frac{c}{\hat{p}}$$

Entanglement estimator

Used 2020–2024 data (80 cases) for numerator c

Used 2014-2024 dataset (175 cases) for estimating detection rate parameters and p

Work in Progress

Model fit

- Evaluated using a simulation approach
- Used model estimates to generate 10,000 new datasets
- Each pseudo-dataset = 175 encounter histories (same as real data)
- Simulated encounter histories = Bernoulli variables based on estimated φ and q
- Summarize for each dataset: total number of resightings per occasion and per case, and proportion of individuals that were ever detected
- Pseudo-datasets looked like real data, suggesting reasonable model fit
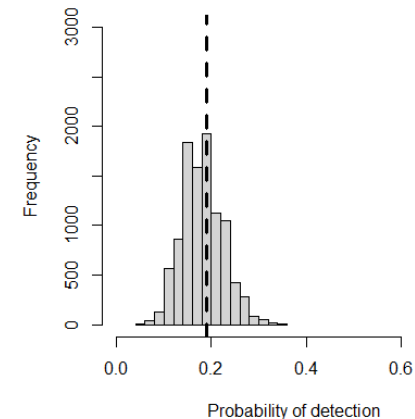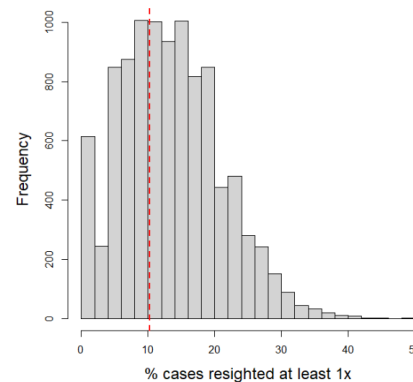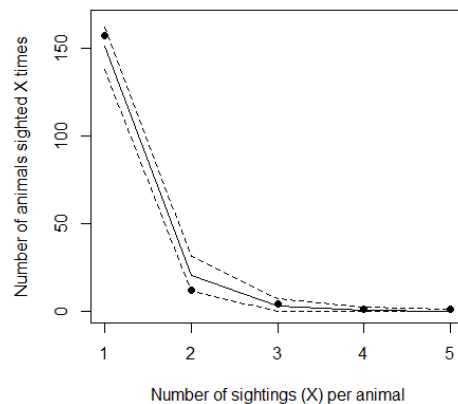
Assumptions

(a) Animals in the sample have the same availability and detection rates as other entangled animals in the population.

Due to "survivorship bias", we are likely underestimating true entanglement

Survivorship bias occurs because we only have data from the animals who were detected. By definition, these animals are more detectable than the ones we never saw.

(b) Entangled animals are not misidentified (e.g., a resighted animal is not labeled as a new animal).

This concerns accuracy of the numerator of: $\hat{C} = \frac{c}{\hat{p}}$

A vetting process developed by WCRO provides good assurance that we are using accurate values for c

Preliminary Estimates (2020 – 2024)

Total entanglement:
$\hat{p}$ = 0.190 (0.036)
c (5 years) = 80
$\hat{C}$ (5 years) = 430.3 (81.6); 296 – 614 $\longrightarrow$
$\hat{C}$ (annual) = 86.05 (16.3); 84 - 123 $\longrightarrow$

Mortality and serious injury

MSI (5 years): 344.24 (65.3); 237 – 491
MSI (annual): 68.9 (13.0); 67 - 98

	PBR	Annual Avg 2016 - 2020 MSI (fisheries)		MSI total
Central America	3.5	8.1		14.9
Mexico	43	11.4		22.11
		Sum = 19.5		

NOAA FISHERIES

Acknowledgements