Characterization of Bycatch for the Menhaden Purse Seine Fishery Occurring off the Coast of Louisiana

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Outline

1. Gulf Menhaden Purse Seine Fishery
2. Objectives & Study Design
3. Sampling Effort & Representativeness
4. Sampling Methods
5. Bycatch Estimation & Verification (Scott)
6. Bycatch Estimates (Scott)
7. Bycatch Survival Study

1 The Gulf Menhaden Fishery

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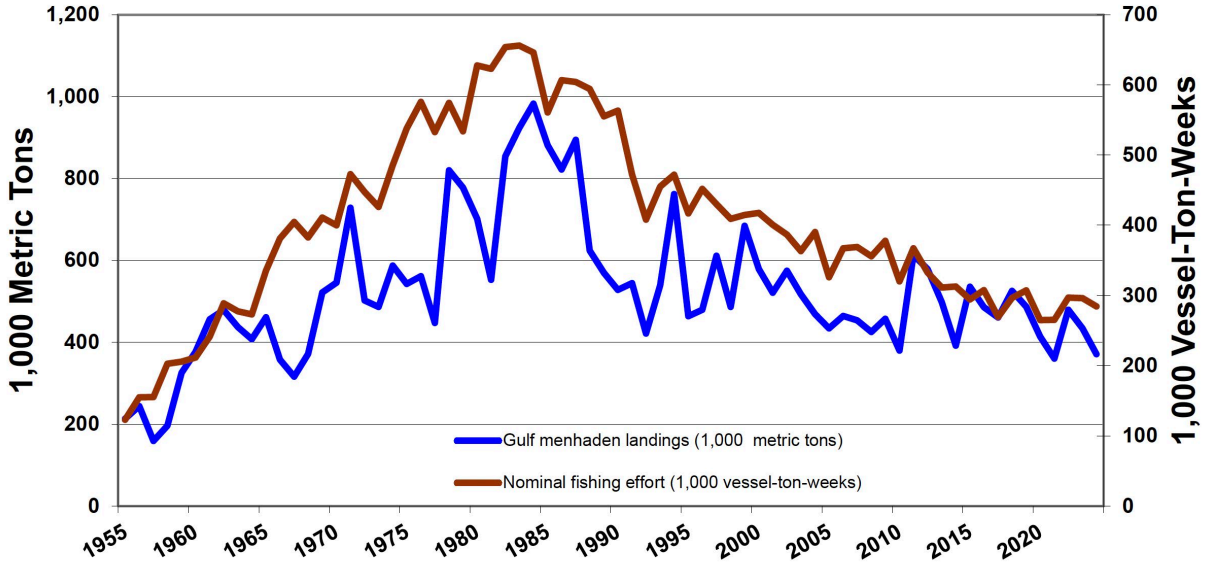
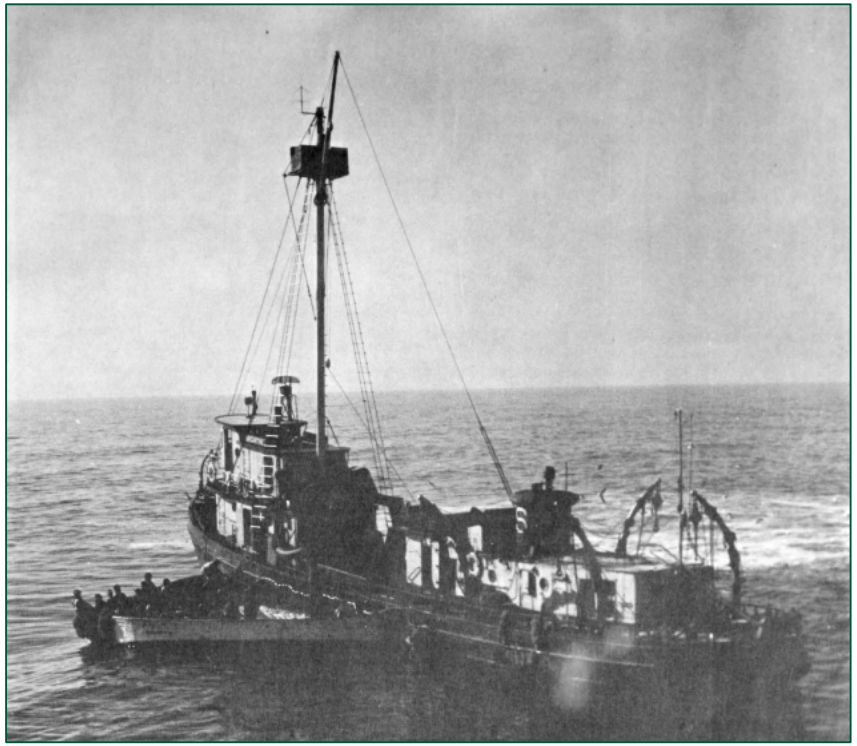
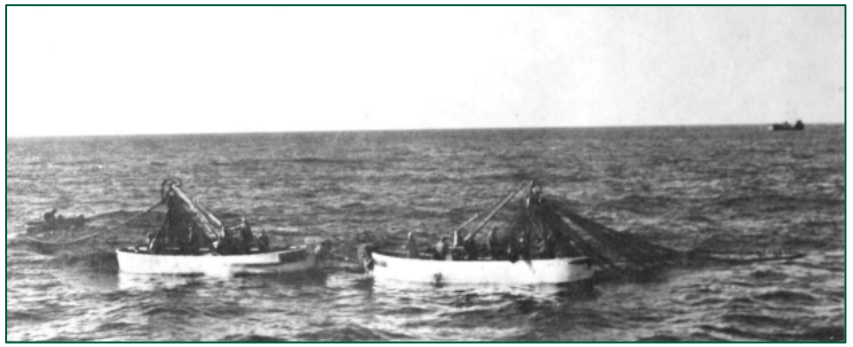
Gulf Menhaden Purse Seine Fishery

- Has existed since the late 1800's and is the largest commercial fishery in the Gulf and the second largest fishery in the U.S. in terms of total landings.
- Landings peaked around 1 million metric tons in the 1980's and have averaged ~500,000 metric tons over the last decade.
- Majority of landings occur in Louisiana: 93.5% in 2024.







Source: June, 1961

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Gulf Menhaden Purse Seine Fishery – Bycatch

1. Fishery lacks a mandated annual bycatch observer program.
2. Bycatch studies have occurred roughly every decade[1-6]
3. Ambiguity over bycatch due to poor temporal resolution and limitations of previous studies:
   - Studies conducted exclusively at the processing plants have failed to quantify the number and fate of bycatch released at sea.
   - At-sea studies have not always had sufficient time to identify all components of the bycatch released at sea.
   - No study has experimentally investigated the post-release survival of bycatch released by industry.
4. The present study was designed to overcome these limitations and to fill these data gaps.

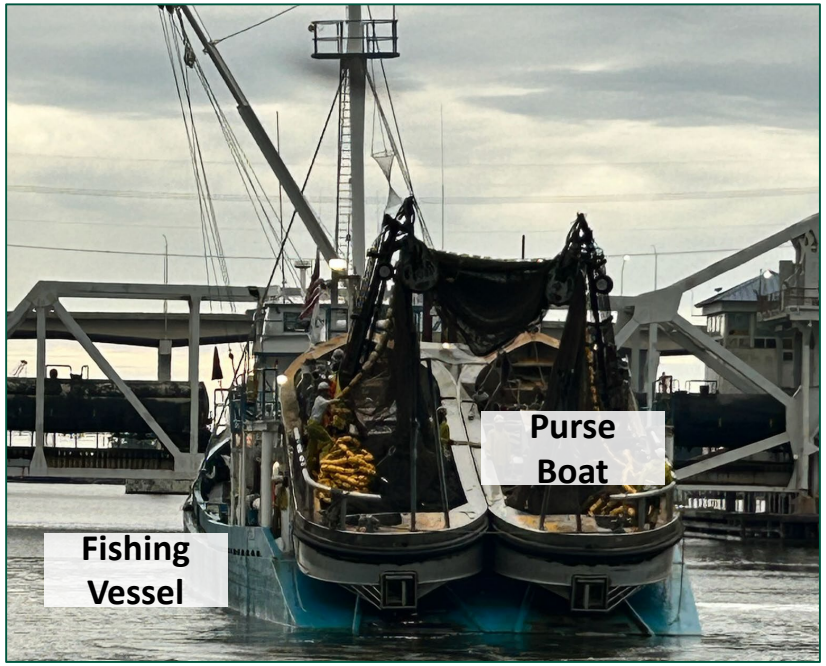
De Silva et al., 2001

[1]Miles and Simmons, 1950 ; [2]Christmas et al., 1960; [3]Guillory and Hutton, 1982 ;[4]Condry, 1994; [5]De Silva et al., 2001; [6]Pulver and Scott-Denton, 2012.

Gulf Menhaden Purse Seine Fishery – Vessels

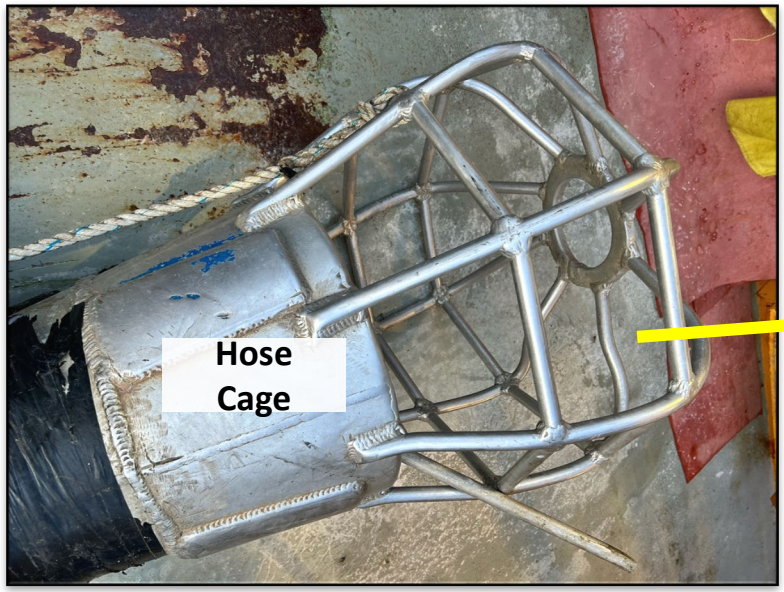
The industry operates via multiple vessels:

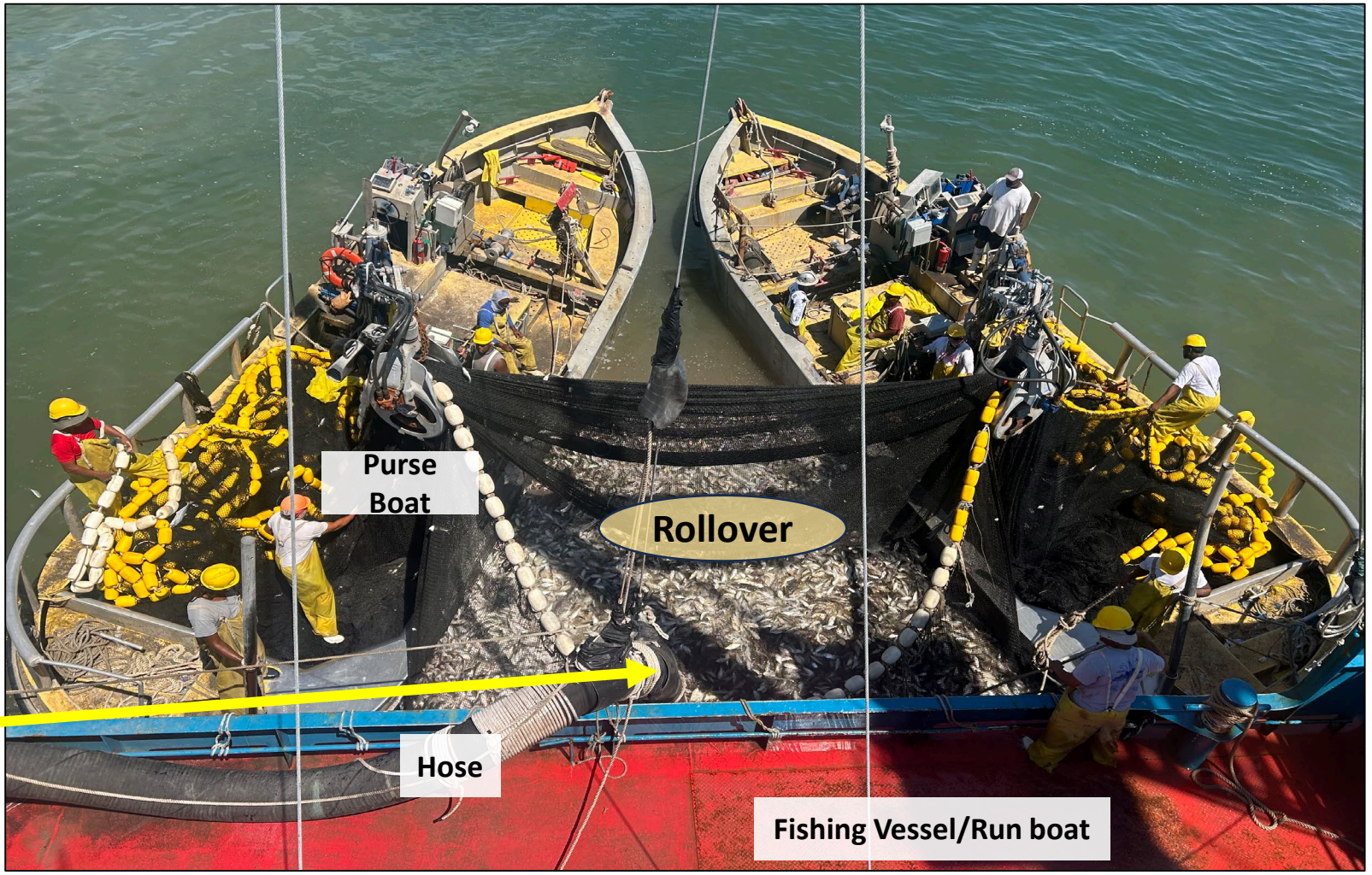
1. Fishing vessels transport gear to the fishing grounds and catch to processing plants.
2. Equipped with twin stern ramps to deploy two, smaller purse boats that set the purse nets on the target school of menhaden.
3. A specialized set of fishing vessels operate as run boats (or tenders) that pump catch directly from the nets (or holds) of fishing vessels into their own holds.
    1. Run boats were key to our study design.



Overview of Catch Sorting Process

- Purse boats tighten the net over span of ~30 minutes.
- Catch (and bycatch) are pumped from the purse net by fishing vessels (and run boats).
- Two bycatch excluder devices have been utilized by industry since ~1950's: (1) Hose Cage
- "Rollover" procedure releases bycatch from the net.





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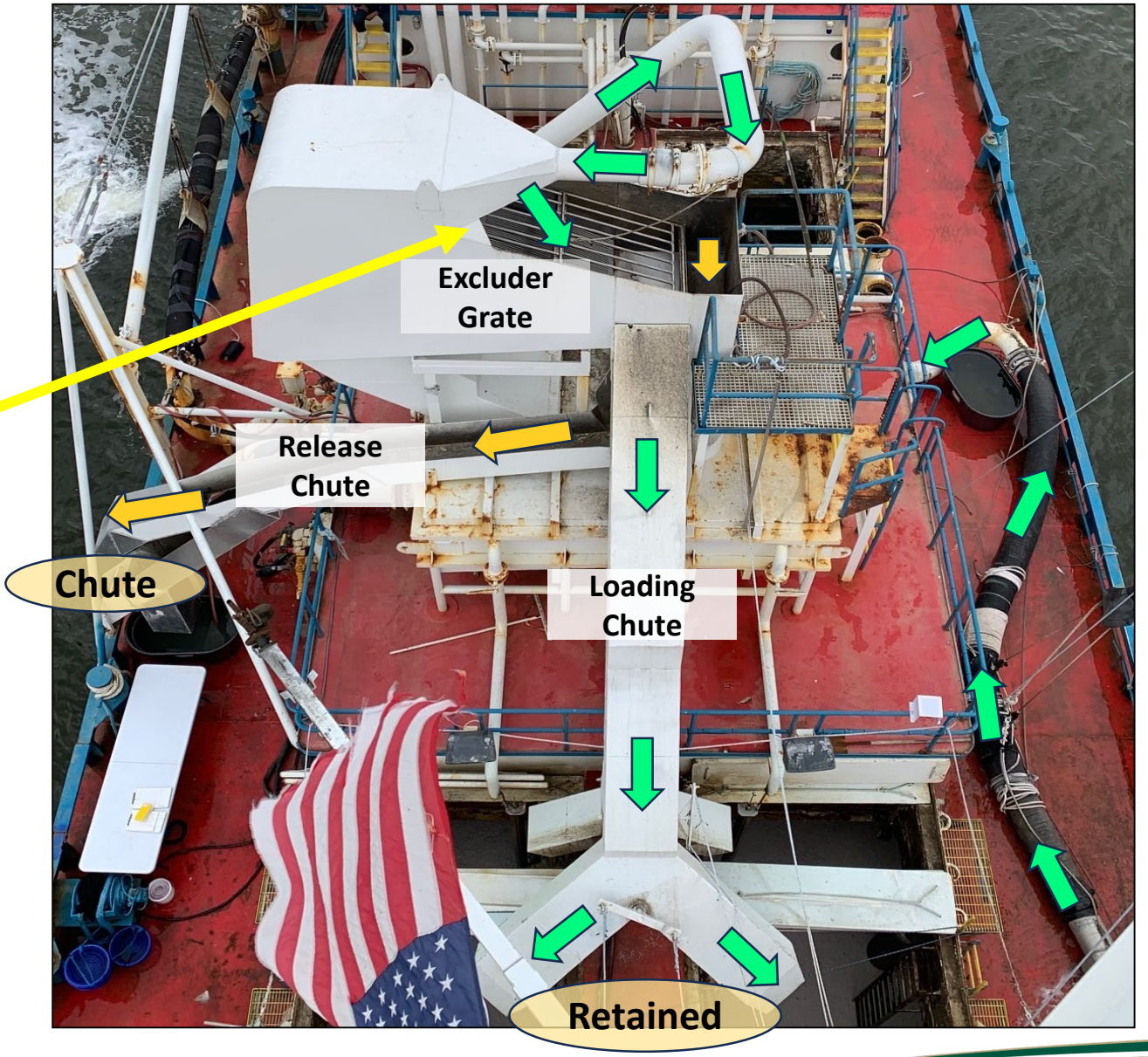
Overview of Catch Sorting Process

- Bird's eye view of where catch travels →
- Catch and bycatch that go through the hose cage travel to the second bycatch excluder device: the excluder grate.



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Main Areas of Bycatch Sampling

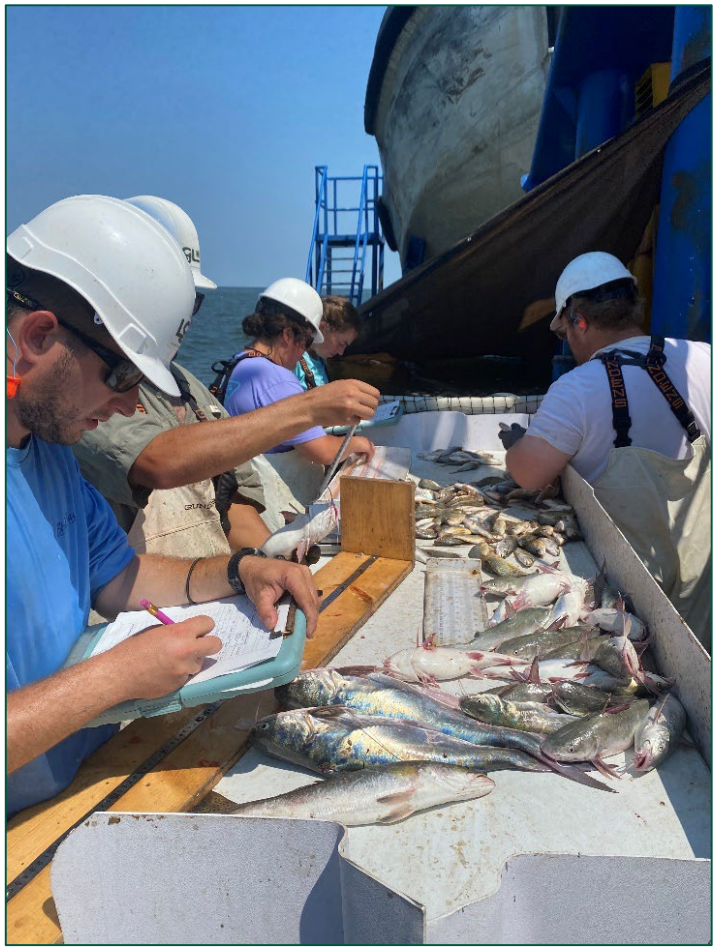
Bycatch can occur in three main areas:

1. Rollover bycatch: large bycatch remaining in the seine once the pumping process is complete and rolled over the cork line for release.
2. Chute bycatch: large individuals separated from the catch by the excluder grate that sends them down a release chute.
3. Retained bycatch: smaller individuals that pass through the grate and end up in the hold along with targeted catch.

Released

Retained

- All three sampled simultaneously using a team of 4-6 at-sea observers.



Observers sorting the retained catch.

❷ Objectives & Study Design

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Objectives & Study Design

Overarching Goal: provide a scientifically robust characterization of bycatch that covers **>2%** of the total sets across the 2024 season (LA state waters & adjacent federal waters).

Objectives for all bycatch areas:

1. Estimate the quantity (#individuals & total weight) and the species composition of bycatch.
2. Estimate species-specific length and weight distributions, as well as sex ratios.

Objectives for released bycatch:

3. Estimate near-term mortality rates ("fate") of key released bycatch species.
4. Record "vitality" of bycatch via condition scores and by assessing Reflex Action Mortality Predictors (RAMP)

"Set" = single net deployment, pump and retrieval

Objectives & Study Design

1. Stratified-random design to allow for spatio-temporal patterns in bycatch to be rendered.
2. Spatial stratification represented by sampling boats operating out of the three processing plants:
   - Empire, LA (West Bank)
   - Abbeville, LA (Omega)
   - Moss Point, MS (Omega)
3. Samples stratified temporally across the seven months (April-October) to address seasonality.
4. Sample size goals conservatively based on historic effort from 2020-22 to meet >2% effort benchmark.

Observers placed on board sampling vessels for 3 weeks a month across the entire 7-month season.

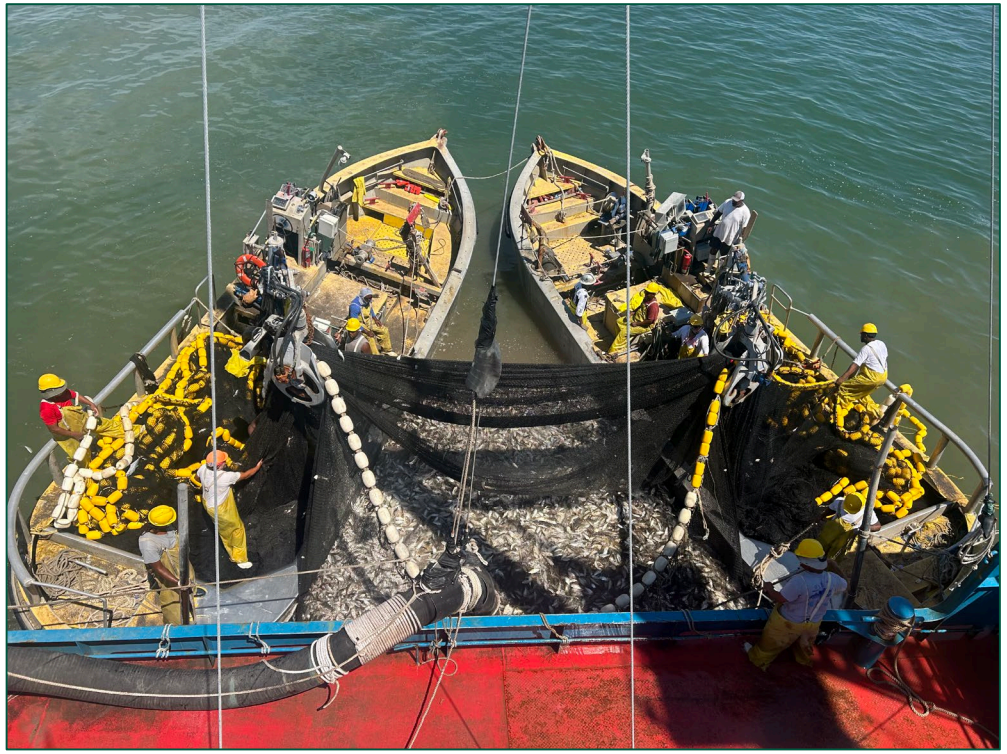
Objectives & Study Design

- Used run boats to sample the fleet. Numerous advantages:
  - Access to a greater number of sets to sample
  - Sampled sets were more statistically independent
  - More space for observers & survival tanks

- Bycatch experiences replicate conditions to that of fishing vessels.

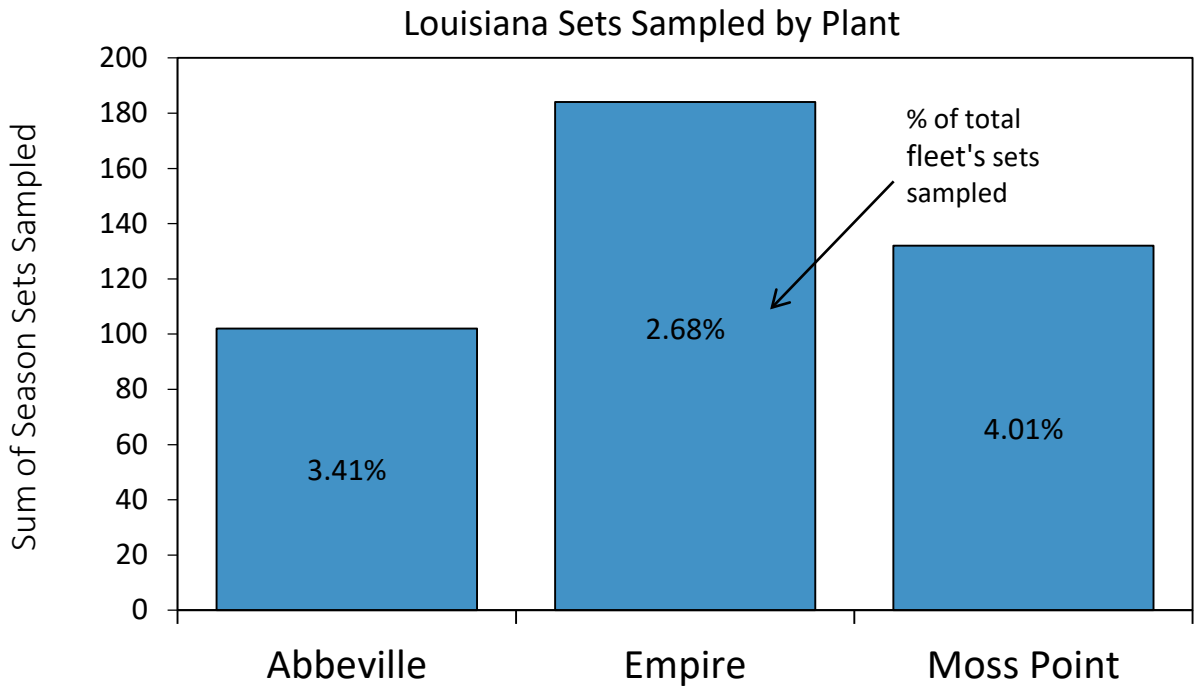
"Fishing boats fish the fish, run boats fish the fleet"

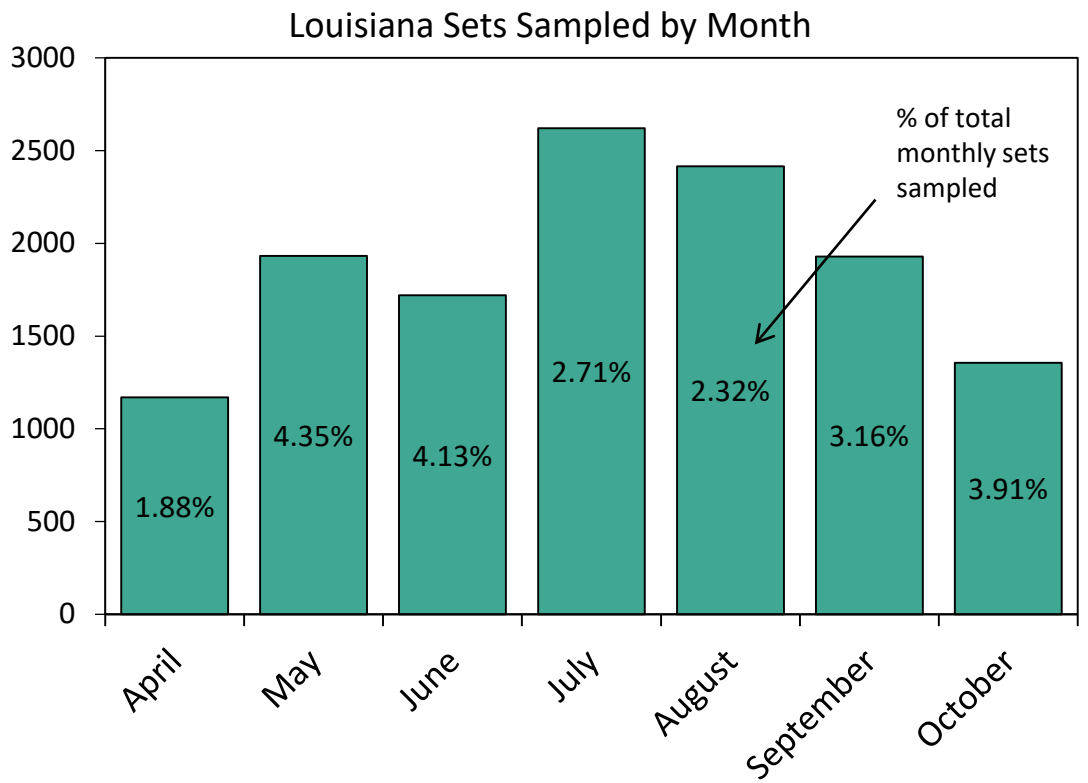
❸ Sampling Effort & Representativeness



Sampling Effort

- Sampled 3.2% of Louisiana sets overall (418 of 13,144)
- Sampling effort proportional across plant & season
- >2% for every month except April
- Each fishing vessel in the fleet was sampled at least 4 times





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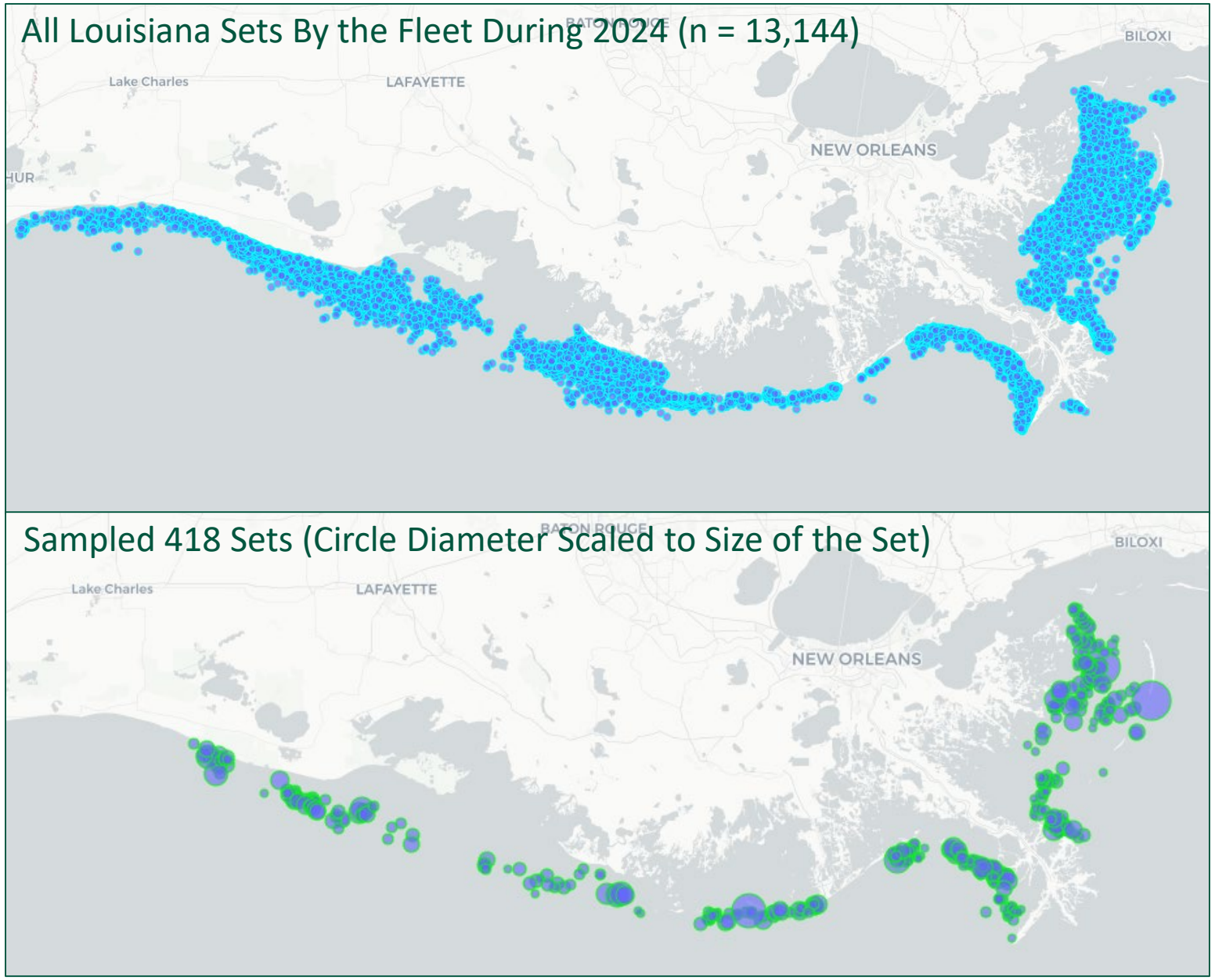
Spatial Representativeness of 418 Sampled Sets



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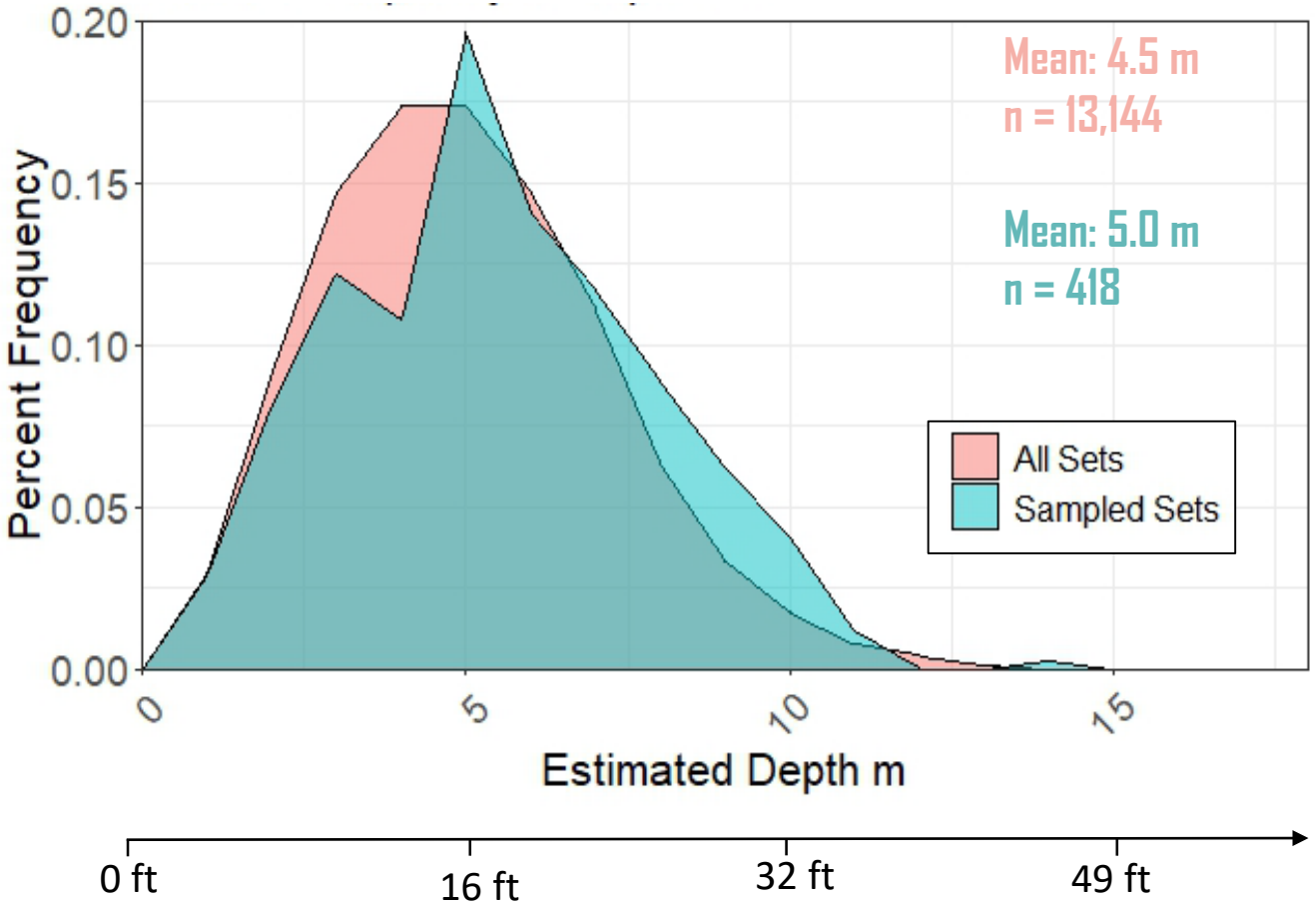
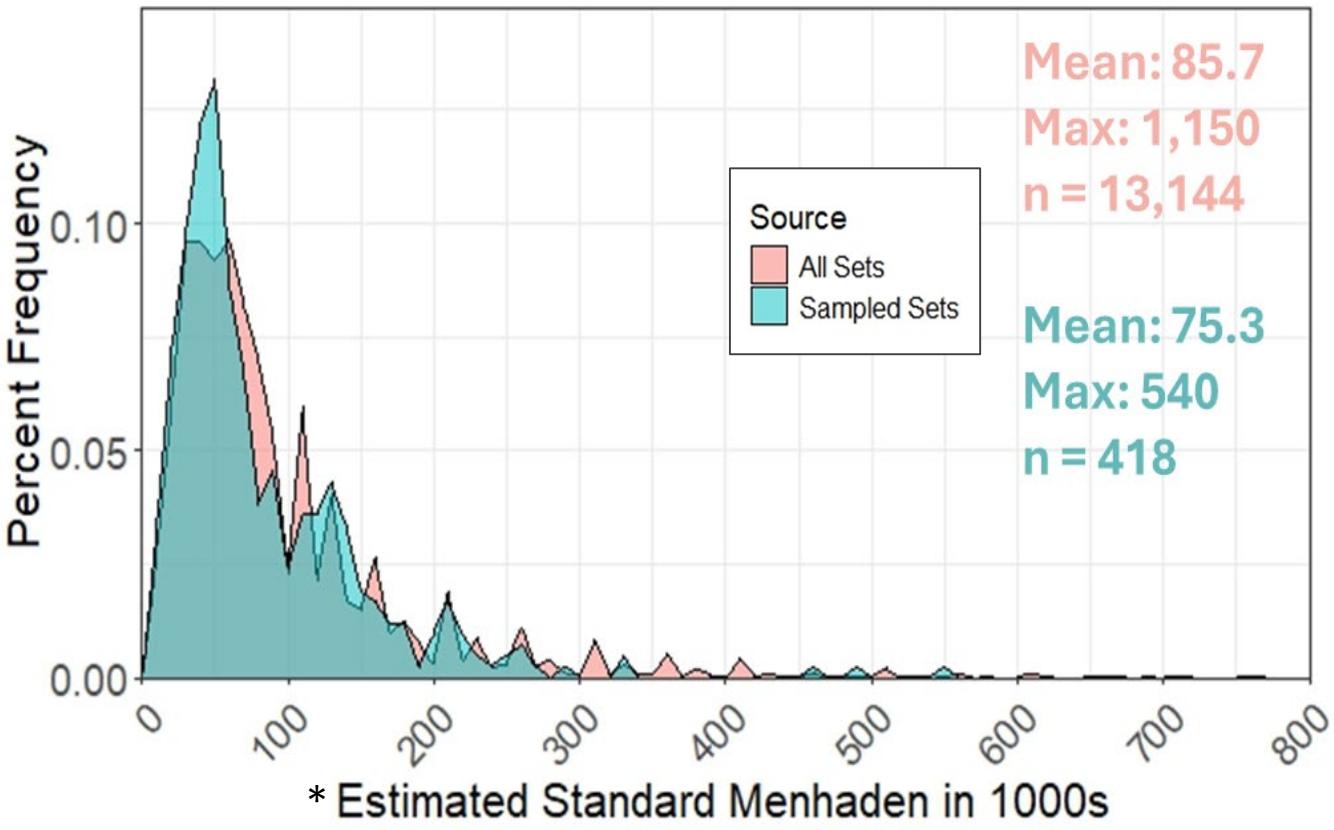
Representativeness in Terms of Set Depth

- Empirical depths lacking for fleet-wide sets.
- Depths extracted from a 3-Arc Coastal Relief Model based on coordinates reported by industry.
- The depth of sets sampled were generally representative of the fleet.



Representativeness in Terms of Set Size

- Standard Menhaden = **0.3 kg**
- Sampled sets ranged in size from 0-540,000 estimated standard menhaden.
- Sets larger than 540,000 were rare events. Consisting of 49 sets and <0.4% of total LA effort.
- Sampled sets were generally representative of the fleet in terms of set size.



*x-axis is restricted to a maximum set size of 800,000 standard menhaden.

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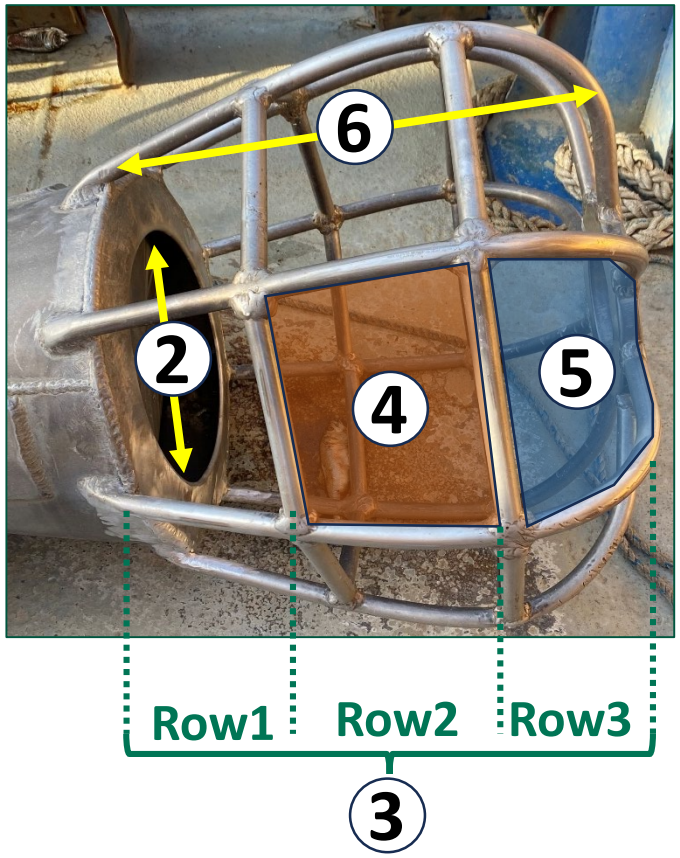
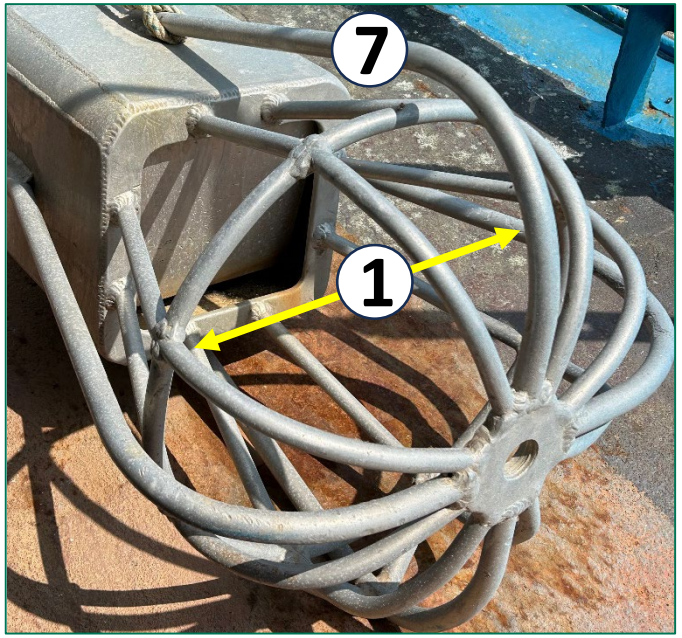
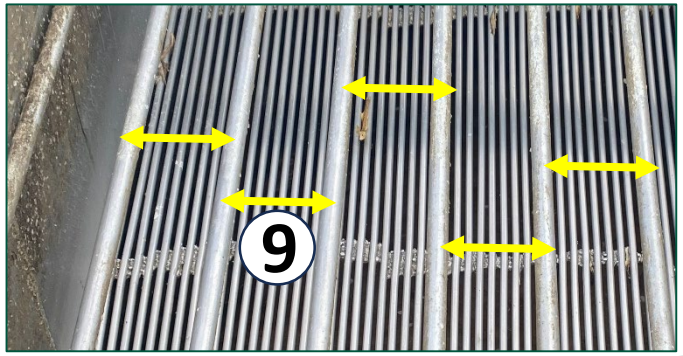
Representativeness of Bycatch Excluder Devices

- Considerable variation in bycatch excluder devices between vessels.
- Characterized the bycatch excluder devices for all 27 fishing vessels and 5 run boats in the fleet.





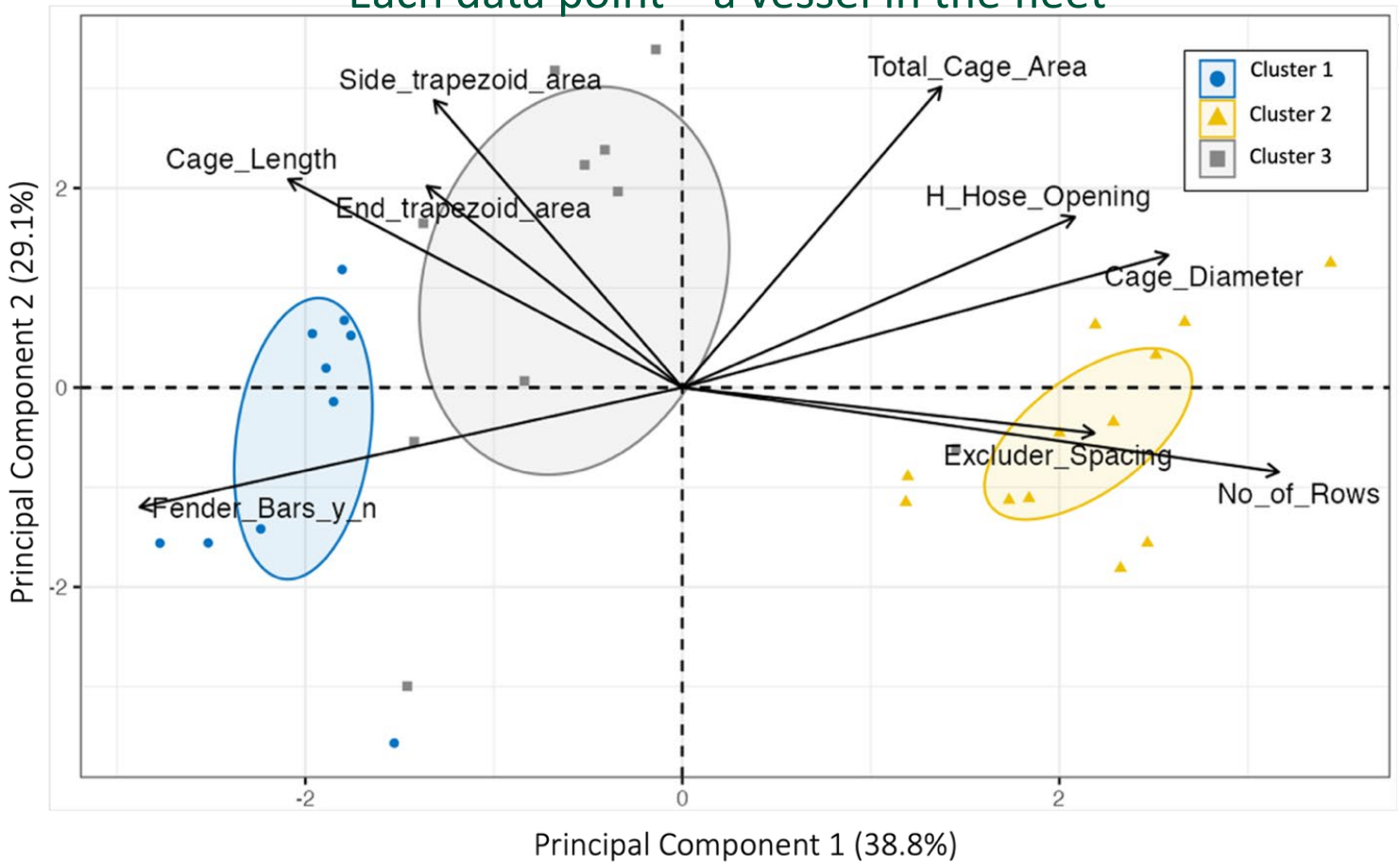


Assessed Following Variables:

1. Hose Cage Diameter
2. Hose Opening Diameter
3. Number of Hose Cage Rows
4. Largest Side Trapezoid Area
5. Largest End Trapezoid Area
6. Total Cage Length
7. Presence/Absence of Cage Fenders
8. Hose Cage Total Area/Volume
9. Excluder Grate Spacing

Principal Components Analysis to Summarize Bycatch Excluder Devices

Each data point = a vessel in the fleet

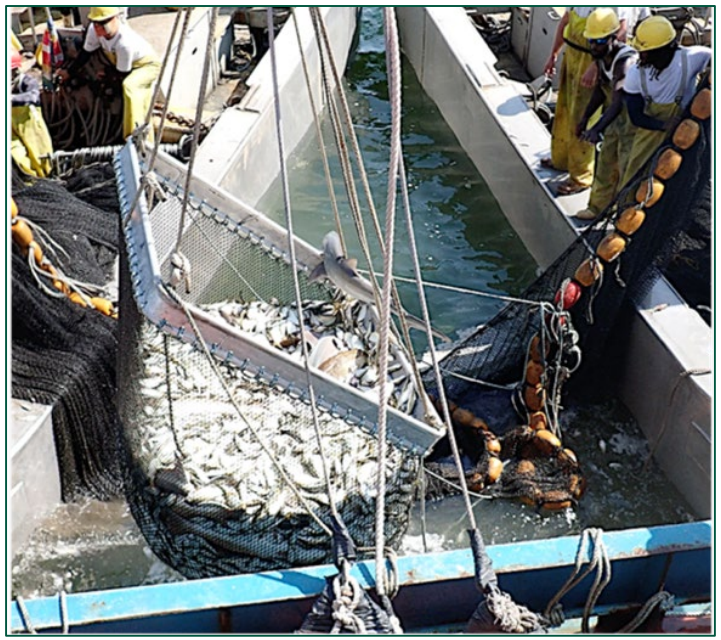


PCA explained ~68% of the variance

- Summarized the 9 variables with a Principal Component Analysis (PCA).
- Reduces dimensionality of complex data –> Two dimensions (principal components)
- Described 68% of the variance in excluder devices across the fleet
- Three primary clusters shown by 99% Confidence ellipses.
- The three chosen sampling vessels originated from each cluster.

❹ Overview of Sampling Methods

Three Main Areas of Bycatch Sampling – Rollover Bycatch



1. Bycatch was intercepted by long-handled landing nets.
2. A large brailer net was utilized on six sets with higher bycatch.
3. To ensure a complete census:
   - Observers counted bycatch that was released.
   - Two fixed cameras (240 fps) and one hand-held camera filmed the rollover procedure.
   - Videos were reviewed to produce final bycatch counts.

Three Main Areas of Bycatch Sampling – Chute Bycatch





1. Bycatch was collected by redirecting the release chute into a 100-gallon tank.
2. This approach resulted in a complete census of the chute bycatch.
3. Bycatch entangled in the grate or chute was recorded (fate = mortality).

- All bycatch collected from the rollover and chute were weighed and measured.

Assessing Released Bycatch Fate – Vitality Scores

1. Only a fraction of the bycatch was used in the survival study.
2. The remainder was evaluated by assessing **Condition Scores.**
3. Evaluated based on external injuries, movement, gill ventilation, etc.

Vitality	Code	Description
Excellent	1	Vigorous body movement. No minor[a] external injuries.
Good/fair	2	Weak body movement. Minor[a] external injuries.
Poor	3	No body movement, but opercular movement. Minor[a] or major[b] external injuries.
Mortality	4	No body or opercular movements. Major[b] external injuries or disfigured/decapitated specimen. Dead or moribund.

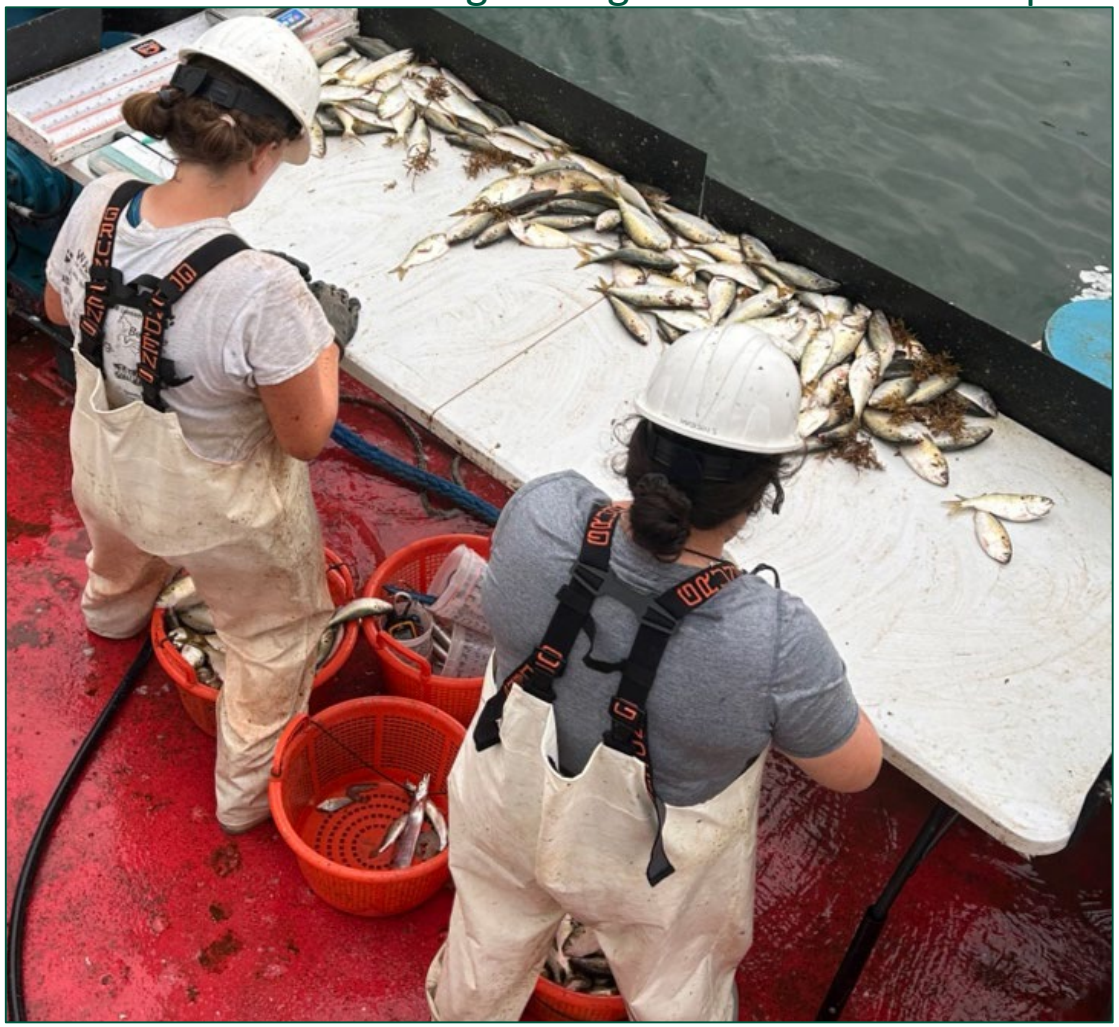
[1]Benoît et al. (2010 and 2012).

Three Main Areas of Bycatch Sampling – Retained Bycatch

1. Sampling menhaden & bycatch that entered the hold of the vessel
2. Vessels are pumping ~15,000 standard menhaden into the hold per minute.
3. Thus, subsampled ~126 kg of catch each set via a sampling cage, davit and winch.
4. Bycatch might not be distributed uniformly
5. Samples collected across the beginning, middle and end segments of the pumping operation.

Three Main Areas of Bycatch Sampling – Retained Bycatch

LGL observers sorting through a retained subsample.



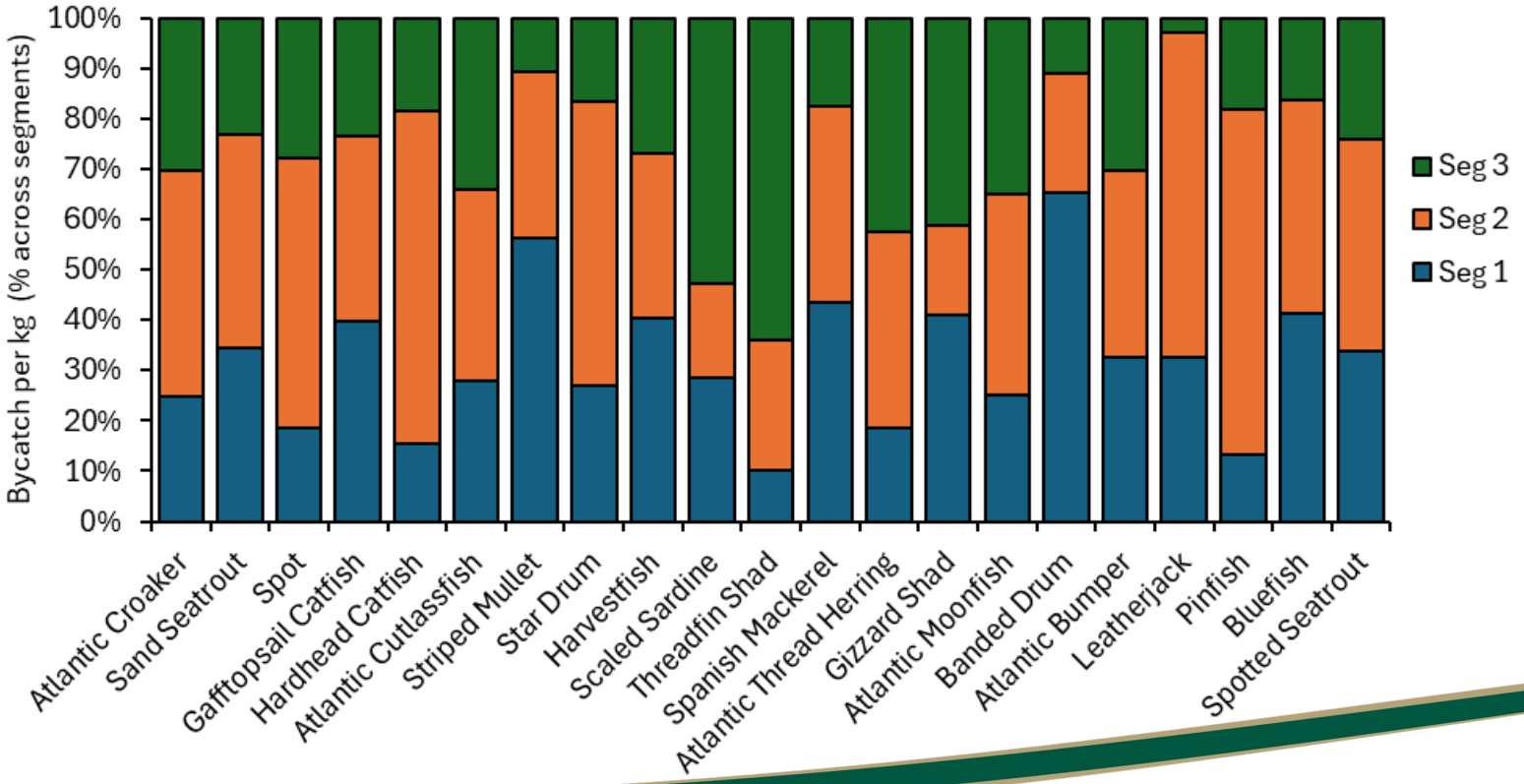
1. Samples sorted by observers.
2. Menhaden separated, counted (two 15 kg baskets) and weighed (all).
3. First 30 bycatch of each species measured and weighed.
4. All bycatch enumerated and weighed
5. Subset of bycatch sexed.
6. Qualitative assessment of reproductive stage.

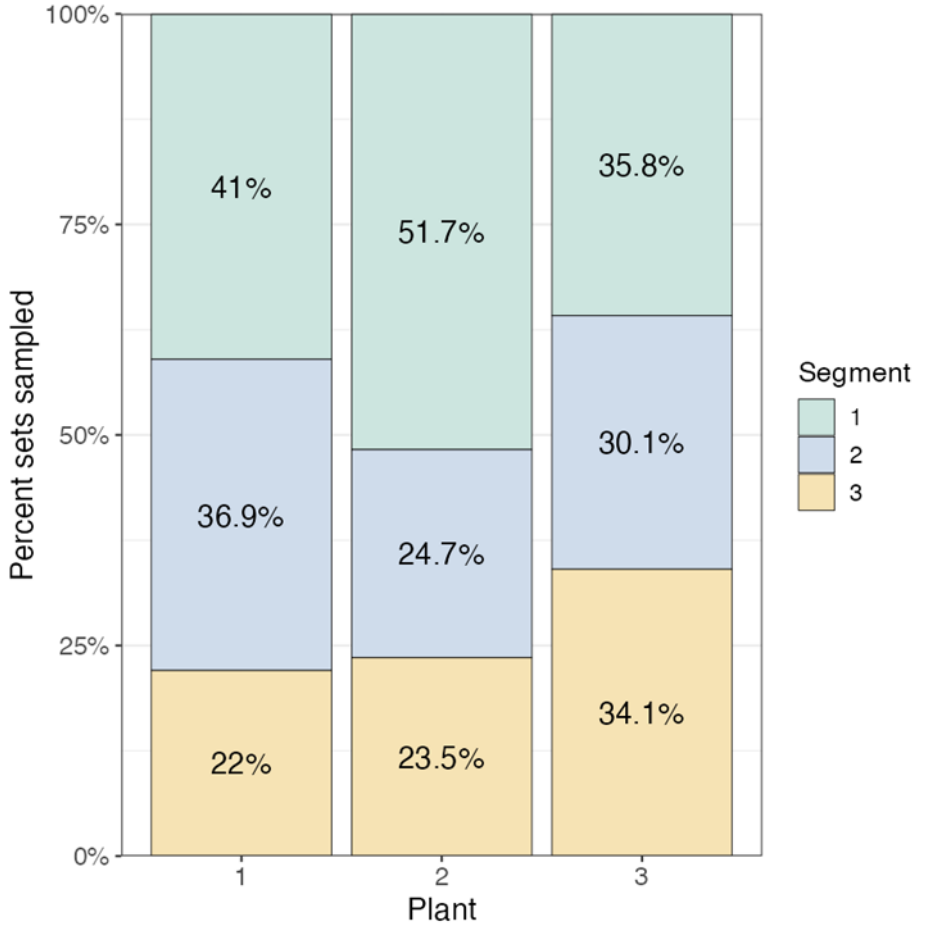
Retained bycatch.

Gafftopsail catfish eggs.

Three Main Areas of Bycatch Sampling – Retained Bycatch

- Sampling effort was relatively balanced across segments within each plant
- Left: Proportion of retained sets sampled by segment was relatively well balanced.
- Bottom: Bycatch per kg expressed as a percentage across segments.
  - Percent similarity index: segments 83% similar in their species compositions.
  - Limited segment-driven bias in catch composition





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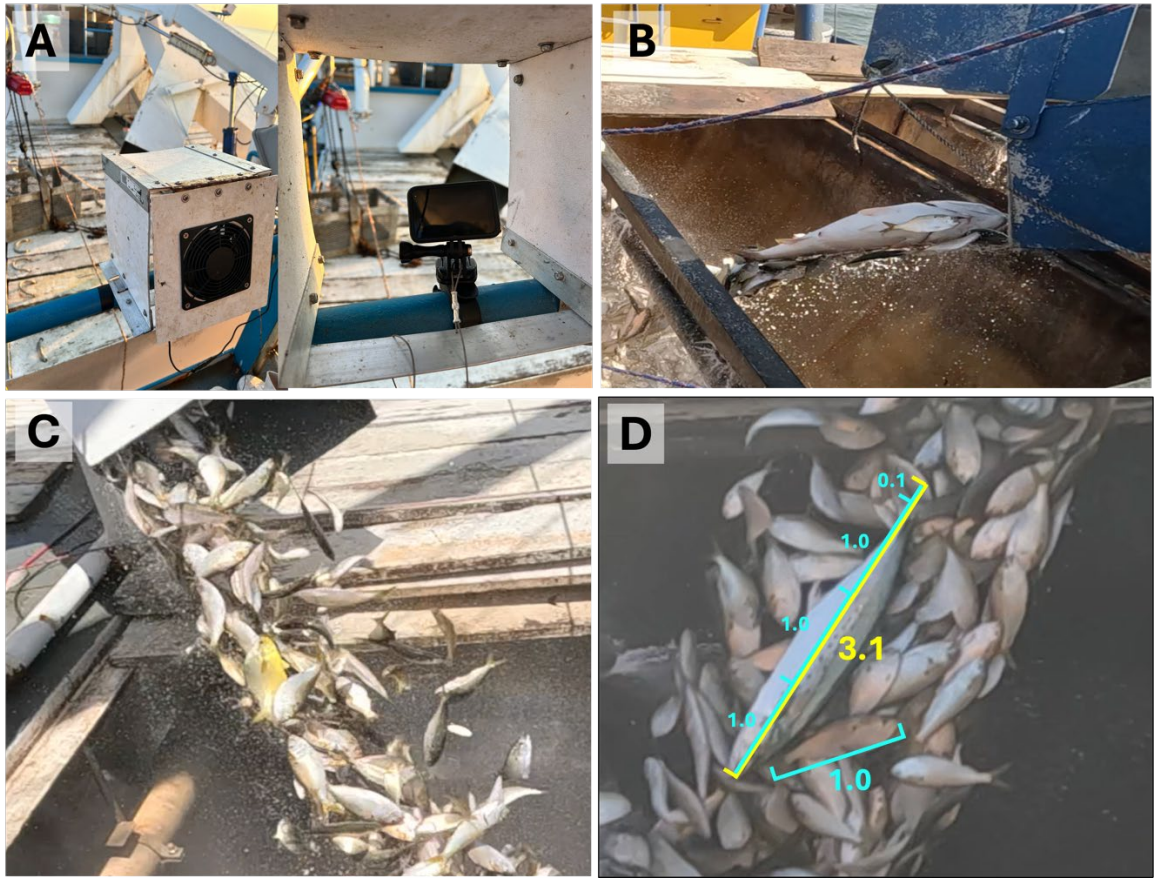
❺ Bycatch Estimation & Verification



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Bycatch estimation and verification

- Bycatch was estimated for each component (rollover, chute, and retained) independently.
- We utilized both **design-based** and **model-based** estimation methods.
- **Design-based:** strive to randomly select a sample from a population. Are reliable when sampling is truly random and representative.
- **Model-Based:** build a model that accounts for expected patterns to generate predictions. Useful when sampling is limited or uneven.

Bycatch Estimation and Verification

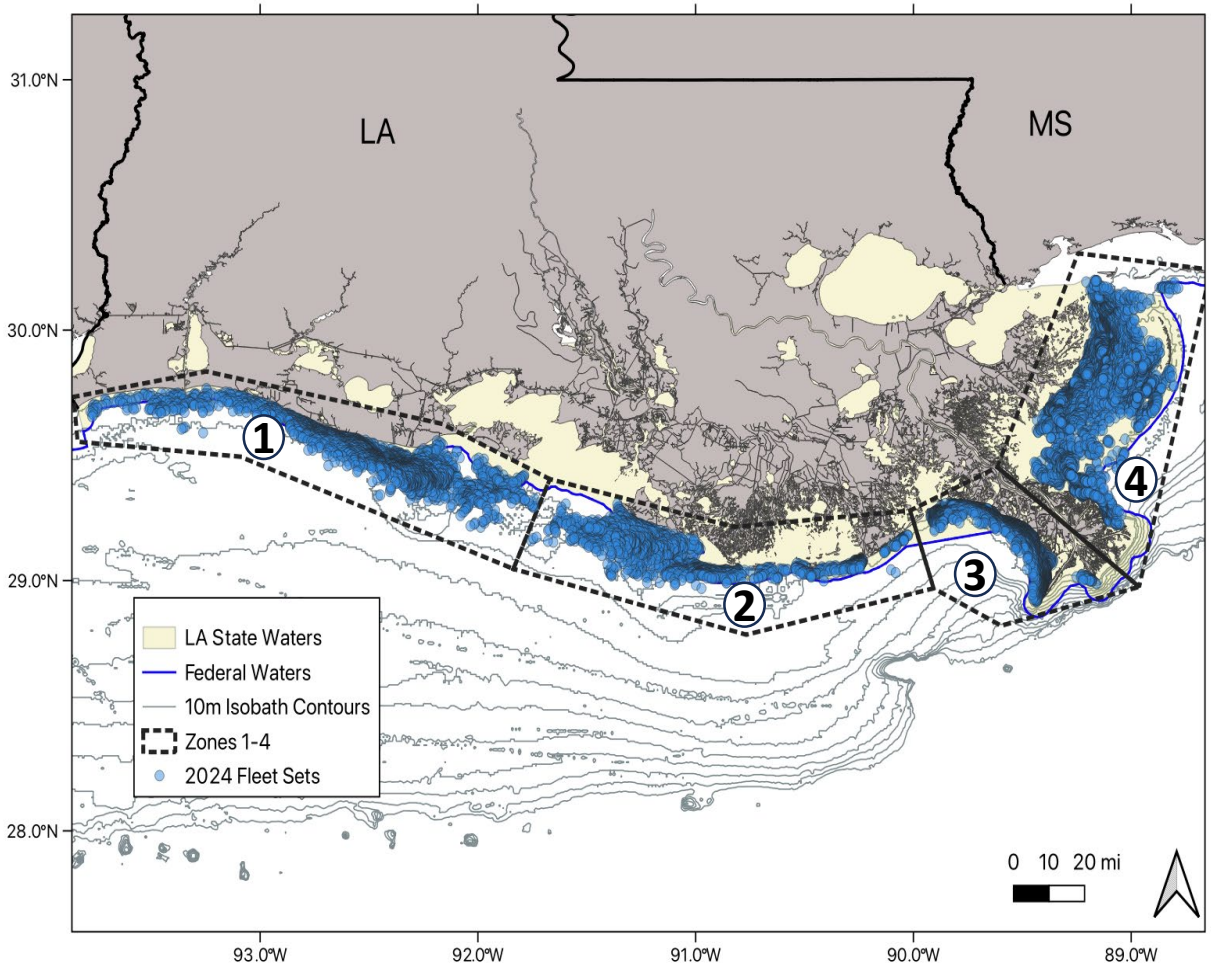
Design-Based Released Bycatch:

- The stratified mean number of individuals per set was calculated by plant and month.
- These estimates and their variances were expanded to the total number of sets made by the fleet for each stratum and summed across strata.

Model-Based Released Bycatch:

- The final model specifications formed Generalized Additive Mixed Models (GAMMs).
- Variables include Plant, Month, Longitude, Area, Bottom Depth, and Day of Year.
- Day of year treated as a random intercept.

Four zones were created to parcel sets by area



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Bycatch Estimation and Verification

Design-Based Retained Bycatch:

- Observed values from the retained bycatch samples did not lend themselves to model parameterization.
- Low frequency of occurrence caused ~95-98% of the observations to be zeroes (e.g. for red drum & spotted seatrout).
- Used an intercept-only negative-binomial (NB) model for each plant-month combination (a hybrid approach).
- Approach yielded similar point estimates as the arithmetic means but allowed for confidence intervals that accounted for overdispersion.

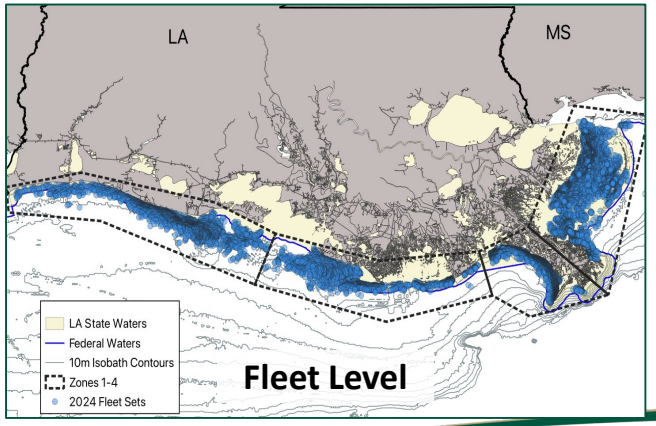
Bycatch estimation and verification

Design-Based Retained Bycatch:

- Subsampling requires expansion first to the total set level and then to the fleet level

Set level:

- The subsample was expanded based on the captain's estimate of total weight (in 0.3 kg standard menhaden) for each set.
- Set weights were proportionally adjusted so that the combined weights matched the reported plant offload weight.
- Average percent difference in estimates: 2.2%



Bycatch estimation and verification

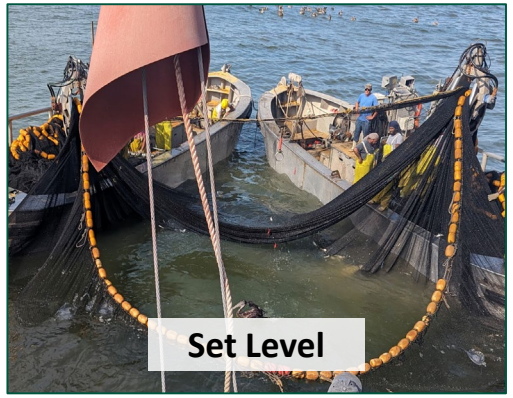
Design-Based Retained Bycatch:

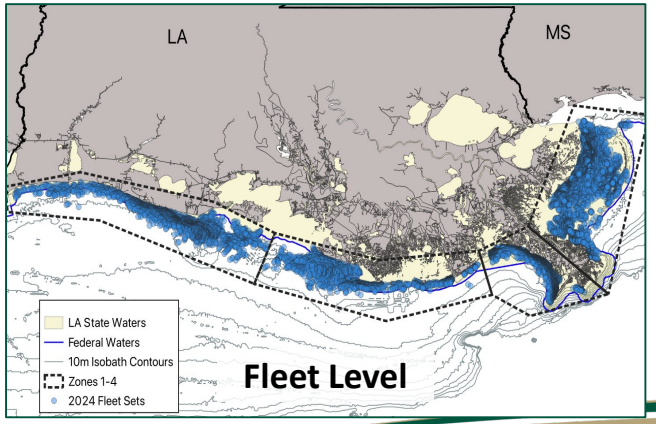
Fleet level:

- Set level point estimates were then expanded to the entire fleet based on the total number of sets per stratum.
- Set level estimates were totaled across all strata to obtain a fleetwide estimation of retained bycatch by species.
- Confidence limits were derived via parametric bootstrapping from the negative-binomial model with 10,000 iterations.

By Weight:

- The estimated number of each species in each component of the bycatch was multiplied by the average weight of individuals of that species collected in that component of the bycatch





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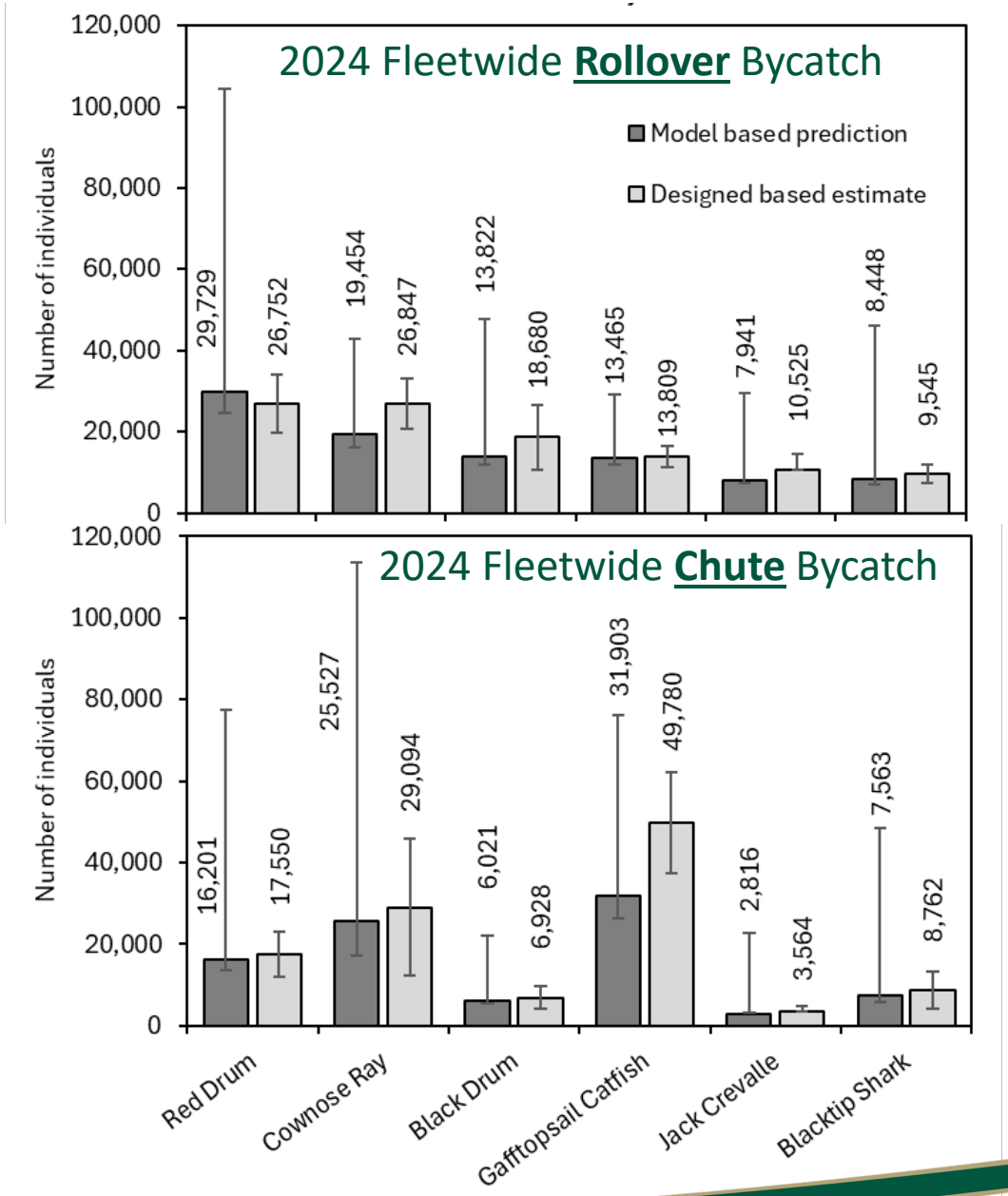
Validation and Verification



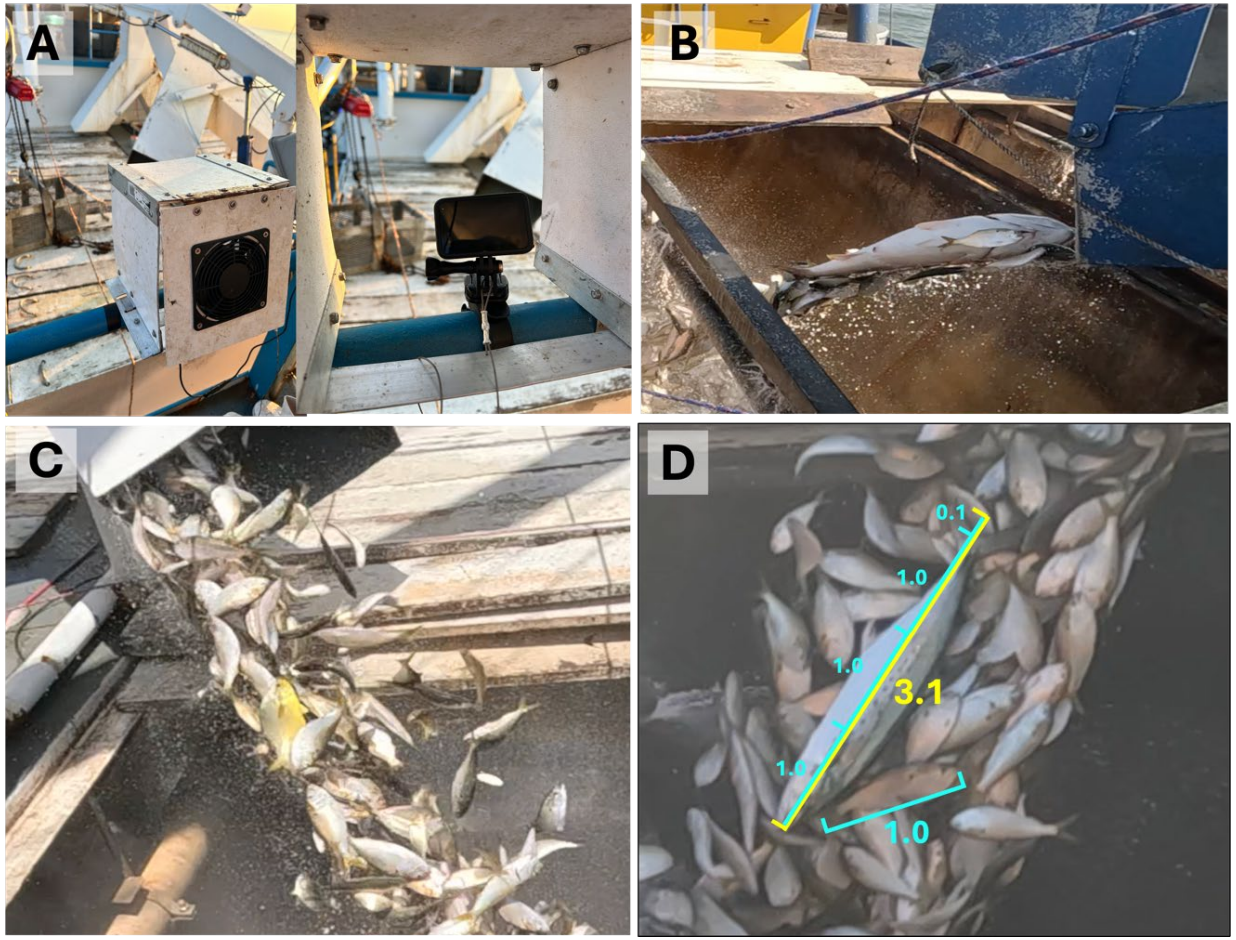
Model vs. Design-based

- **Left:** Season estimated bycatch (# individuals) for both design and model-based estimation methods of the six most abundant species in the released bycatch. A) Rollover bycatch. B) Chute bycatch.
- Model based bycatch estimates for abundant species in the rollover and chute were close to those generated by design-based means.
- Suggests our sampling was representative of the fleet & that our models were conditioned to yield unbiased predictions.
- Therefore, design-based means are used to estimate the released bycatch.

Validation and Verification – Retained Bycatch

Cross Verification Via Video Analysis

- High speed video (240 fps) recorded catch entering the hold.
- Videos analyzed across 241 random sets.
- All bycatch observed was counted and measured relative to the length of the menhaden surrounding it.
- Designed to detect large bycatch species such as red drum.
- For these verification species, video estimates of bycatch should approximate the expanded subsampled estimates from the baskets.



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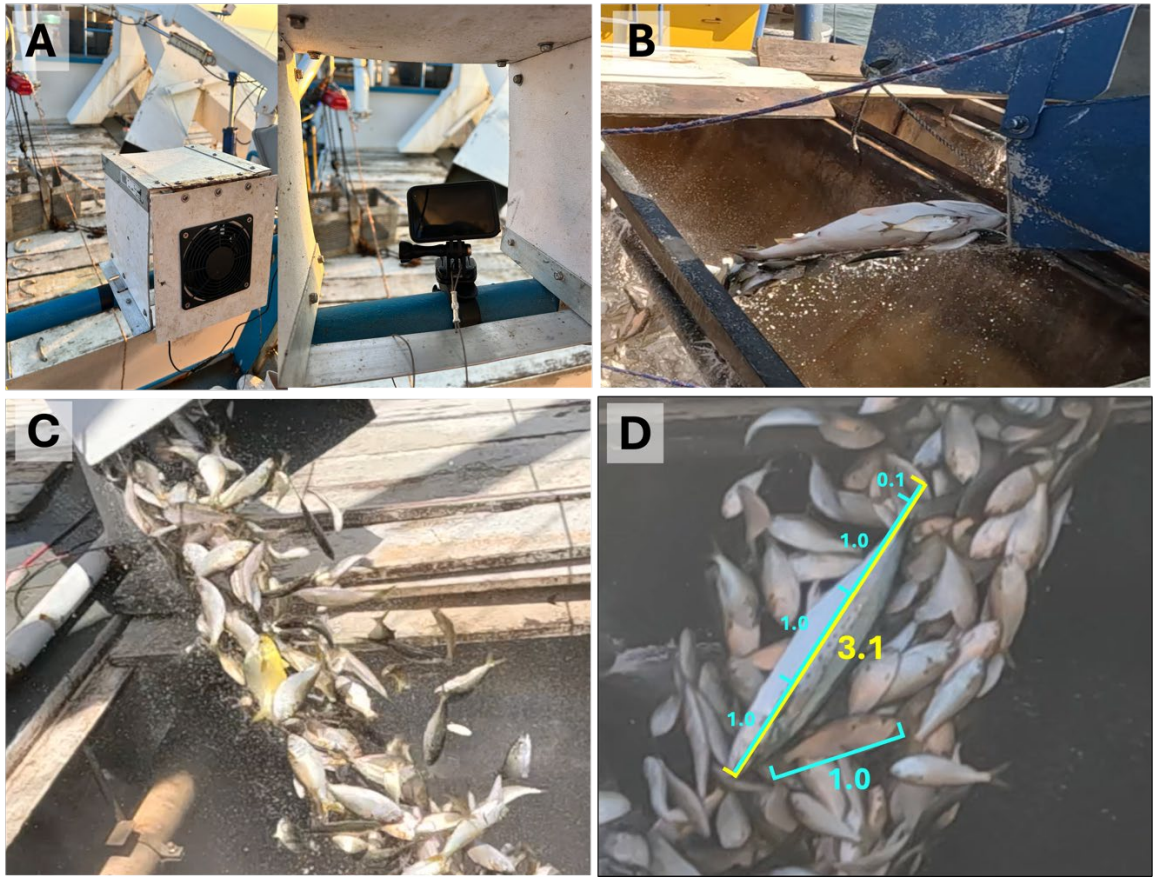
Validation and Verification – Retained Bycatch

Video analysis subject to low detectability bias



Subsampling method prone to sampling error and bias if not expanded and estimated correctly

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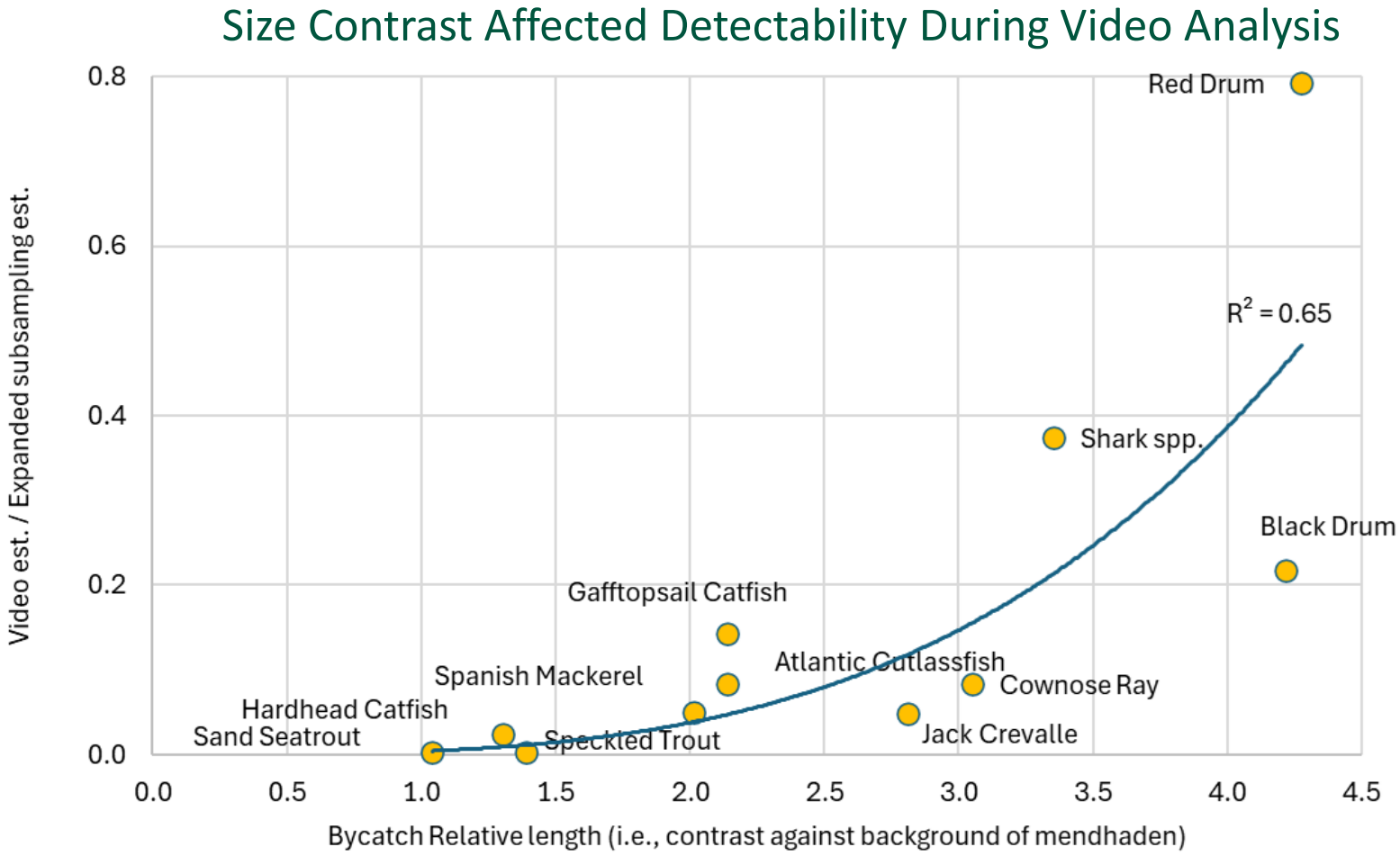
Validation and Verification – Retained Bycatch

- Right: the ratio of video averages to subsampling averages for species numerous enough to compare.
- Restricted to only sets analyzed with video (n=241)
- Closer to 1 = more closely aligned estimates.
- The ratio declines as the size of bycatch species decreased against the background of menhaden.
  - **Red drum video:** 1.24 per set (0.66-1.82)
  - **Red drum subsample:** 1.56 per set.
- No evidence from the video analyses that the subsampling estimates were biased low.



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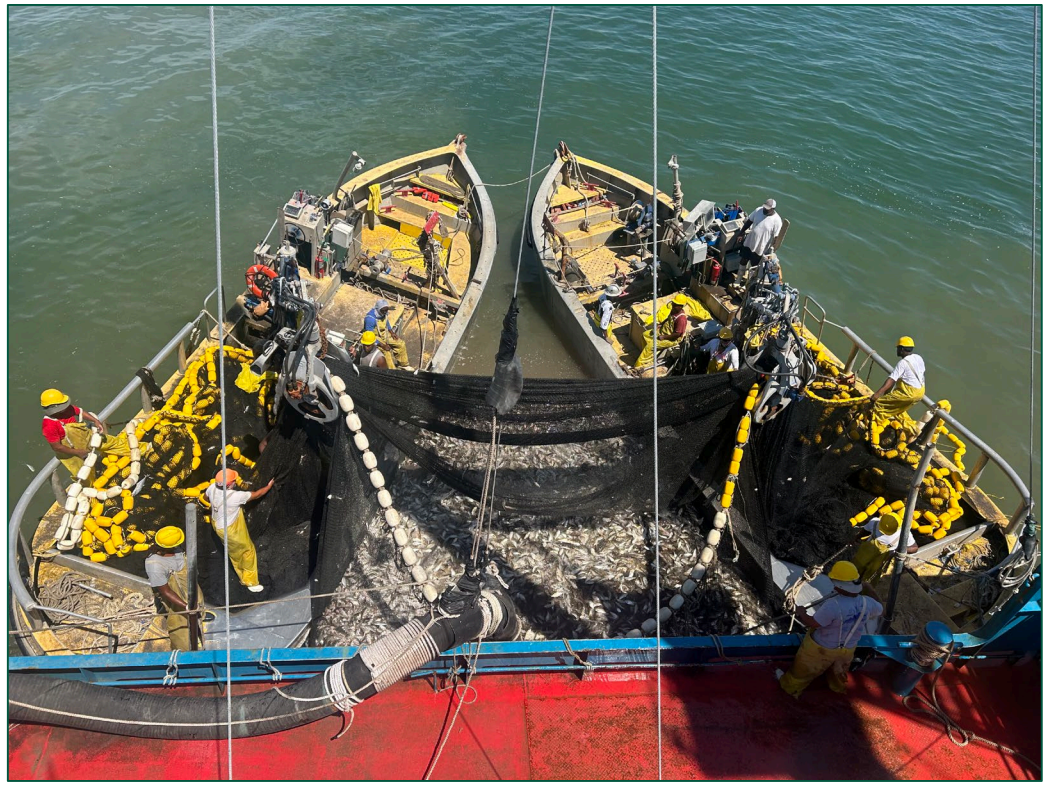
6 Bycatch Totals

Rollover Bycatch

- Rollover bycatch sampled during 415 sets, ~10% of which had no bycatch.
- In total, 43 different bycatch species were encountered. Average: 11 individuals per set (max =128).
- Fish generally healthy upon release. Fish in good or excellent condition:
  - 96% red drum
  - 88% cownose rays
  - 78% blacktip sharks
  - 67% bull sharks



Rollover Bycatch – Top 10 Constituents

- Spotted seatrout largely absent in the rollover: 3 individuals observed, total estimated catch of 114 individuals.
- Rollover total: **145,095** by number and **~1.48 million** kg by weight.

Species	Total # Individuals Observed	Max Observed per Set	Average number per set	Total Catch #Individuals	Total Weight kg
Cownose Ray	880	44	2.04 (1.57-2.52)	**26,847** (20,580-33,115)	**244,149** (185,652-302,647)
Red Drum	865	71	2.04 (1.49-2.58)	**26,752** (19,578-33,926)	**261,049** (190,905-331,193)
Black Drum	629	70	1.42 (0.82-2.02)	**18,680** (10,745-26,615)	**144,668** (83,100-206,236)
Gafftopsail Catfish	425	33	1.05 (0.85-1.25)	13,809 (11,199-16,420)	18,207 (14,571-21,842)
Crevalle Jack	353	27	0.80 (0.50-1.10)	10,525 (6,599-14,450)	117,939 (73,841-162,036)
Blacktip Shark	274	15	0.73 (0.55-0.90)	9,568 (7,261-11,874)	186,032 (139,930-232,133)
Blacktip/Spinner Shark	274	17	0.66 (0.47-0.85)	8,660 (6,198-11,123)	177,139 (125,584-228,694
Carcharhinus sp.	247	19	0.61 (0.40-0.81)	8,004 (5,303-10,705)	160,905 (105,865-215,945)
Striped Mullet	245	96	0.54 (0.06-1.02)	7,112 (791-13,433)	3,232 (340-6,123)
Hardhead Catfish	105	16	0.28 (0.15-0.40)	3,629 (1,970-5,289)	1,631 (788-2,475)
Total	**4,676**	**–**	**11.04 (0.00-29.31)**	**145,095 (129,586-160,604)**	**1,488,724 (1,337,028-1,640,419)**

Chute bycatch

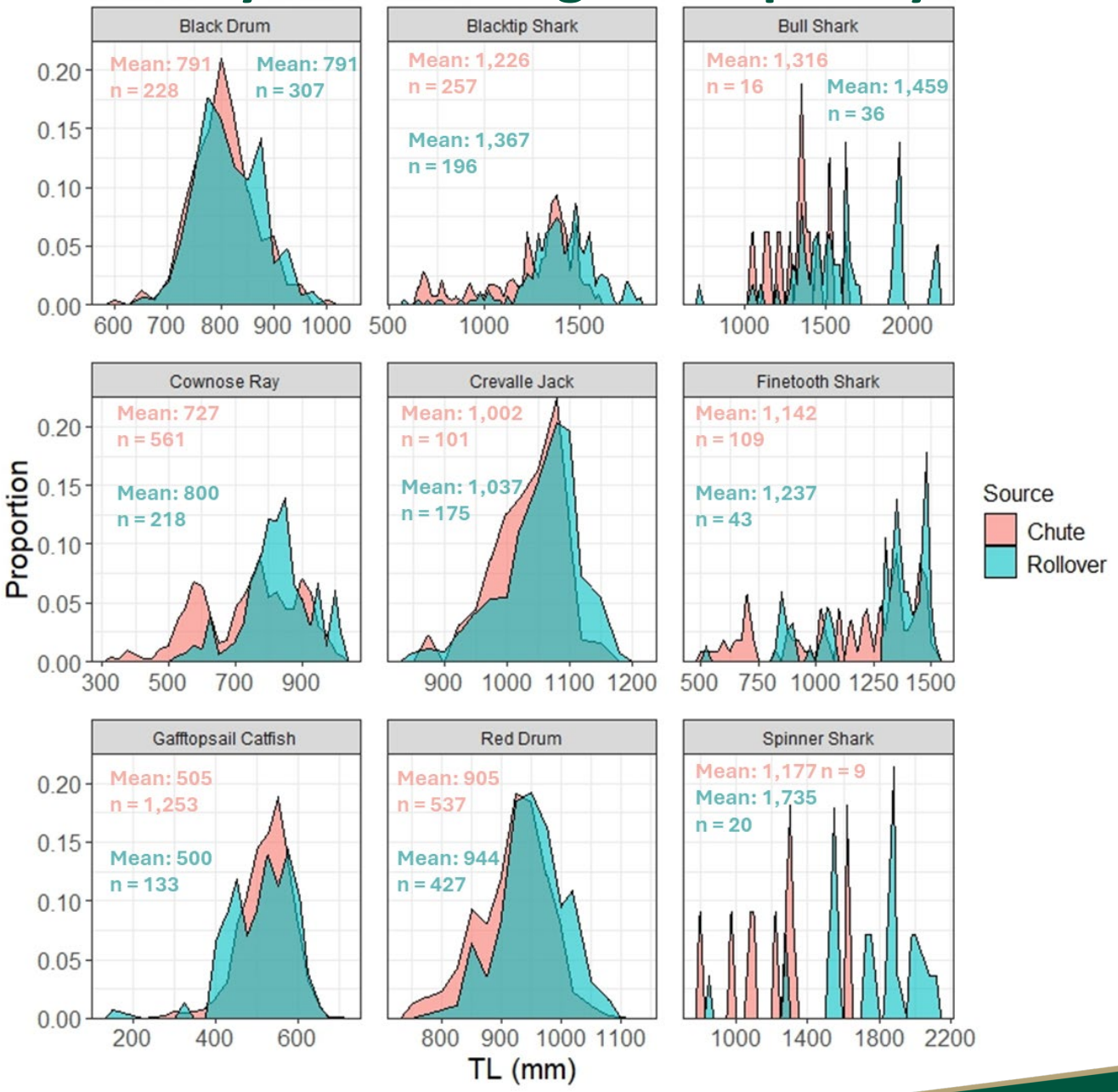
- Chute bycatch sampled during 414 sets, ~28% of which had no bycatch.
- In total, 41 different bycatch species were encountered. Average: 10.6 individuals per set (max =220).
- Fish generally in poorer condition, % assessed as good or excellent:
  - 16.6% of red drum
  - 23.4% cownose ray
  - 4.8% crevalle jack
  - 76% gafftopsail catfish

Chute Bycatch – Top 10 Constituents

- Spotted seatrout largely absent in the chute: 10 individuals observed, total estimated catch of 291 individuals.
- Chute total: **~139 thousand** by number and **~729 thousand** kg by weight.

Species	Total # Individuals Observed	Max Observed per Set	Average Number per Set	Total Catch (#)	Total Weight (kg)
Gafftopsail Catfish	1,622	130	3.79 (2.86-4.72)	**49,780** (37,534-62,025)	**64,432** (48,532-80,331)
Cownose Ray	1,041	166	2.21 (0.93-3.50)	**29,094** (12,244-45,945)	**196,909** (82,538-311,279)
Red Drum	681	128	1.36 (0.94-1.78)	**17,841** (12,315-23,367)	**150,769** (104,026-197,511)
Blacktip Shark	287	56	0.67 (0.32-1.02)	8,818 (4,226-13,409)	121,299 (57,790-184,807)
Black Drum	250	28	0.53 (0.32-0.74)	6,957 (4,247-9,667)	50,927 (31,036-70,818)
Striped Mullet	244	99	0.46 (0.08-0.84)	6,033 (997-11,069)	2,789 (458-5,120)
Crevalle Jack	167	18	0.29 (0.16-0.42)	3,816 (2,074-5,559)	40,757 (22,082-59,433)
Sand Seatrout	123	43	0.23 (0.05-0.41)	3,015 (686-5,344)	459 (99-820)
Hardhead Catfish	110	20	0.23 (0.11-0.35)	2,997 (1,458-4,537)	1,095 (522-1,668)
Finetooth Shark	114	7	0.22 (0.16-0.28)	2,888 (2,148-3,627)	29,174 (21,048-37,301)
Total	**4,954**	**–**	**10.61 (2.40-18.82)**	**139,470 (115,816-163,124)**	**729,971 (539,772-825,818)**

Released Bycatch – Length-Frequency



- Left: length frequency of common species observed in the rollover and release chute bycatch
- Fish above ~160 cm (62”) are completely excluded by the hose cage.
- Mean size of red drum: 90cm (35”) in chute and 94cm (37”) in the rollover.
- Bony fish had size ranges that completely overlapped in both the chute and rollover.
- Sharks and rays had large enough size distributions to exhibit smaller individuals in the chute than the rollover.

Retained Bycatch

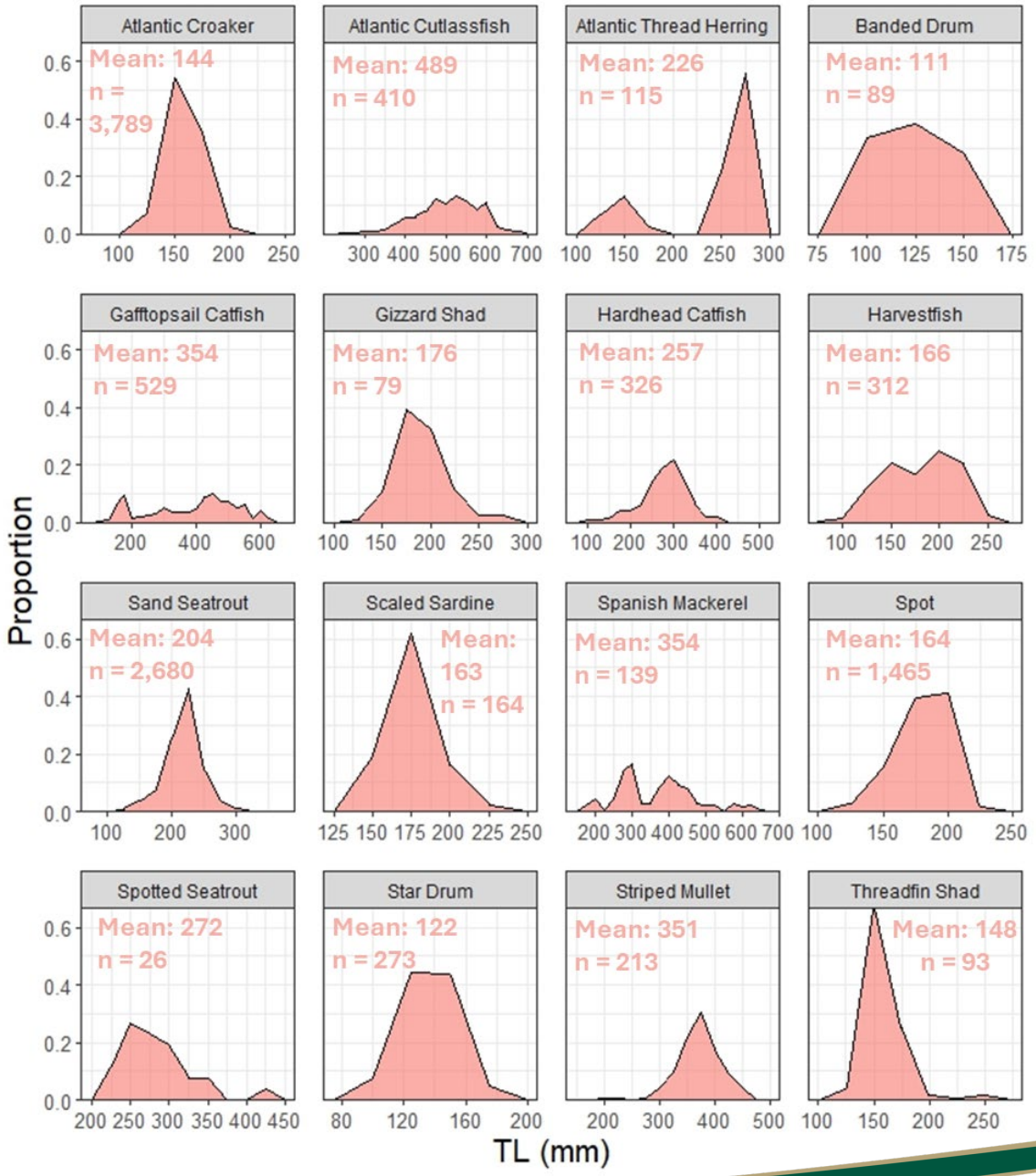
- Retained sampled during 415 sets. Bycatch was observed in the retained sampling cage in all sets sampled.
- In total 62 different bycatch species were encountered. Average: 59.8 individuals per sampling cage (max =1,678).
- Mostly smaller bycatch species mixed with menhaden.
- Atlantic croaker, sand seatrout, spot, and white shrimp comprise 84% of the estimated total retained bycatch by # and 51% by weight.

Retained Bycatch – Top 10 Constituents

- Spotted seatrout 25th most abundant species: ~240,000 estimated individuals.
- Red drum were largely absent in subsampling (50th most abundant), ~8,000 estimated individuals.
- Retained total: **~145 million** by number and **~10 million** kg by weight.

Species	Mean Observed Per Set	Total Catch by Number	Total Weight Kg
Atlantic Croaker	6,376 (4,496-8,929)	**80,592,690** (57,477,689-110,644,805)	2,484,620 (1,557,623-3,411,616)
Sand Seatrout	1,741 (1,411-2,152)	**24,750,238** (19,411,626-31,524,147)	1,949,187 (1,414,735-2,483,639)
Spot	951 (687-1,291)	**11,685,469** (8,549,694-15,609,587)	680,720 (451,795-909,646)
White Shrimp	519 (388-665)	5,699,563 (4,112,730-7,449,761)	156,794 (106,021-207,567)
Hardhead Catfish	276 (108-742)	3,802,183 (1,527,034-9,808,642)	690,749 (0-1,783,403)
Gafftopsail Catfish	227 (187-275)	2,985,451 (2,393,299-3,702,681)	1,737,206 (1,298,779-2,175,633)
Atlantic Cutlassfish	166 (119-221)	2,204,329 (1,484,234-3,067,746)	158,401 (95,946-220,856)
Harvestfish	150 (99-240)	1,903,687 (1,224,533-3,021,111)	175,066 (71,779-278,353)
Striped Mullet	146 (43-323)	1,843,220 (491,670-4,348,934)	727,743 (0-1,717,781)
Star Drum	120 (83-178)	1,701,593 (1,115,808-2,581,706)	37,292 (17,898-56,685)
Spotted Seatrout	15 (9-24)	240,368 (119,953-413,098)	45,901 (11,461-80,341)
Red Drum	1 (0-3)	8,354 (0-22,323)	69,754 (0-186,535)
Total	**11,291 (0-31,911,593)**	**145,519,692 (145,519,688-145,519,696)**	**10,326,782 (7,970,802-12,682,763)**

Retained Bycatch – Length Frequency



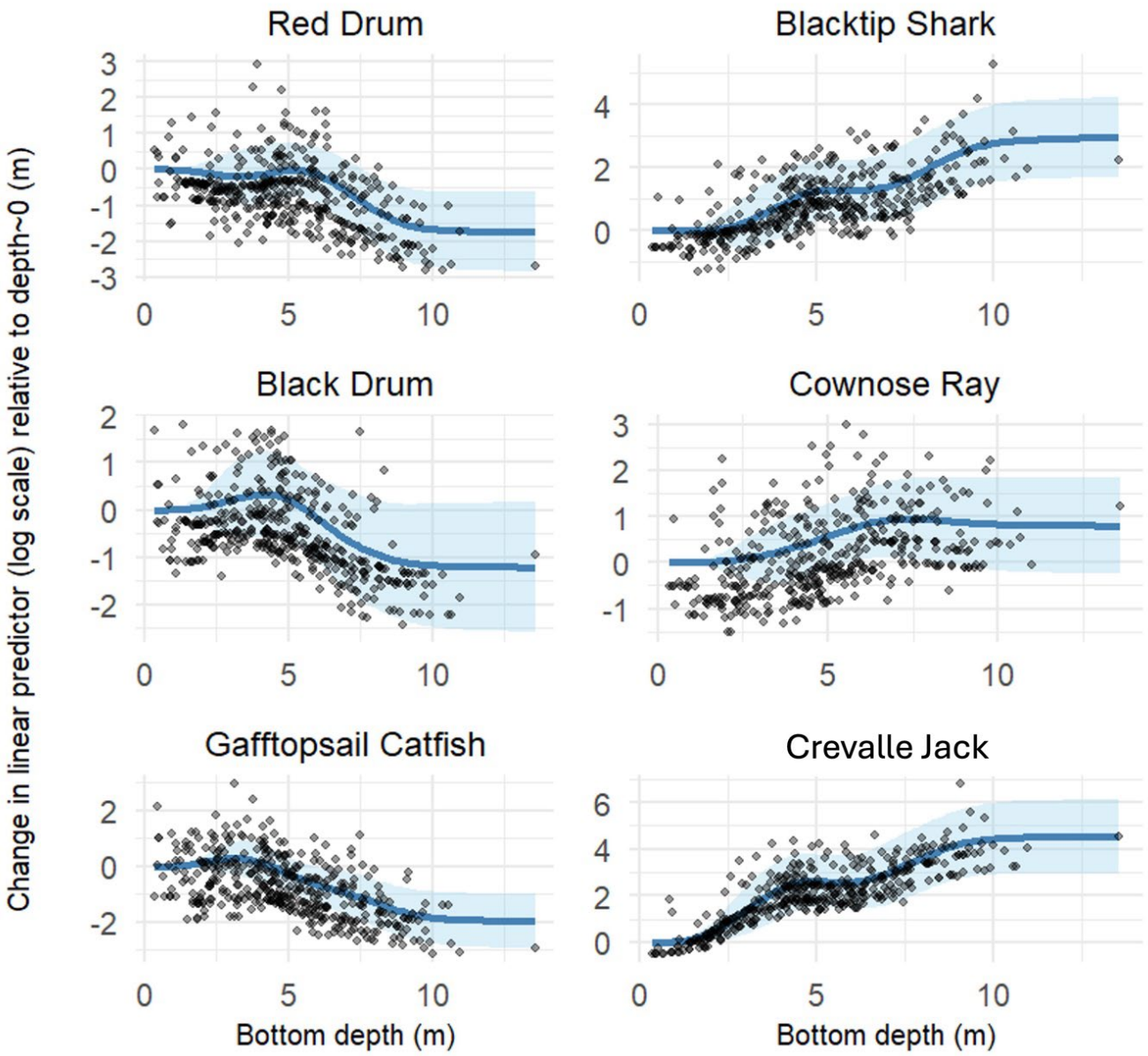
- **Left:** Length frequency distribution of total length (mm) of 16 species observed in the retained bycatch.
- The length frequency has been weighted for individuals not measured within each set.
- Mean length of spotted seatrout in the retained: 272 mm (~10”)
- Mean length of Atlantic croaker in the retained: 144 mm (~5”)

Total Bycatch (Released + Retained)

Total fishery bycatch estimates for the 2024 season by total number (N), total weight (W) and total landings (L) for each bycatch component and for overall bycatch. The proportion of retained bycatch in the landings as calculated by the weighted mean percent bycatch in each subsample then stratified by plant and month yielded a similar bycatch estimate of 2.62% (2.15 - 3.09).

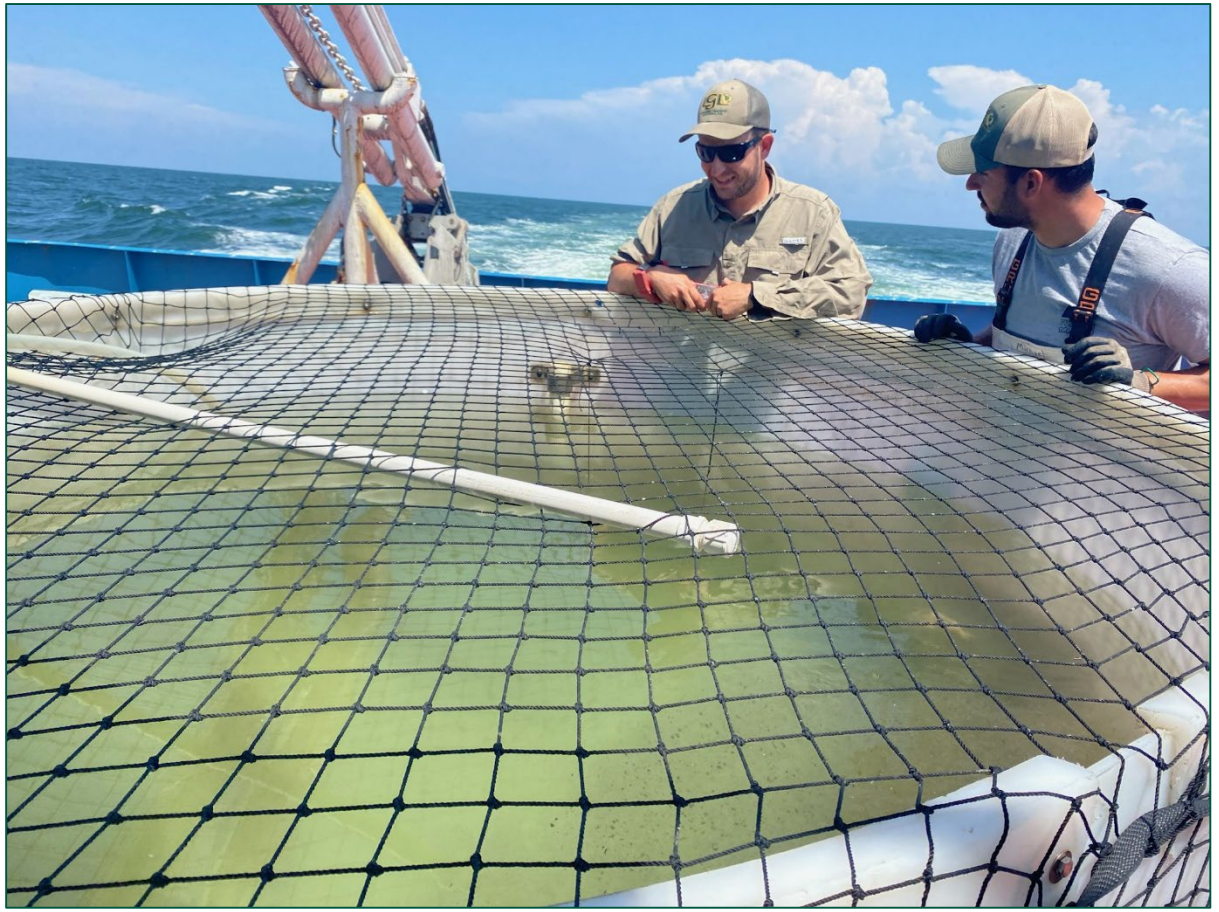
Component	Number of individuals	Weight (kg)	%N	%W	% L
Roll	145,095	1,488,724	0.005%	0.43%	0.43%
Chute	139,470	729,971	0.004%	0.21%	0.21%
Retained	145,519,692	10,326,782	4.57%	2.96%	2.98%
Total bycatch	**145,804,257**	**12,545,477**	**4.57%**	**3.59%**	**3.62%**
Retained bycatch and menhaden catch (i.e. Landings; kg)		346,925,262			
All Bycatch and menhaden catch (kg)		349,143,957			
Menhaden catch (individuals)	3,041,916,145				
All Bycatch and menhaden catch (individuals)	3,187,720,402				

Model Predictions Showing the Effect of Depth



- Left: GAMM predictions showing the effect of depth (meters) on the change in the #bycatch individuals in a set (six species).
- Each panel displays the estimated smooth function (solid blue line) with 95% confidence bands.

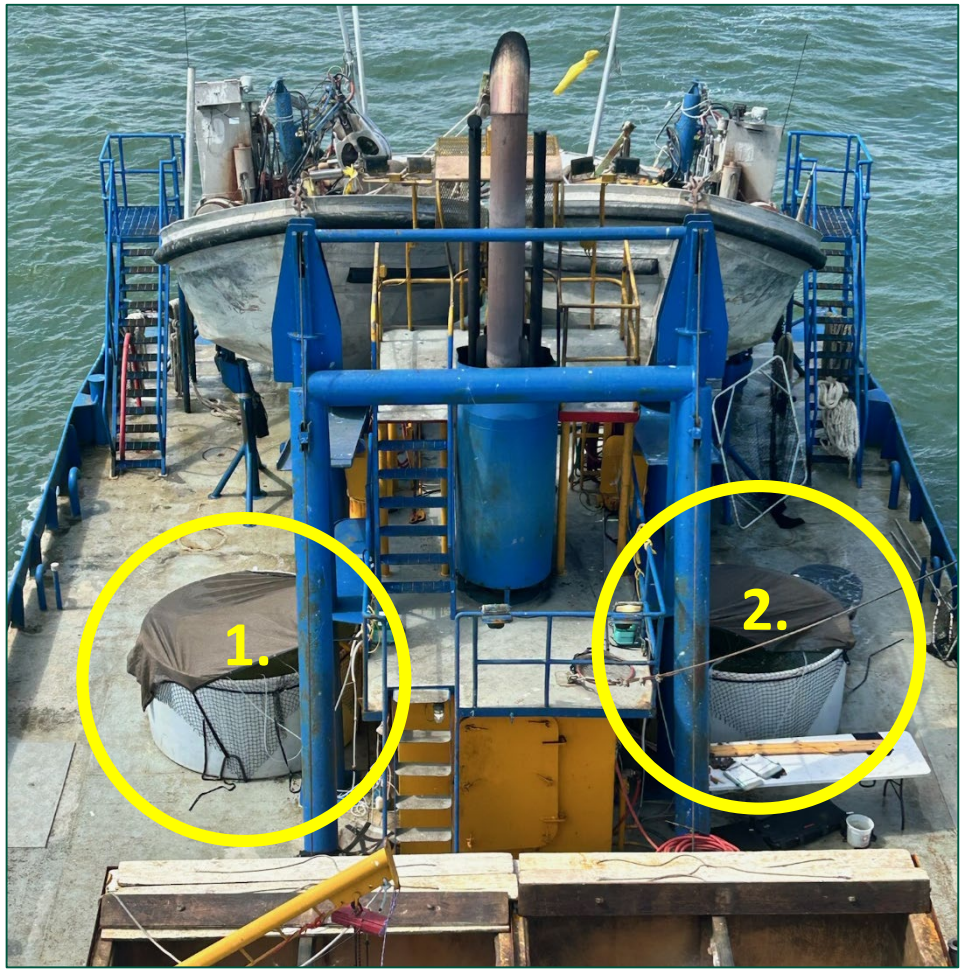
6 Survival Study



Survival Study

Objective 3: Estimate near-term mortality rates ("fate") of released bycatch species (chute & rollover).

1. Confinement study with two 1,200-gallon tanks onboard, 24-h period.
2. Species: red drum, black drum and gafftopsail catfish.
3. Tanks were shaded and flow-through to minimize stress and best mimic ambient conditions.
4. Sea surface conditions were checked periodically, and additional aeration and flow was added as needed.
5. Stocking density: 1lb fish per 10 gallons. Equivalent to 5-10 adult drum depending on size/species.
6. DO, Temperature, Salinity loggers in tanks for the duration of experiments.



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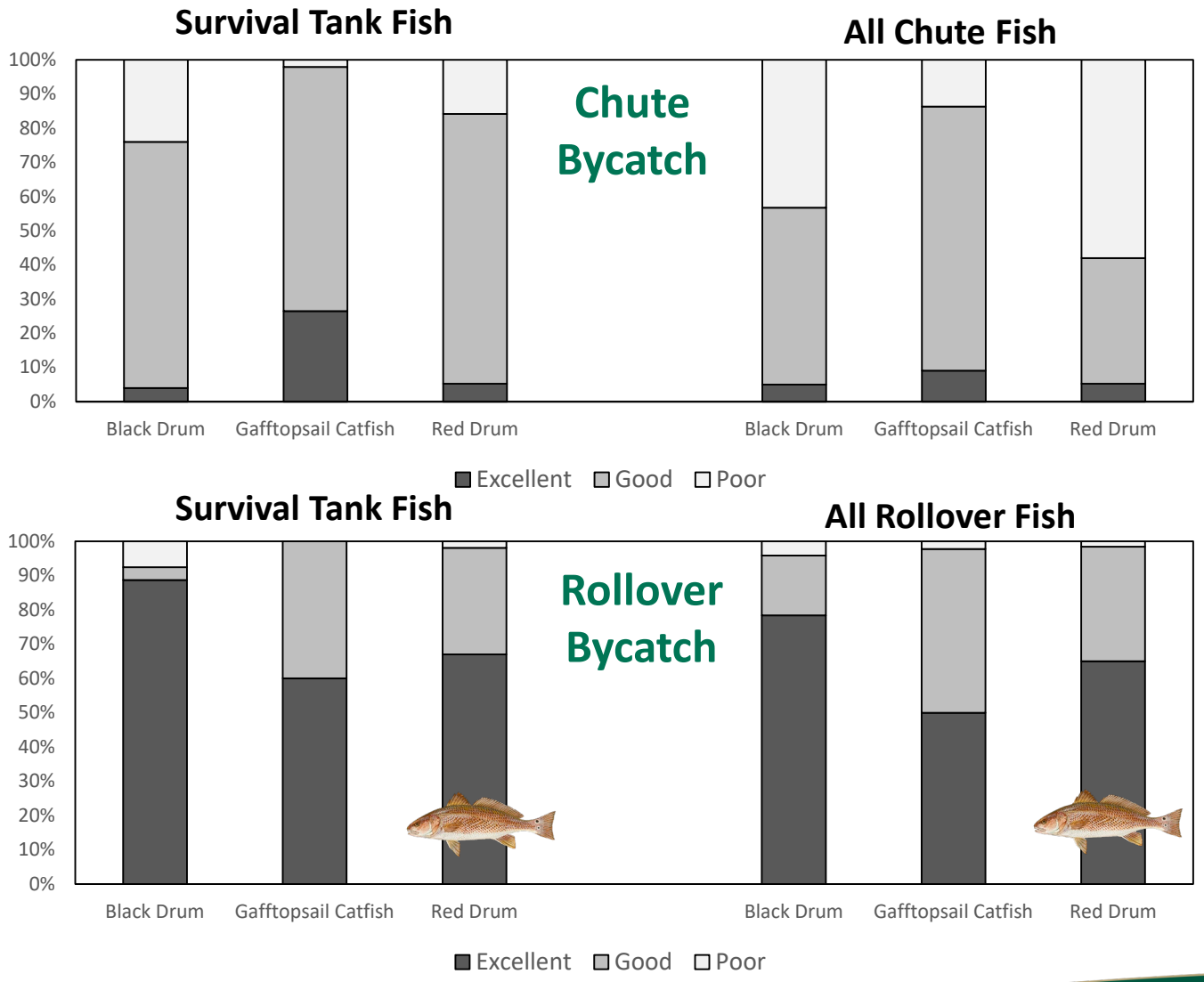
Survival Study

1. Fish from the rollover and chute were double tagged and quickly transferred to the holding tanks.
2. Only fish in Excellent, Good, or Poor condition were tested.
3. Fish were measured, weighed and fate determined at the end of the 24-hr period.
4. Fish that survived were released double tagged with dart tags.

Survival Study – Representativeness

1. First available bycatch selected until stocking density was reached.
2. Ensured the condition of holding study fish was representative of overall bycatch condition.
3. Right: %Condition scores for survival fish compared to all chute and rollover bycatch.



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Survival Study – Condition Scores

Number of sampled Fish Across Condition Categories

Source	Species	Number of individuals assessed	%Excellent (n)	%Good/Fair (n)	%Poor (n)	%Mortality (n)
Rollover	Red Drum	666	70.4% (469)	25.5% (170)	1.1% (7)	3.0% (20)
	Black Drum	462	80.7% (373)	14.3% (66)	2.8% (13)	2.2% (10)
	Gafftopsail Catfish	186	45.7% (85)	42.5% (79)	1.6% (3)	10.2% (19)
Chute	Red Drum	643	2.2% (14)	15.4% (99)	24.3% (156)	58.2% (374)
	Black Drum	245	2.9% (7)	29.8% (73)	24.9% (62)	42.4% (104)
	Gafftopsail Catfish	1275	8.7% (111)	74.2% (946)	13.1% (167)	4.0% (51)

Survival Study – following 24-h holding study estimates

- Holding study: 157 red drum, 88 black drum, 66 gafftopsail catfish
- Survival estimates account for individuals assigned mortalities
- Present two analysis methods:
  1. Survival rate **A** includes all fish held in survival tank
  2. Survival rate **B** excludes fish from 4 experiments that artificially experienced hypoxia >1 hour

Take home:

- Rollover survival is high:
  - ~83% for red drum
  - ~87% for black drum
  - ~73% for gafftopsail catfish
- Chute survival was low:
  - ~2% for red drum
  - ~2% for black drum
  - ~40% for gafftopsail catfish

Final % survival after accounting for assigned mortality scores

Source	Species	Survival Rate (%) [A]	Survival Rate (%) [B]
Rollover	Red Drum	83.91% (77.1 – 89.0)	82.76% (75.0 – 88.7)
	Black Drum	87.82% (77.5 – 94.1)	91.93% (81.7 – 96.5)
	Gafftopsail Catfish	73.46% (43.3 – 87.7)	73.46% (43.3 – 87.7)
Chute	Red Drum	2.1% (0.0 – 10.4)	2.47% (0.0 – 12.0)
	Black Drum	2.19% (0.0 – 11.3)	0% (0.0 – 8.5)
	Gafftopsail Catfish	40.9% (28.0 – 54.5)	40.51% (26.6 – 55.5)

Survival Estimate – All Species

The estimated survival (number and weight) of **red drum, black drum, and gafftopsail catfish** released in the fishery (rollover and chute).

Source	Total Estimated Catch	Total Estimated Weight kg	Total Released Alive	Total Weight Released Alive kg
Red Drum 	**44,593 (35,537-53,648)**	**411,818 (327,528-496,107)**	**22,805 (16,516-29,093)**	**222,061 (160,735-283,388)**
Black drum 	**25,637 (17,252-34,023)**	**195,595 (130,895-260,295)**	**16,551 (9,401-23,701)**	**128,116 (72,657-183,577)**
Gafftopsail 	**63,589 (51,068-76,110)**	**82,639 (66,329-98,948)**	**29,608 (20,910-38,306)**	**38,568 (247,230-49,905)**

Red drum released from the holding tanks

Survival Study – RAMP

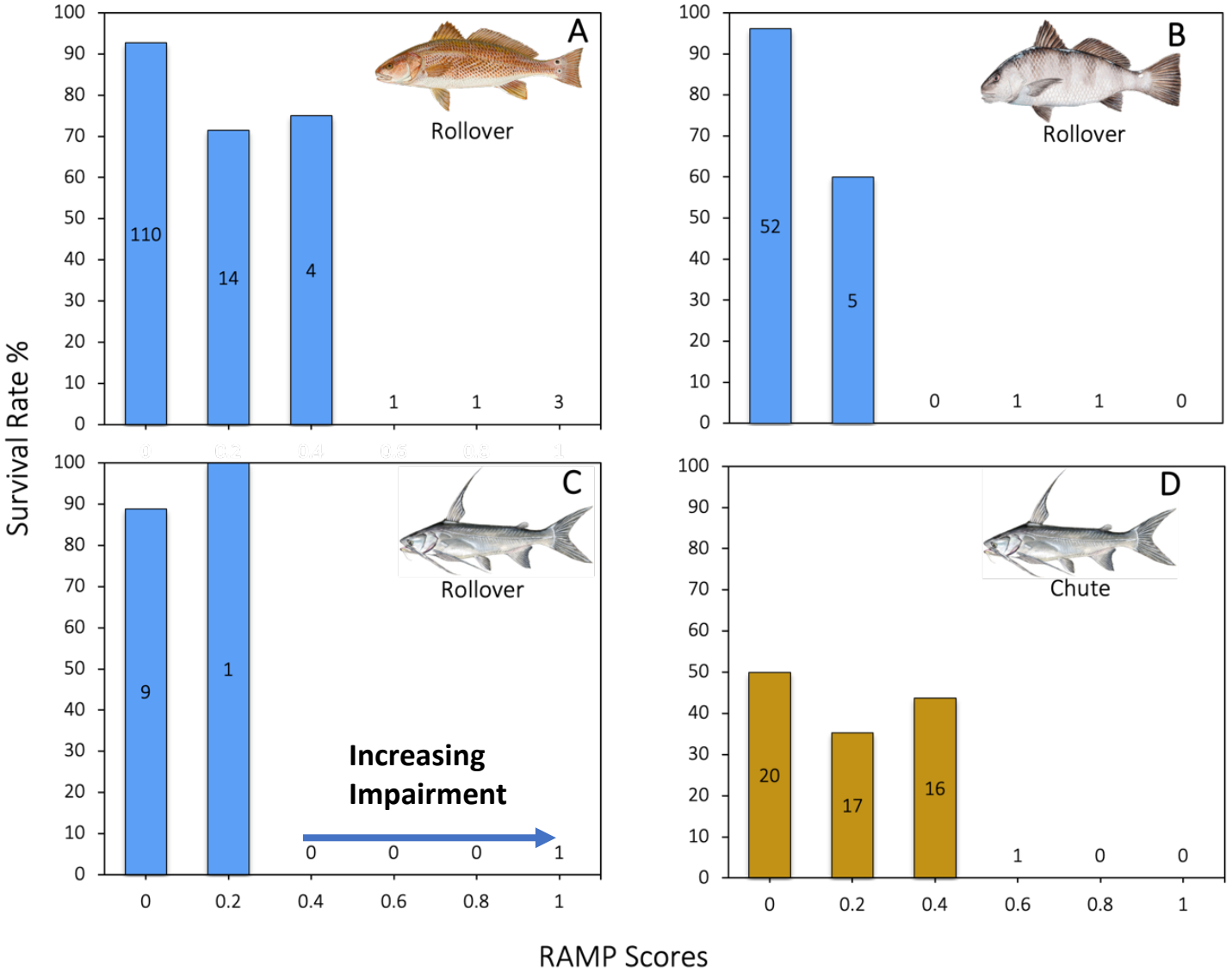
Objective 4: Record "vitality" of bycatch via condition scores and by assessing RAMP scores

1. Reflex Action Mortality Predictors (RAMP): ~5 reflexes present in vigorous individuals tested in survival study.
2. Established method used in other purse seine fisheries (Raby et al. 2015)
3. Rapid ~10 second assessment of reflexes:

Reflex	Description
HEAD COMPLEX	Regular pattern of ventilation (out of water).
VOR (vestibular ocular response)	Fish turned on its side lengthwise. An unimpaired VOR is characterized by the fish's eye rolling to maintain level pitch, tracking the handler.
BODY FLEX	Tested by holding the fish out of water using two hands wrapped around the middle of the body. If the fish actively attempts to struggle free it is characterized as unimpaired.
TAIL GRAB	An unimpaired response is characterized by the fish attempting to burst-swim immediately upon contact with the caudal fin.
ORIENTATION	Each fish is placed upside-down just below the surface: an unimpaired orientation reflex occurs if the fish rights itself within ~3 s.

Red drum in holding tank.

Survival Study – RAMP



Survival rates within each assigned RAMP score by species and bycatch component.

- The numbers by each bar represent the total number of fish assigned each RAMP score.
- Higher RAMP scores denote fish with more extreme levels of reflex impairment.
- Red drum and black drum from the chute bycatch, where overall survival was exceedingly low irrespective of the assigned RAMP scores, are not shown.

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