RUTGERS
New Jersey Agricultural Experiment Station

Estimating and Reducing the Discard Mortality Rate of Black Sea Bass in Offshore Recreational Rod-and-Reel Fisheries

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MAFMC Meeting – June 5-7, 2018 – Philadelphia, PA

Anderson Cabot Center for Ocean Life at the New England Aquarium

UMASS BOSTON

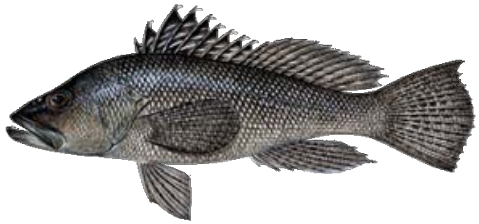
MarineFisheries Commonwealth of Massachusetts

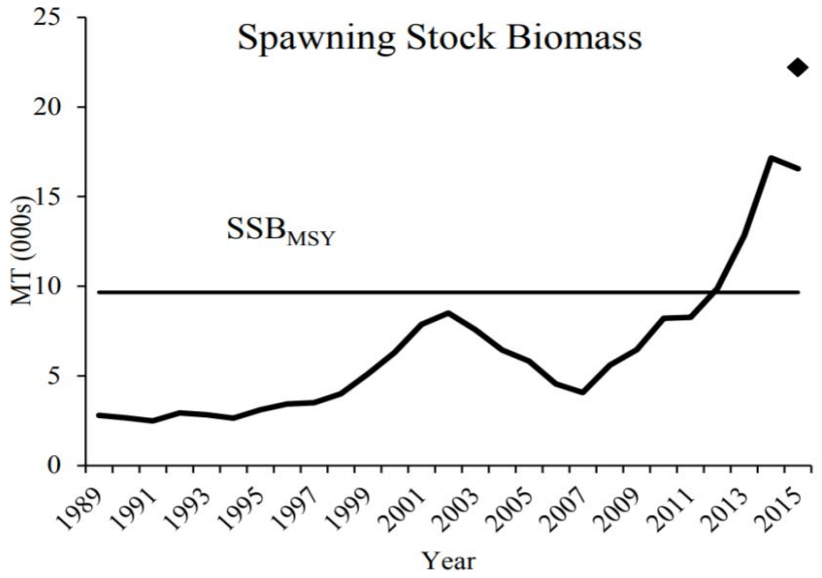
MID-ATLANTIC FISHERY MANAGEMENT COUNCIL

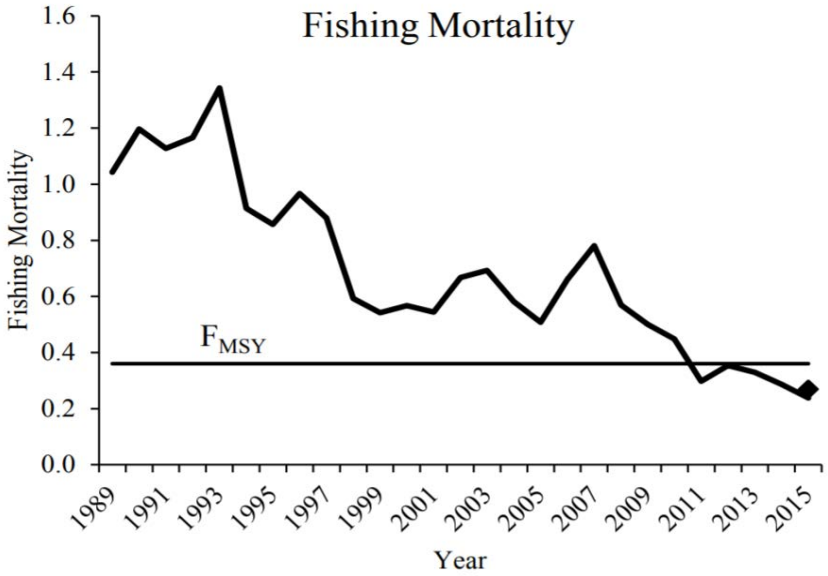
MAFMC 2016-2017
Collaborative Research Program

Black Sea Bass

- The North Atlantic stock of black sea bass is not overfished (SSB = 22,176 mt) and overfishing is not occurring (F_{4-7} = 0.27).



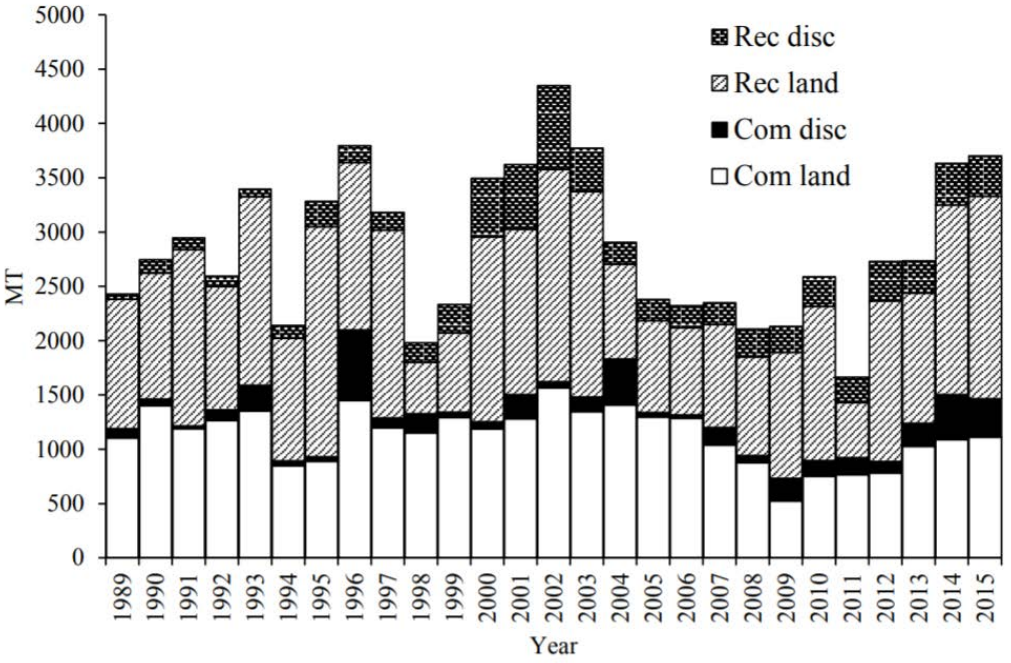


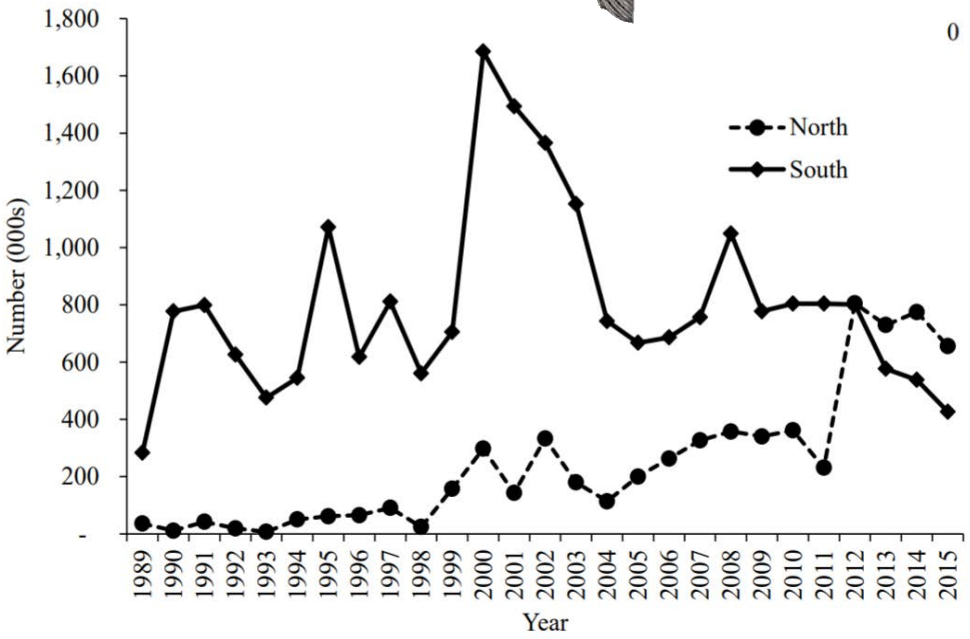


NOAA NEFSC (2017)

Recreational Fishery

- The recreational rod-and-reel fishery harvests a significant proportion of the total catch.
  - 2,235 mt in 2015 (61% of total catch)



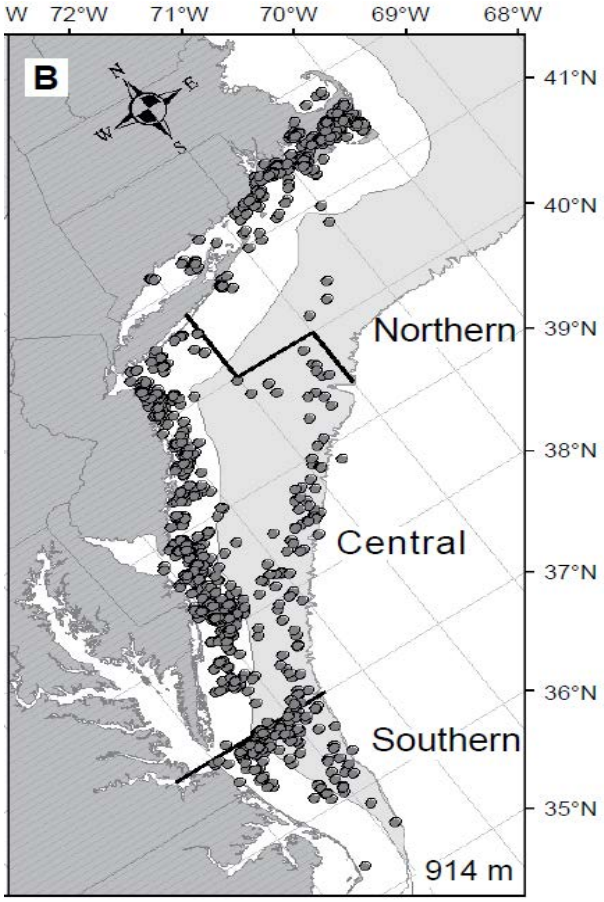


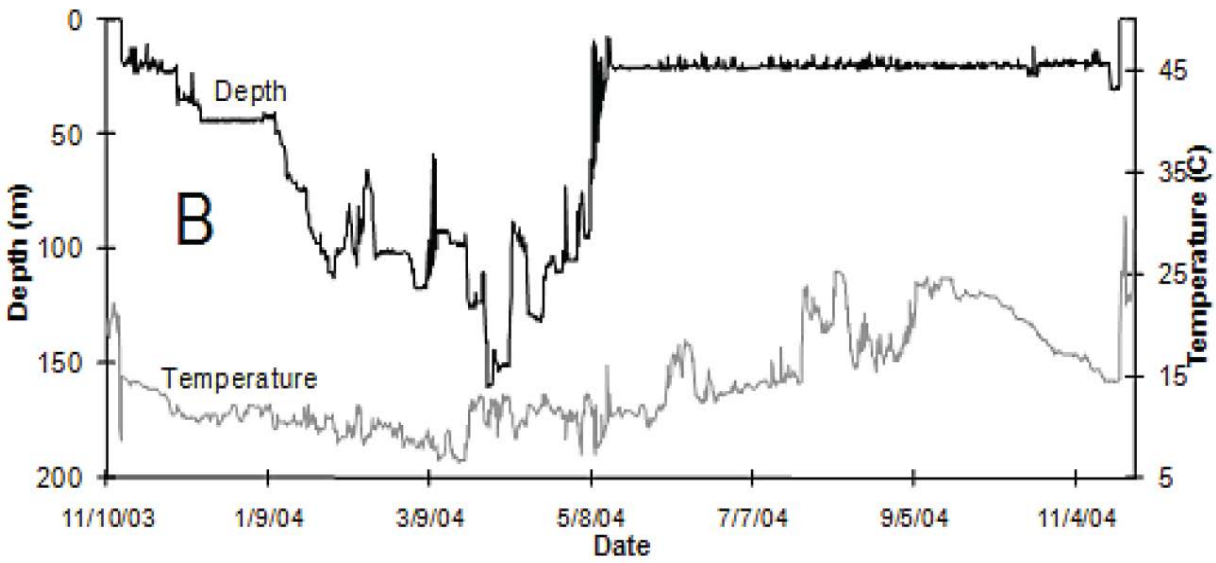
- 15 % discard mortality rate estimate currently assumed for the recreational fishery.
  - 2015: 1.08 million fish, 317 mt

NOAA NEFSC (2017)

Recreational Fishery

- Most recreational fishing effort occurs from July through October.
- Black sea bass migrate inshore-offshore seasonally and anglers also catch black sea bass offshore as the target species or bycatch.

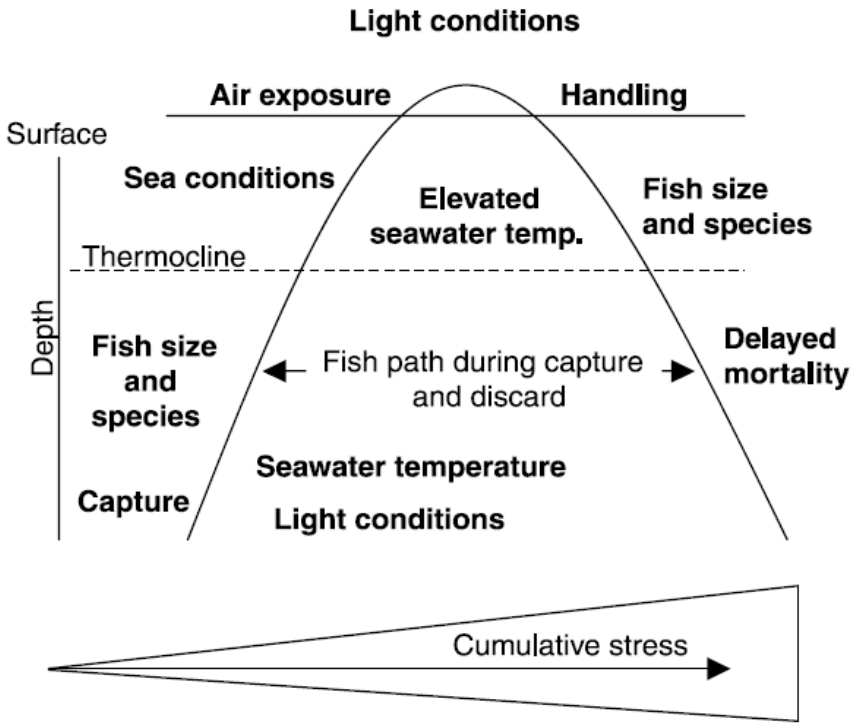




Moser and Shepherd (2009)

Discard Mortality

- Many factors during the capture, handling, and release processes can impact discard mortality.
- Multiple studies have estimated black sea bass discard mortality:
  - 5% discard mortality in 20-40 ft
    (Bugley and Shepherd, 1991)
  - 19% discard mortality in 65-115 ft
    (Rudershausen et al., 2014)
  - 39% discard mortality in 140-180 ft
    (Collins et al., 1999)



Davis (2002)

Project Objectives

(1) Estimate the discard mortality rate of black sea bass following capture with rod-and-reel fishing gear at a deepwater offshore shipwreck in the Mid-Atlantic.

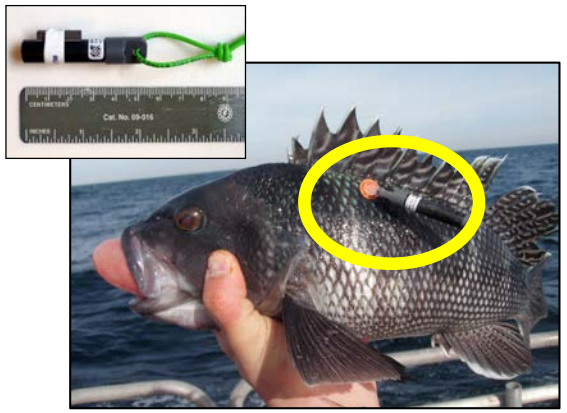
(2) Identify the capture-related factors that influence black sea bass discard mortality.

(3) Utilize our results to establish “best practice” guidelines for reducing the mortality of discarded black sea bass.

(4) Conduct a broad outreach effort to disseminate project results to invested stakeholder groups.

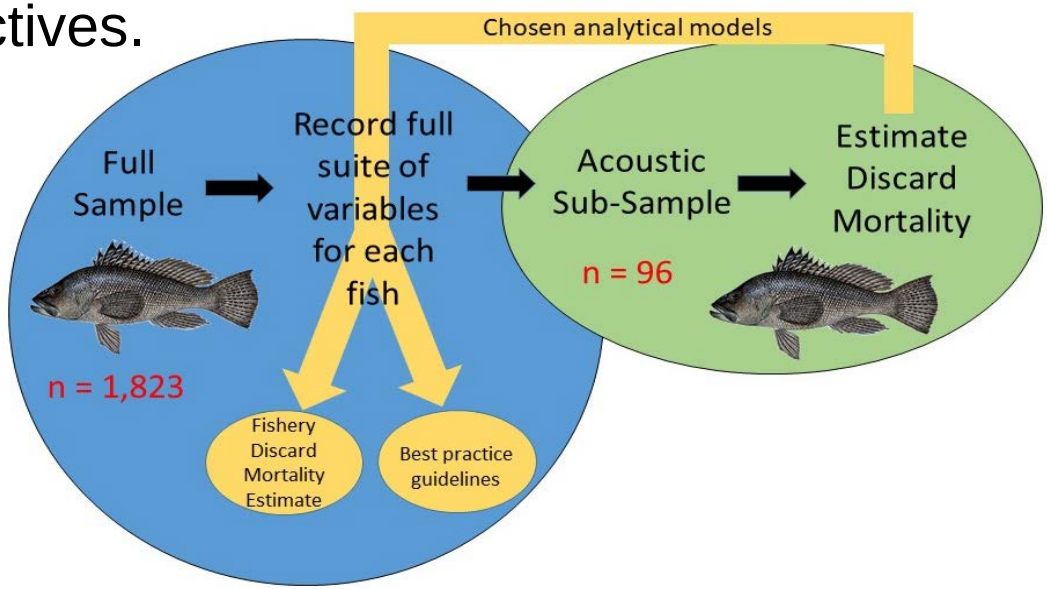
Methods

- This project built off previous studies completed in New England:
  - Analytical methods: Benoît et al. (2015), ICES JMS 72: 1834-1847
  - Atlantic cod: Capizzano et al. (2016), ICES JMS 73: 2342-2355
  - Little, winter, and barndoor skates: Knotek et al. (2018), Fish Res 198: 50-62
  - Haddock: Capizzano et al. (*In Review*)
  - Cusk: Capizzano et al. (*In Prep*)
  - Thorny skates: Knotek et al. (*In Prep*)
- Utilized a combined approach of acoustic telemetry and conditional reasoning to meet our objectives.



Vemco V9P-2H

Vemco VR2W

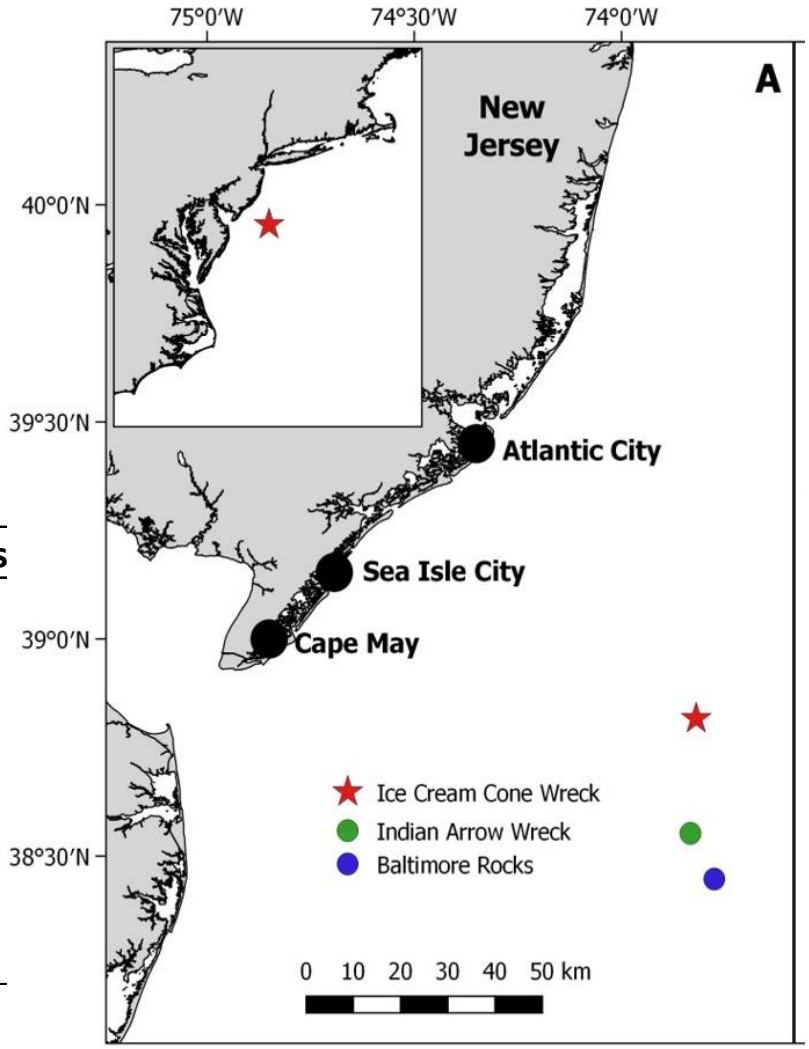


Tagging Trips

F/V Susan Hudson
Sea Isle City, NJ

F/V Porgy IV
Cape May, NJ

Date	Location	Depth (ft)	Anglers	Acoustic	T-Bars	Observations
12/5/16	ICCW	148	7	20	172	197
12/13/16	ICCW	148	7	24	168	202
12/21/16	ICCW	148	7	24	73	98
1/17/17	ICCW	148	10	18	37	55
2/3/17	ICCW	148	7	10	4	14
2/18/18	BR	220	14	0	316	362
2/24/17	BR	220	14	0	427	440
3/21/17	IA	190	13	0	270	455
		Total	**50**	**96**	**1467**	**1823**



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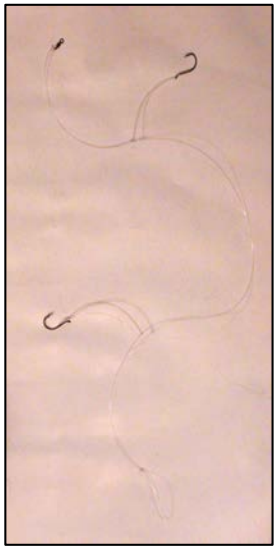
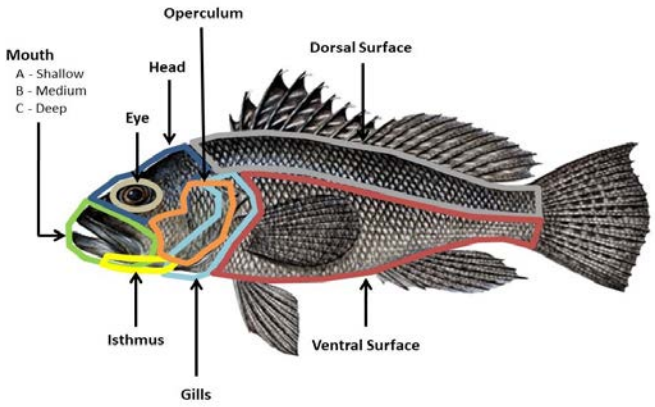


- Online survey (n=282 anglers)
- “High-Low rig”
- 5/0 Mustad Octopus hooks, 50 lb test

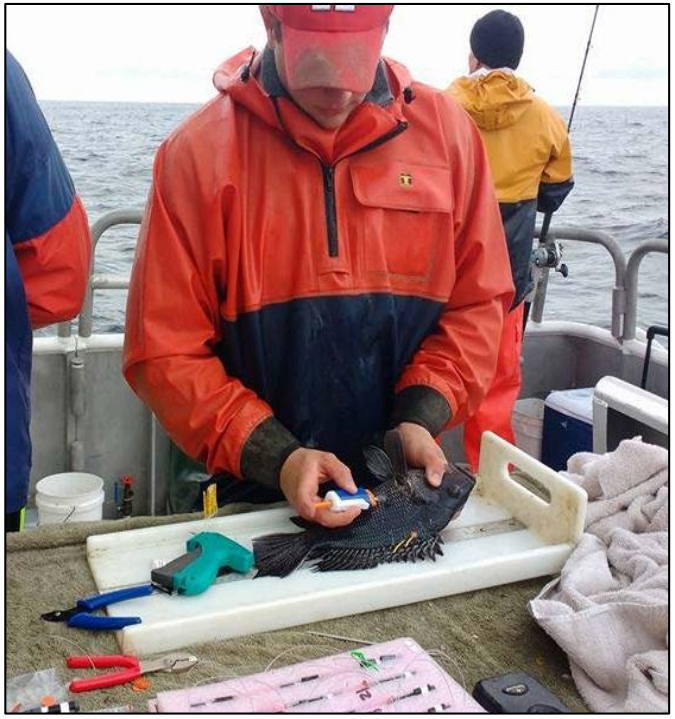


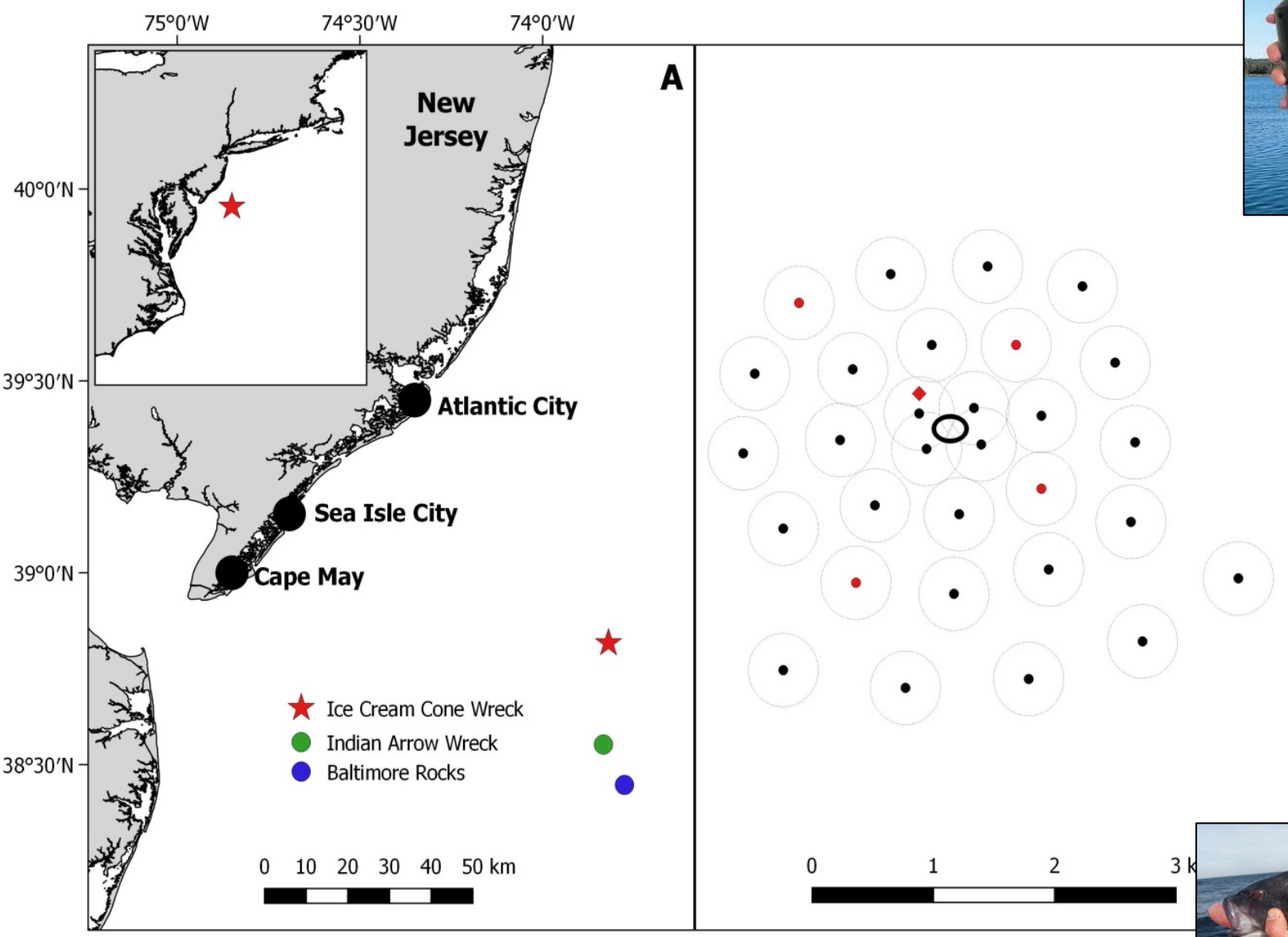
Variable	Description
Technical	
Capture depth	Water depth at the location of capture
Angler experience	Angler experience score as quantified by questionnaire
Fight time	Elapsed time from when a fish was hooked to when it reached the surface
Unhooking time	Elapsed time from surfacing until the fish was unhooked
Handling time	Elapsed time from surfacing until fish was released (time out of water)
Hook location	Location where the fish was hooked on the body
Hook removal method	Manner in which the fish was unhooked
Angler hand	Fish was unhooked by hand by the capturing angler
Mate hand	Fish was unhooked by hand by a fishing vessel mate/deckhand
Biological	
Total length	Length from the tip of the snout to the tip of the center of the tail
Air temperature	On deck temperature at the time of capture
Surface temperature	Water temperature at the surface
Bottom temperature	Water temperature at the bottom/wreck
Delta temperature	Difference between surface and bottom water temperatures
Release behavior	Observed behavior exhibited by a fish immediately upon release
Floating	Fish floated on surface
Swam down	Fish swam down towards bottom
Erratic swimming	Fish swam erratically and appeared disoriented
Sinking	Fish sank without swimming
Injury score	
Present (1)	Hook or other wound present >2 cm in length
Absent (0)	Injury limited to hook entry/exit
Barotrauma score	
Exopthalmia	
Present (1)	Eyes bulging from orbitals, bubbles may be present in eyes
Absent (0)	Eyes not bulging from orbitals
Stomach eversion	
0	Stomach not everted
1	Stomach everted but remains within mouth cavity
2	Stomach everted but is protruding from the mouth
3	Stomach everted and ruptured

Swim Bladder Venting

- Collins et al. (1999) found that venting reduced discard mortality from 39% to 0% – 15% in 140-180 ft off South Carolina.
  - Small sample sizes, monitored fish in cages for 24 h, different predators and environmental conditions
- Use of swim bladder venting versus weighted release devices.

VENTAFISH
Fish Venting Tool
http://www.ventafish.com/

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New Jersey
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Sea Isle City
Cape May
Ice Cream Cone Wreck
Indian Arrow Wreck
Baltimore Rocks
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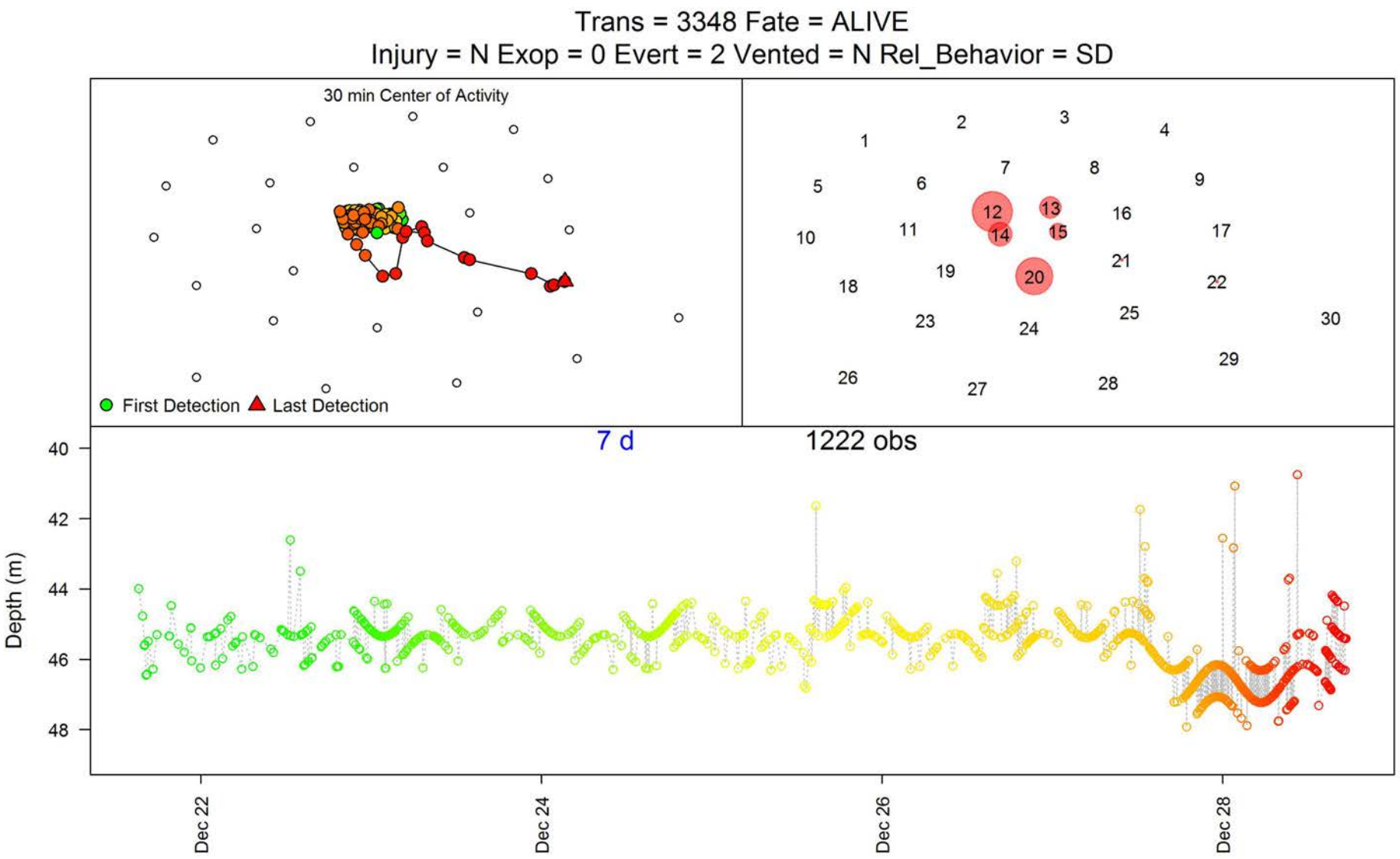
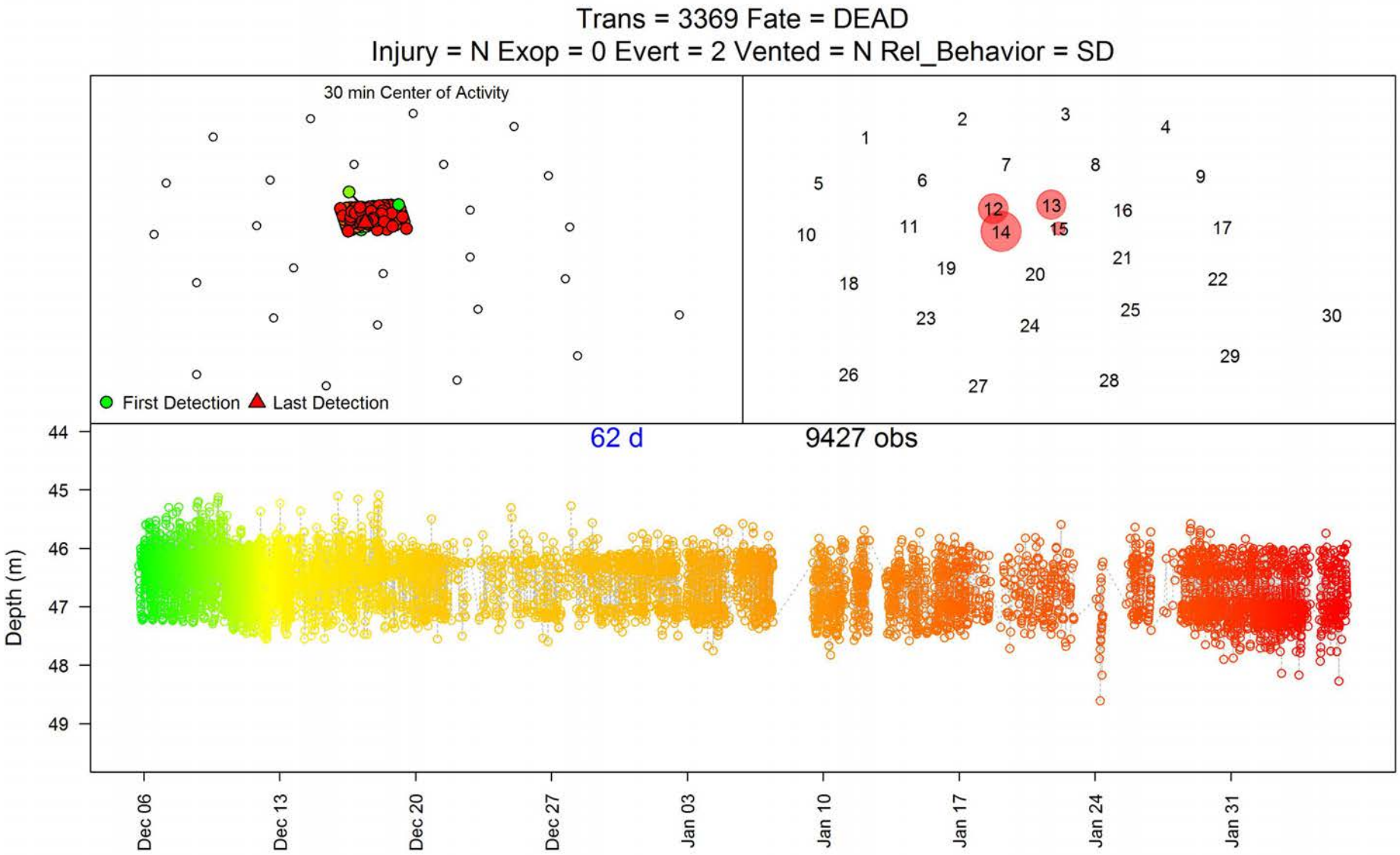
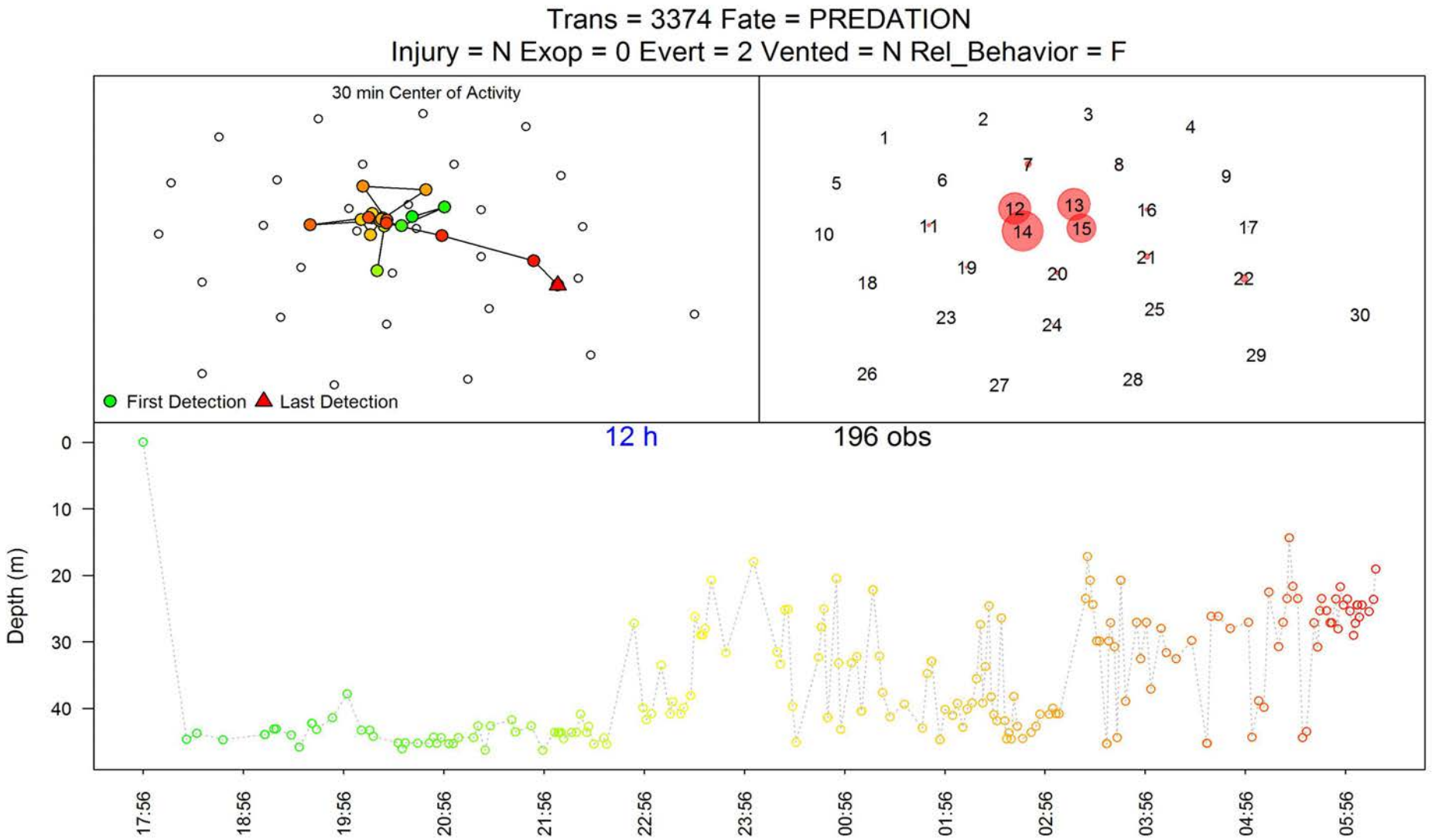


Positive Controls: n = 7 (3 recaptures, 4 ACT network detections)



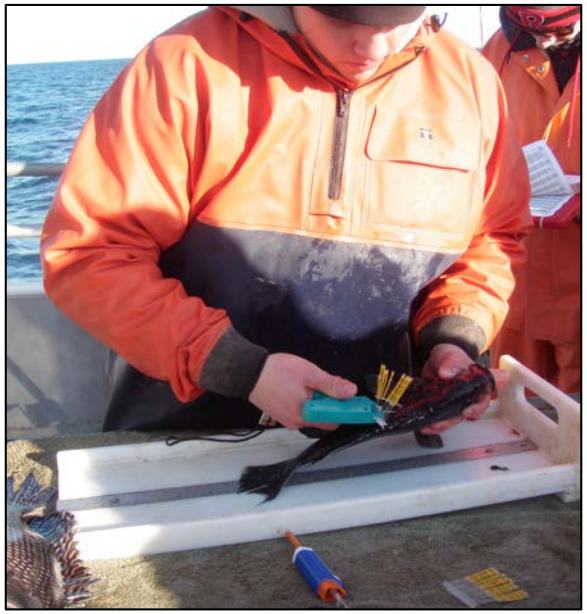
Negative Controls: n = 2+



Predation events were identified in 9 of 96 fish tagged with acoustic transmitters.

Tagging Results

- Total of 1,823 black sea bass were sampled
  - mean = 13.4 ± 2.8 in, range = 5.4 – 24.1 in
  - 321 “double-header” catch events
- 1,713 fish released: 957 vented, 756 unvented
- 1,467 fish tagged with conventional t-bar tags
- 96 fish tagged with acoustic transmitters
  - (48 vented, 48 unvented)
- 92.2% hooked shallow or medium mouth
- 304 (17%) black sea bass incurred injuries (wounds > 2 cm)
  - Mostly due to hooking trauma



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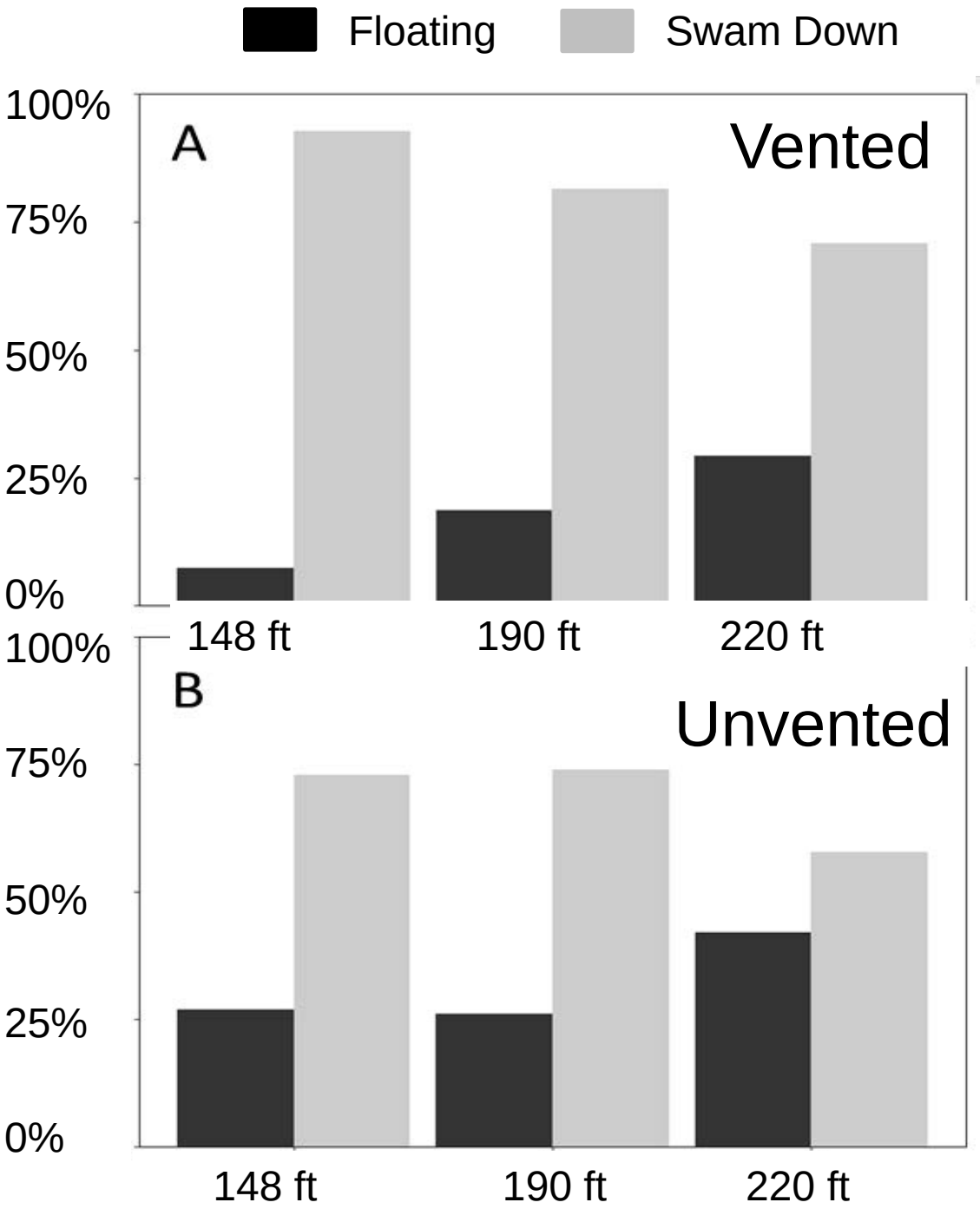
95% of black sea bass exhibited barotrauma

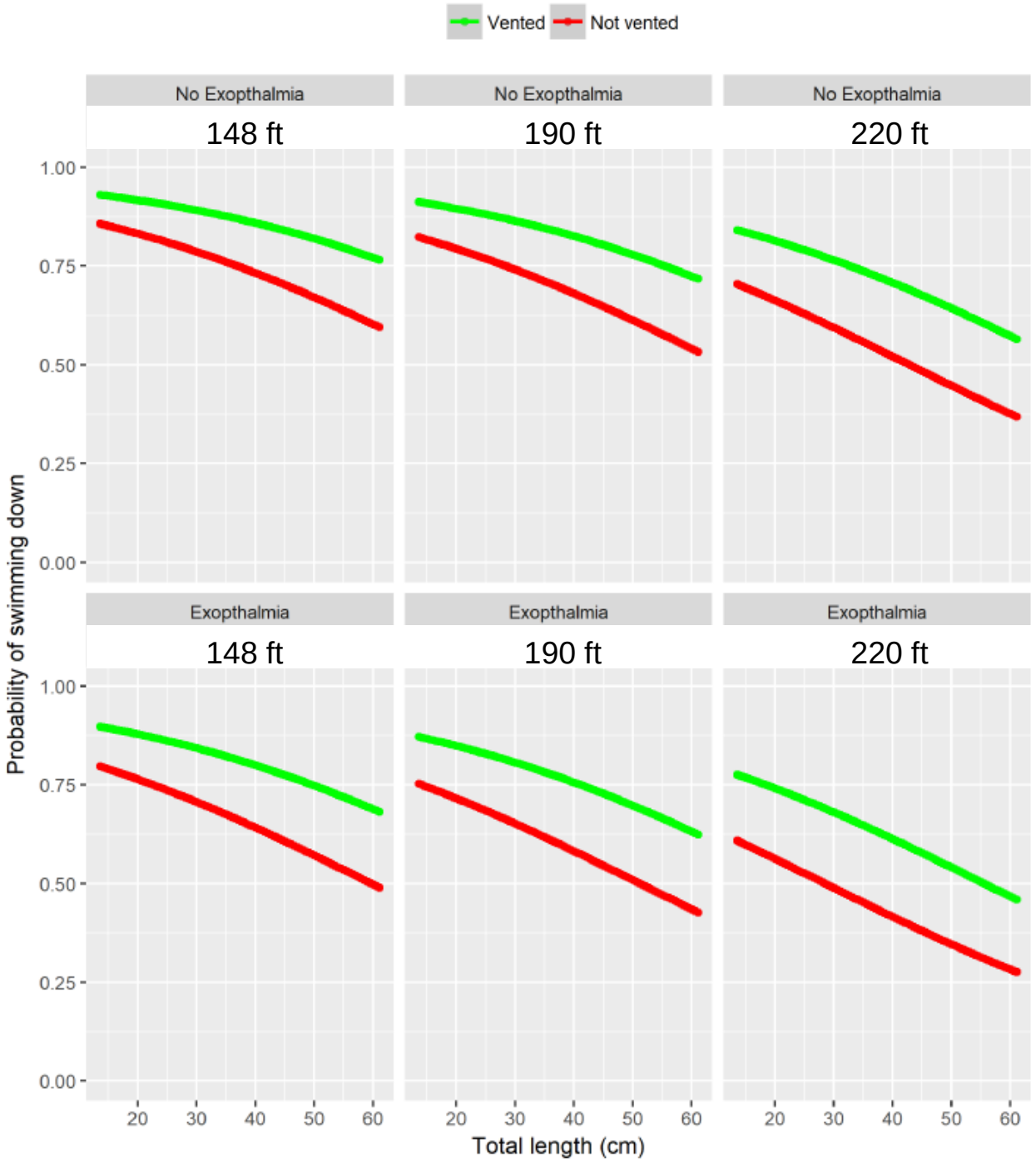
68% with stomach eversion score # 2

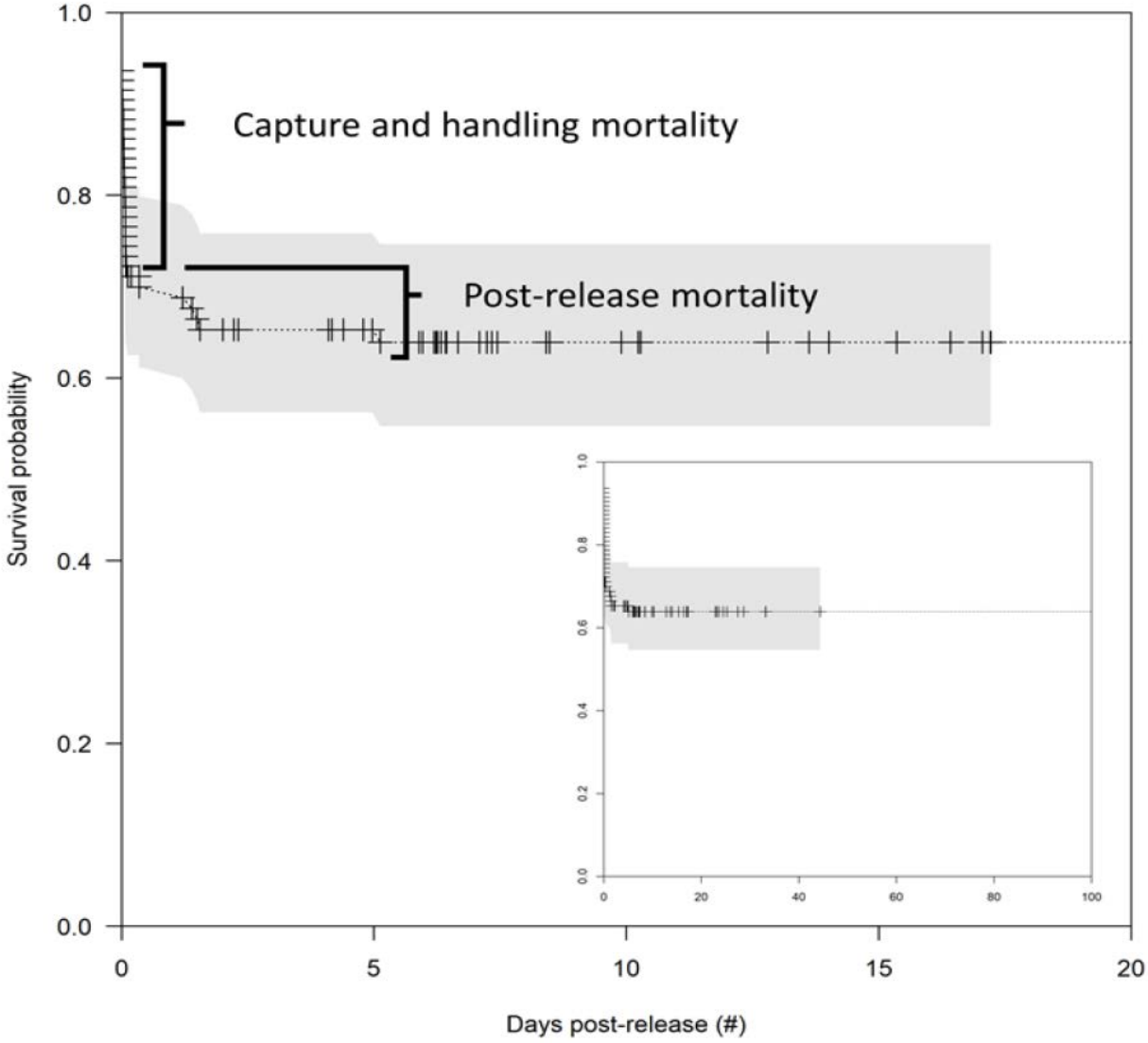
Exopthalmia present in ~10% of fish

Barotrauma was generally more prevalent at deeper depths



- Results from a fixed-effects logistic regression that evaluated release behavior against all plausible covariates.
- Larger fish that were not vented, caught at deeper depths, and experienced exopthalmia had a lower probability of swimming down.





n = 94 detected fish

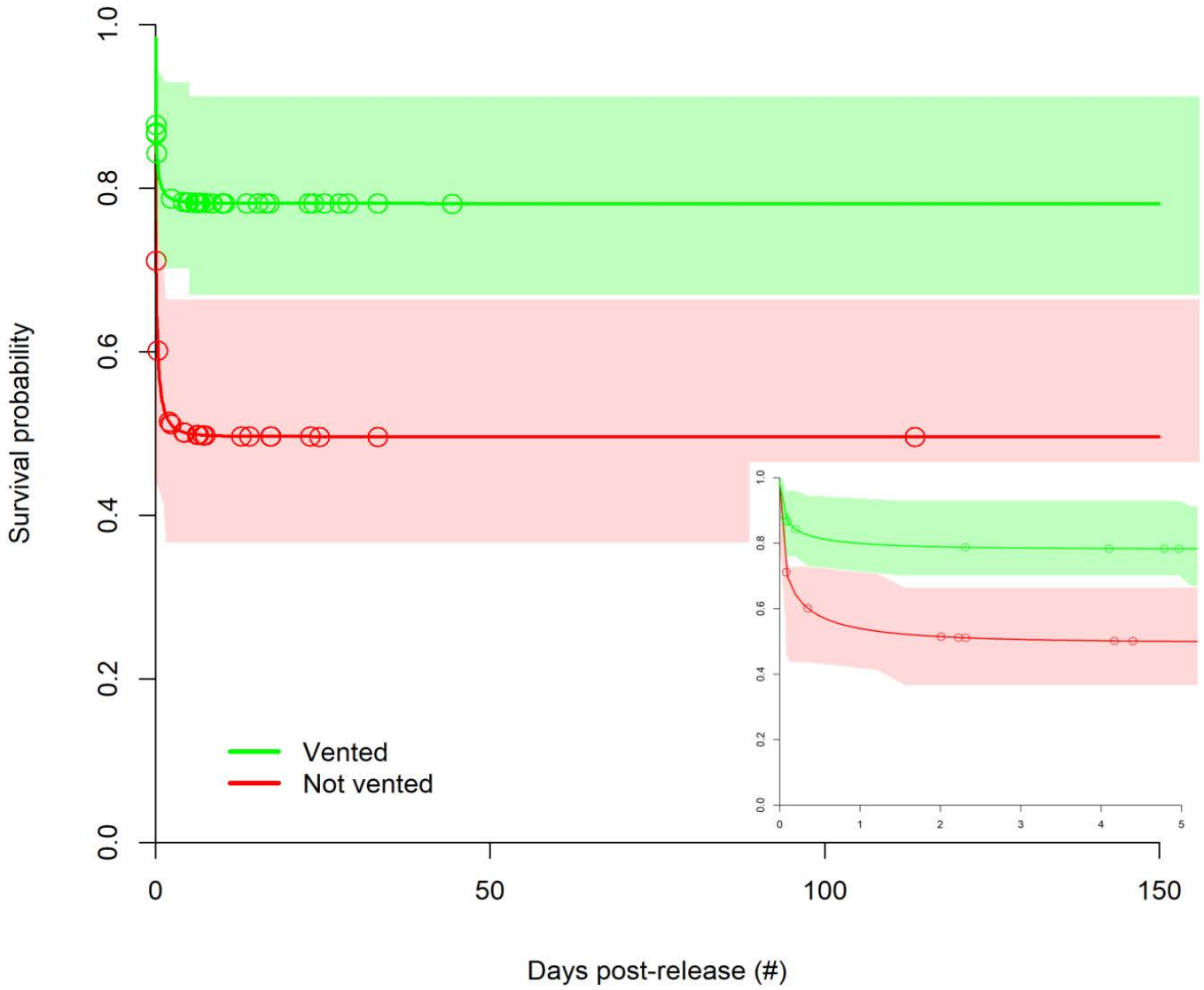
n = 61 alive

n = 33 dead

n = 9 predation events (<19 h post-release)

80% of mortality occurred <24 h

Plot of the Kaplan-Meier estimator of the overall survival function of all tagged and released black sea bass

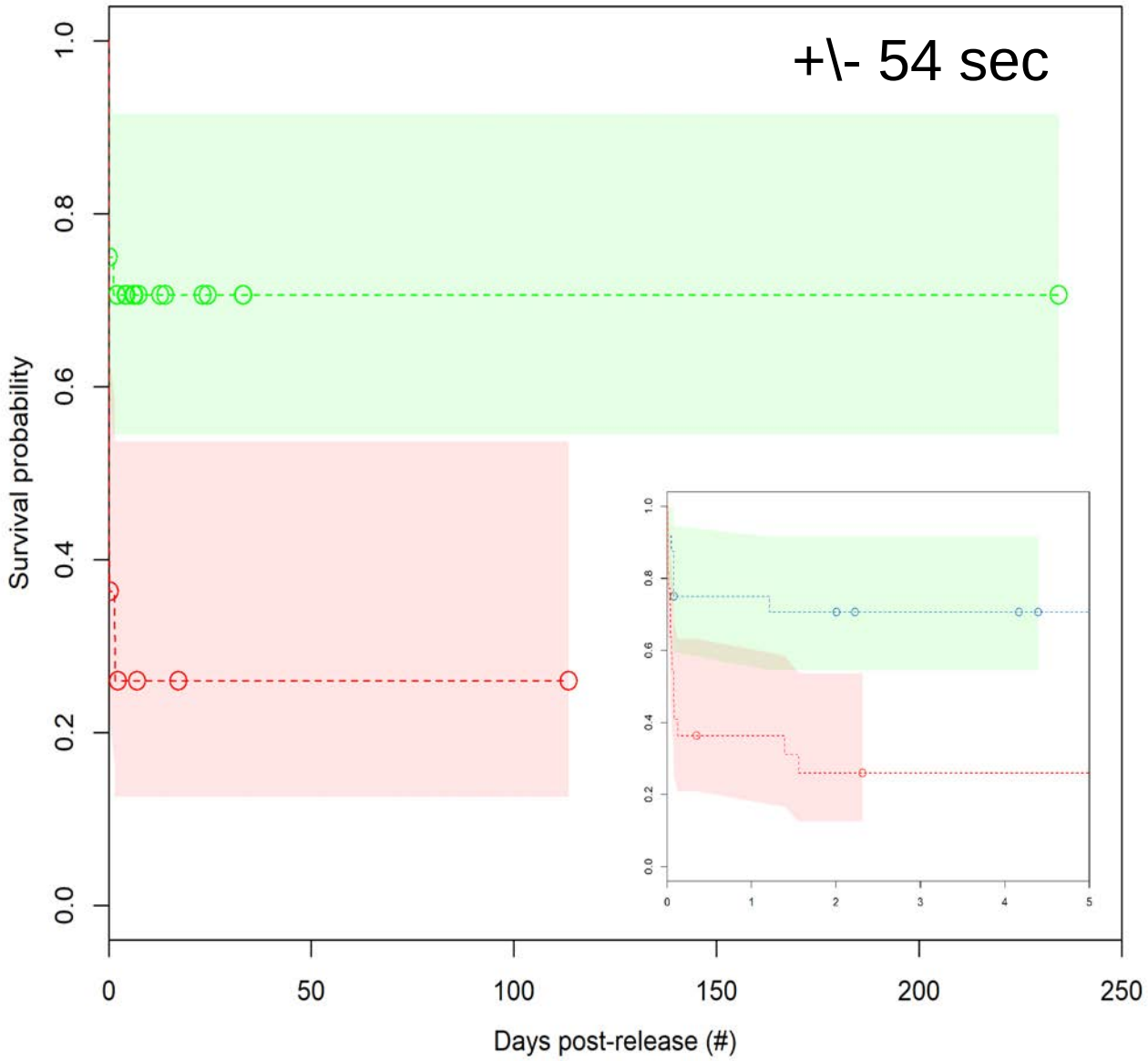


Mean discard mortality rates for unvented fish was nearly 2.5 times more than vented fish

<u>Vented</u>
Mean = 0.21
CI: 0.12, 0.37

<u>Unvented</u>
Mean = 0.52
CI: 0.38, 0.67

The best fitting Cox Proportional Hazards Model (CPHM) retained only the effect of venting.



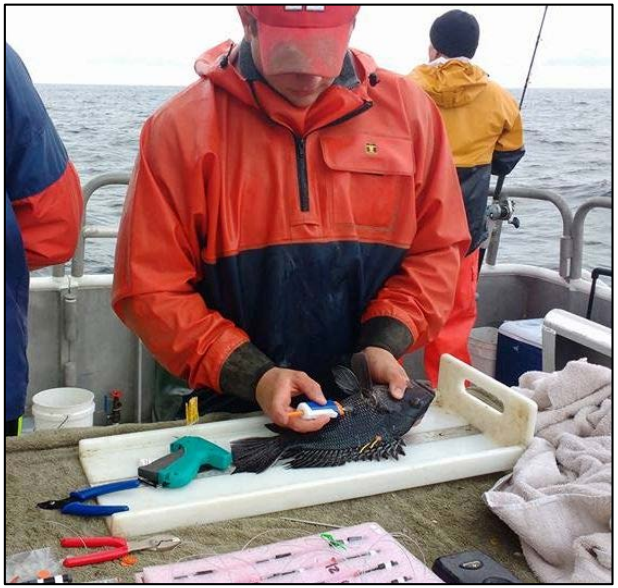
- Only fight time predicted survival for unvented fish using the CPHM.
- Fight time:
  - Mean = 78 ± 32 s
- Fight time was influenced by:
  - Capture depth
  - Fish length
  - Double headers
- Discard mortality is expected to be higher at deeper depths.

Recommended Best Practices

- Vent the swim bladder of all black sea bass before release in the offshore winter fishery.
- Reduce fight times of black sea bass caught in the offshore winter fishery: Depth, strength tackle, number of hooks, rate of retrieve
- Avoid fishing in locations where black sea bass are abundant during seasonal closures.
- Refrain from “high-grading”.
- Potential “sweet spot” to open fishery when predator abundance is low and black sea bass are not at their deepest depths, if concerned about discards.

Discussion

- Acoustic telemetry and longitudinal survival analysis were effective for estimating black sea bass discard mortality and identifying factors influencing mortality.
- The black sea bass discard mortality rate following capture by rod-and-reel in 147 ft was estimated to be 52%, but venting reduced discard mortality to 21%.
  - Discard mortality is expected to be greater at deeper depths
- Extension programming is ongoing to educate anglers on recommended best catch-and-release practices.
- Results will be valuable for consideration in future fishery management plans and stock assessment models.



Acknowledgements

- Funding obtained from the 2016–2017 Collaborative Research Program of the Mid-Atlantic Fishery Management Council.
- Partnership for Mid-Atlantic Fisheries Science (PMAFS)
- Captains and crews of fishing industry collaborators:
  - Tagging: *F/V Susan Hudson*, Sea Isle City, NJ; *F/V Porgy IV*, Cape May, NJ
  - Receivers*: F/V Rachel Marie*, Sea Isle City, NJ
- Volunteer anglers (n=42) and data recorders (n=8)
- Fishermen who reported recaptured black sea bass
- ACT Network members for sharing detections data

BONUS SLIDES

Holding Tank Study

- Completed a holding tank study to evaluate tag application methods, fish survival, and minimum acceptable fish size (10.5”) for tagging from September–November, 2016.
  - Tested two different tag attachment methods
  - No tag shedding or tagging-induced mortality after up to 62 days of observation

Table 7 – Summary of capture variables for all vented and non-vented black sea bass ('All observations'), including the 96 fish that were tagged with acoustic transmitters ('Transmitters'). Values in parentheses represent the mean ± standard deviation.

Category	Number of fish	Length range (mm)	Range of time (seconds)		
			Fight	Unhooking	Handling
All observations					
Vented	957	136-612 (349±66)	12-251 (80±32)	2-215 (17±18)	16-420 (141±77)
Non-vented	756	194-548 (323±69)	18-240 (75±69)	3-189 (18±19)	13-575 (142±81)
Total	**1713**	**136-612 (339±70)**	**12-251 (78±32)**	**2-215 (17±19)**	**13-575 (142±81)**
Transmitters					
Vented	48	278-546 (351±61)	17-225 (57±31)	2-42 (12±10)	80-326 (158±50)
Non-vented	48	279-485 (357±52)	29-90 (55±13)	3-52 (17±12)	91-310 (171±51)
Total	**96**	**278-546 (354±57)**	**17-225 (56±24)**	**0-52 (15±11)**	**80-326 (164±51)**

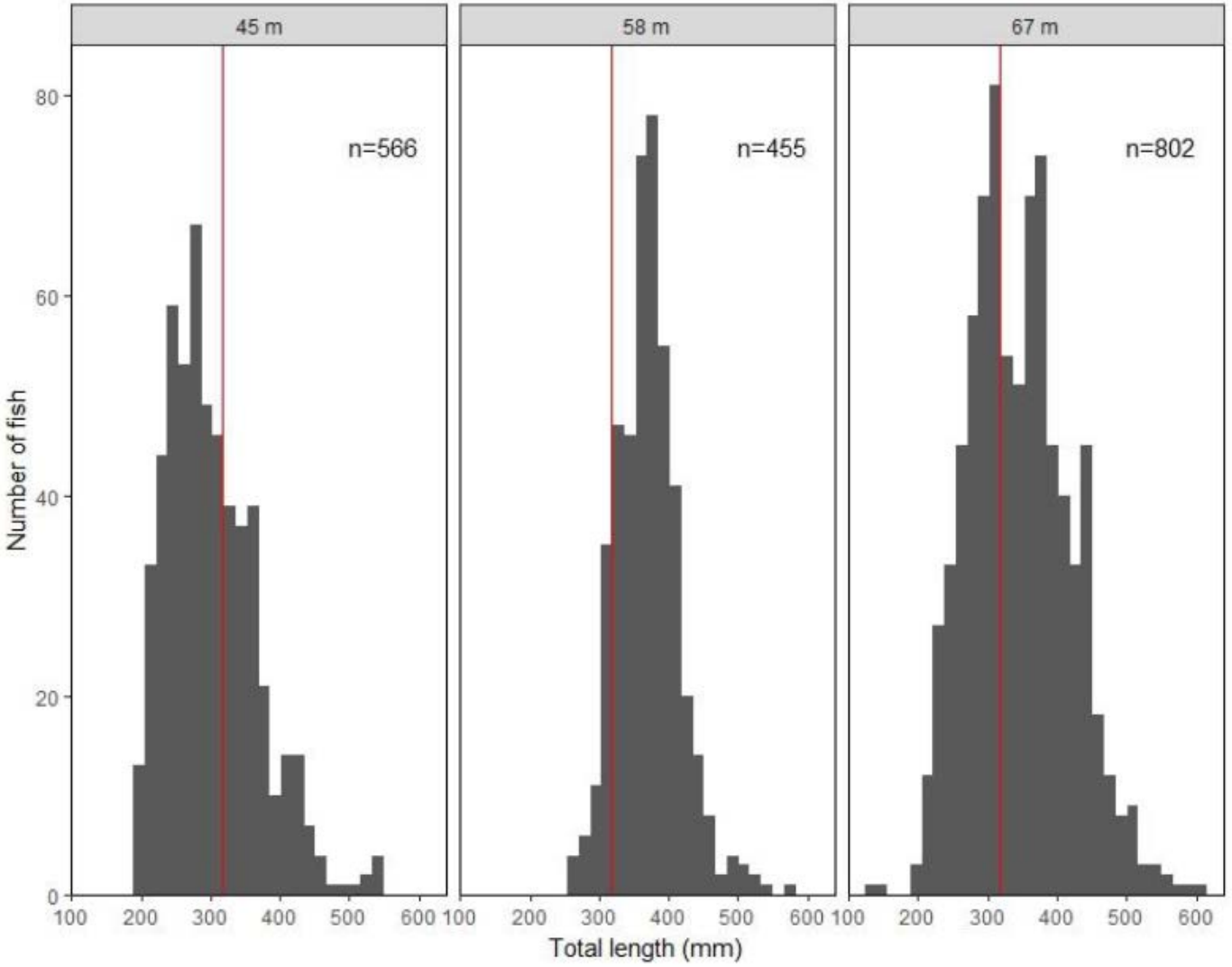


Figure 7 – Length frequency histograms of black sea bass captured at each depth. Sample sizes are presented for each depth. Red lines represent the federal minimum black sea bass size limit (12.5", 318 mm).

Table 8 – Summary of capture variables recorded for all captured black sea bass ('All observations') and the subset of 96 fish that were tagged with acoustic transmitters ('Transmitters'). Values in parentheses represent the mean ± standard deviation.

Variable	Transmitters	All observations
Capture depth (m)	45	45, 58, 67
Total length (mm)	278 – 546 (354 ± 57)	136 – 612 (339 ± 70)
Fight time (s)	17 – 225 (56 ± 24)	12 – 251 (78 ± 32)
45 m	17 – 225 (56 ± 24)	12 – 225 (55 ± 22)
58 m	-	32 – 240 (80 ± 27)
67 m	-	35 – 251 (94 ± 30)
Unhooking time (s)	2 – 52 (15 ± 11)	10 – 215 (17 ± 19)
Angler hand	2 – 49 (15 ± 11)	1 – 215 (18 ± 20)
Mate hand	3 – 52 (15 ± 12)	2 – 173 (17 ± 17)
Experienced anglers	2 – 52 (14 ± 11)	1 – 189 (17 ± 19)
Inexperienced anglers	13 – 36 (29 ± 9)	2 – 215 (19 ± 21)
Handling time (s)	80 – 326 (164 ± 51)	13 – 575 (142 ± 81)
Air temperature (°C)	5.9 – 15.1 (10.7 ± 2.3)	4.7 – 17.4 (13.9 ± 2.4)
Sea surface temperature (°C)	7.4 – 13.8 (11.4 ± 2.1)	7.2 – 13.9 (12.4 ± 1.7)*
Bottom temperature (°C)	7.4 – 13.8 (11.3 ± 2.0)	7.5 – 13.4 (12.2 ± 1.4)*
Delta temperature (°C)	-0.6 – 0.4 (0.1 ± 0.3)	-0.3 – 0.5 (0.3 ± 0.3)*

* Data only available for trips to the Ice Cream Cone wreck

Table 10 – Summary of hooking locations for all captured black sea bass ('All observations') and the 96 fish that were tagged with acoustic transmitters ('Transmitters'). Percentages represent the percent of total observations in each group.

	Transmitters		All Observations	
Hook Location	**Observations**	**%**	**Observations**	**%**
Shallow mouth	47	49.5%	955	54.0%
Medium mouth	38	40.0%	675	38.2%
Deep mouth			9	0.5%
Eye	1	1.1%	5	0.3%
Gills			6	0.3%
Head	1	1.1%	8	0.5%
Isthmus	7	7.4%	96	5.4%
Operculum			5	0.3%
Dorsal surface			5	0.3%
Ventral surface	1	1.1%	4	0.2%
Total	95		1768	

Table 11 – Summary of the number of black sea bass that exhibited each release behavior in the full set of observations ('All observations') and the subset of 96 fish that were tagged with acoustic transmitters ('Transmitters'). ES=Erratic swimming; F=Floating; S=Sinking; SD=Swam down

Category	Release behavior			
	ES	F	S	SD
All observations				
Vented	3	190	6	724
Non-vented	4	234	4	465
Total	**7**	**427**	**10**	**1190**
Transmitters				
Vented		1		47
Non-vented		11		37
Total		**12**		**84**

Table 12 - Forward selection process for the logistic regression model that evaluated release behavior against a set of sensible covariates for all released black sea bass (*n*=1594). Covariates that produced a conservative corrected Akaike Information Criterion (AICc) reduction of three or more units from the previous model were retained (see ΔAICc). An asterisk (*) denotes the final model.

Run	Covariates	AICc	ΔAICc
1	~1	1832.163	
2	~depth	1783.034	49.129
3	~depth + venting	1747.244	35.79
4	~depth + venting + total length	1740.044	7.2
5*	~depth + venting + total length + exopthalmia	1736.882	3.162
6	~depth + venting + total length + exopthalmia + injury	1738.367	-1.485

Table 14 – Summary of the number of black sea bass that exhibited exopthalmia and each stomach eversion score in the full set of observations ('All observations') and the subset of 96 fish that were tagged with acoustic transmitters ('Transmitters').

Category	Exopthalmia		Stomach Eversion Score			
	Present	Absent	0	1	2	3
All observations						
Vented	92	863	30	193	714	18
Non-vented	80	670	65	207	442	36
Total	172	1533	95	400	1156	54
Transmitters						
Vented	1	47	2	8	35	3
Non-vented	5	43	4	13	29	2
Total	6	90	6	21	64	5

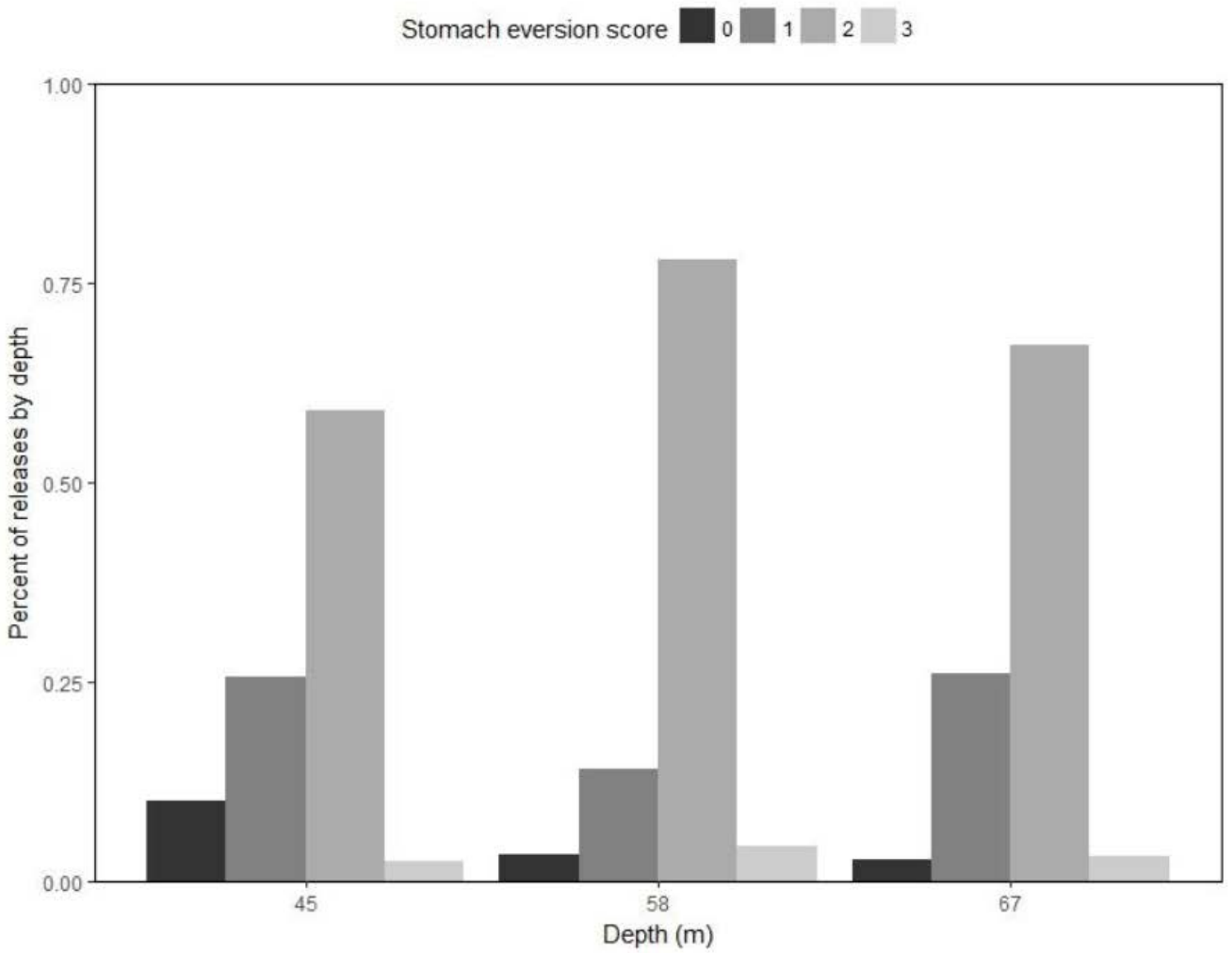


Figure 16 – Histogram of the percent of total fish releases that experienced stomach eversion scores 0, 1, 2, and 3 for each capture depth. Score 0: Stomach not everted; Score 1: Stomach everted but remains within mouth cavity; Score 2: Stomach everted but is protruding from the mouth; Score 3: Stomach everted and ruptured.

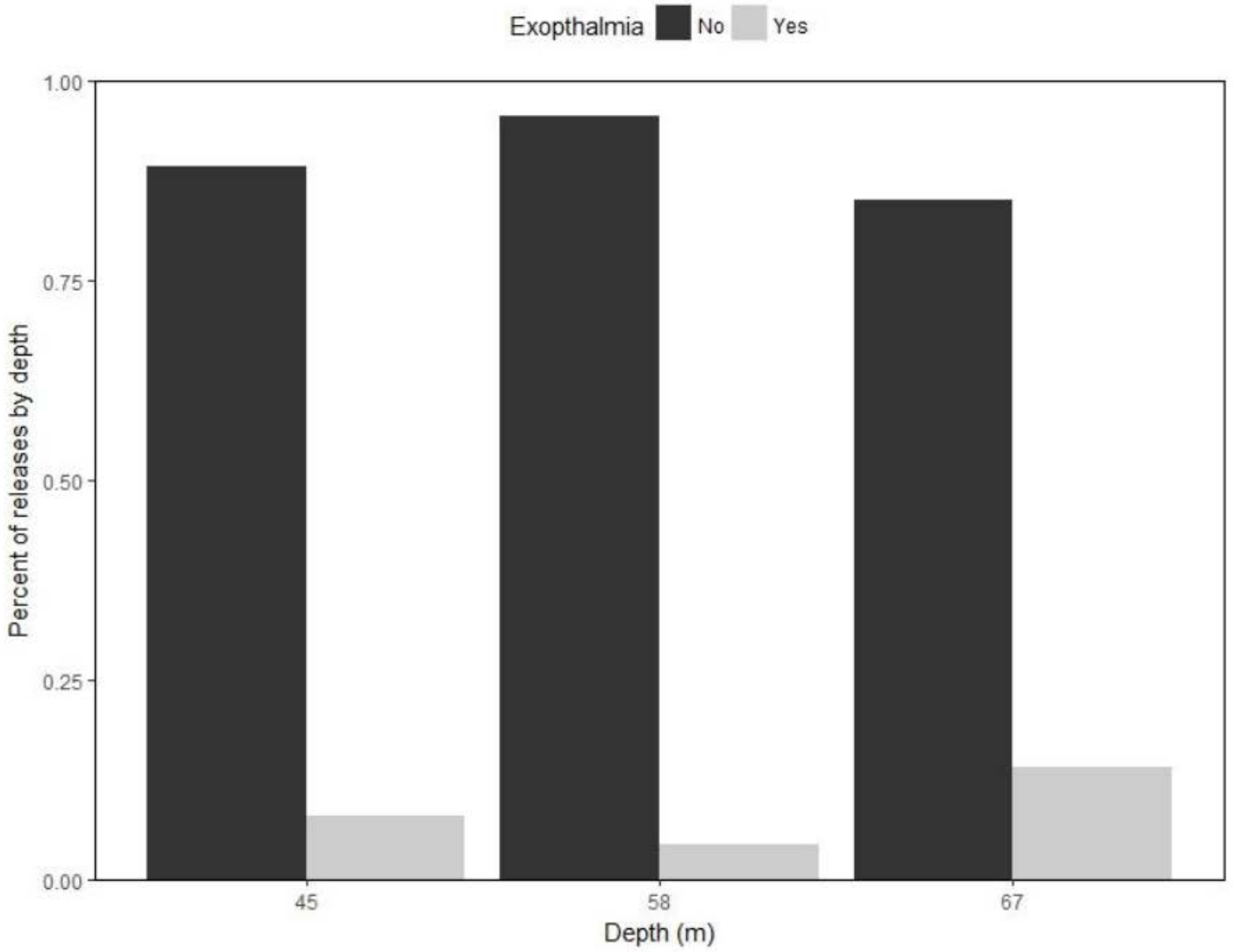


Figure 17 – Histogram of the percent of total fish released by depth that experienced exopthalmia.

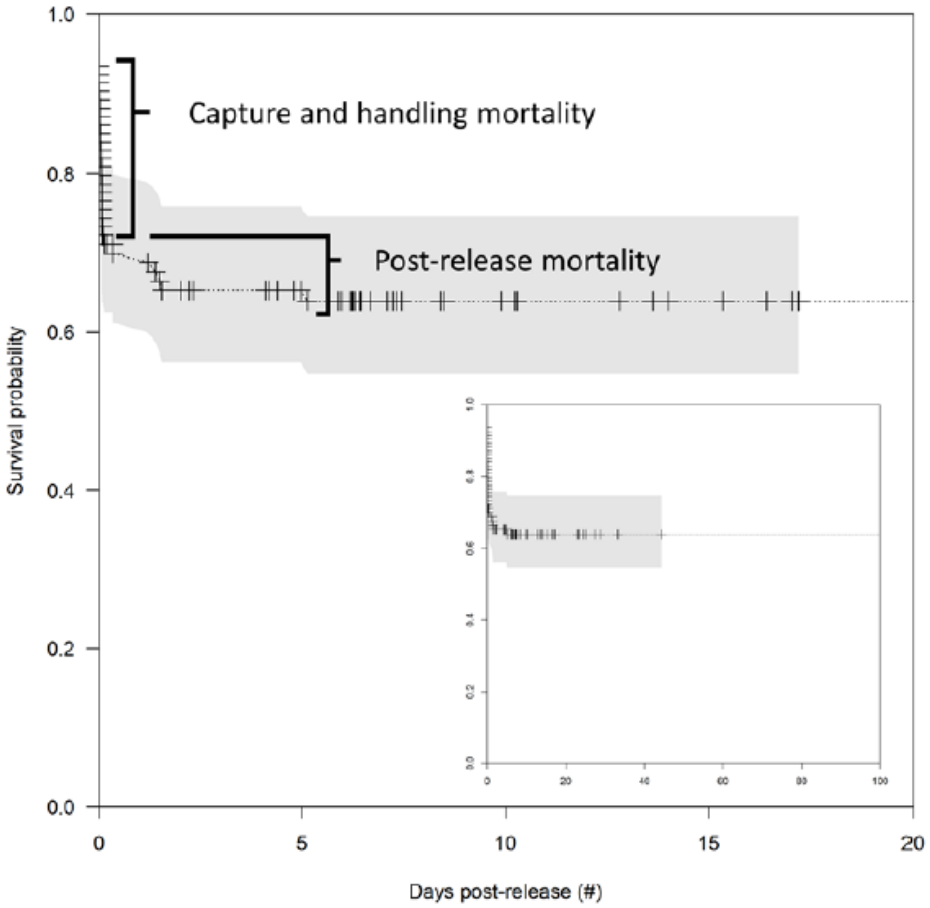


Figure 6 - Plot of the Kaplan-Meier estimator of the overall survival function for all tagged and released black sea bass over the first 20 days, with the 95% confidence interval indicated by shaded areas, and times of right censoring indicated with plus (+) signs. Time zero is the time of release back into the water. The plot is annotated to indicate the presence of two types of mortality over time for black sea bass that were captured and released (no evidence of natural mortality). The inset plot displays the Kaplan-Meier estimator of the overall survival function for these fish over 100 days.

Table 17 - Sample sizes and estimates of key parameters for the analysis of survival data for vented black sea bass. The number of fish that died upon release (dead), that died during capture and handling or immediately after release (left-censored), and that were last seen alive (right-censored) are presented. Estimates (95% confidence intervals) of the capture and handling mortality rate ($1-\tau$), the conditional post-release mortality rate ($\tau \cdot \pi$) and the total mortality rate associated with the fishing event (i.e., discard mortality; $1-\tau+\tau \cdot \pi$) are presented by treatment group.

		Numbers			Fishing mortality rates		
Season	Total	Dead	Left	Right	Capture-Handling	Post-Release	Total
Vented	48	9	1	38	0.017 (0.001, 0.158)	0.203 (0.107, 0.351)	0.219 (0.131, 0.406)
Not vented	46	18	5	23	0.017 (0.001, 0.158)	0.487 (0.319, 0.633)	0.504 (0.362, 0.662)

Table 15 - Forward selection process for the Cox Proportional Hazards Model that evaluated the survival function for black sea bass in the acoustic transmitter subsample over a set of sensible covariates determined from Figures A1 – A3 and Table A1 (Appendix 4). Covariates that produced a conservative AICc reduction of three or more units from the previous model were retained (see ΔAICc). An asterisk (*) denotes the final model and parsimonious set of covariates to be considered in the parametric survival analysis. Note: model variants 2 and 3 were indistinguishable by AICc, thus, the most parsimonious model (run 2) was selected as the final model.

Run	Covariates	AICc	ΔAICc
1	~1	285.175	
2*	~ venting	278.2613	6.913218
3	~ venting + total length	277.8582	0.403035

Table 18 - Forward selection process for the Cox proportional hazards regression model that evaluated the survival function for only unvented black sea bass in the acoustic subsample over a set of sensible covariates determined from Figures A4 – A6 and Table A2 (Appendix 4). Covariates that produced a conservative AICc reduction of three or more units from the previous model were retained (see ΔAICc). An asterisk (*) denotes the final model

Run	Covariates	AICc	ΔAICc
1	~1	162.0427	
2*	~ fight time	154.6790	7.3637
3	~ fight time + handling time	155.7066	-1.0276

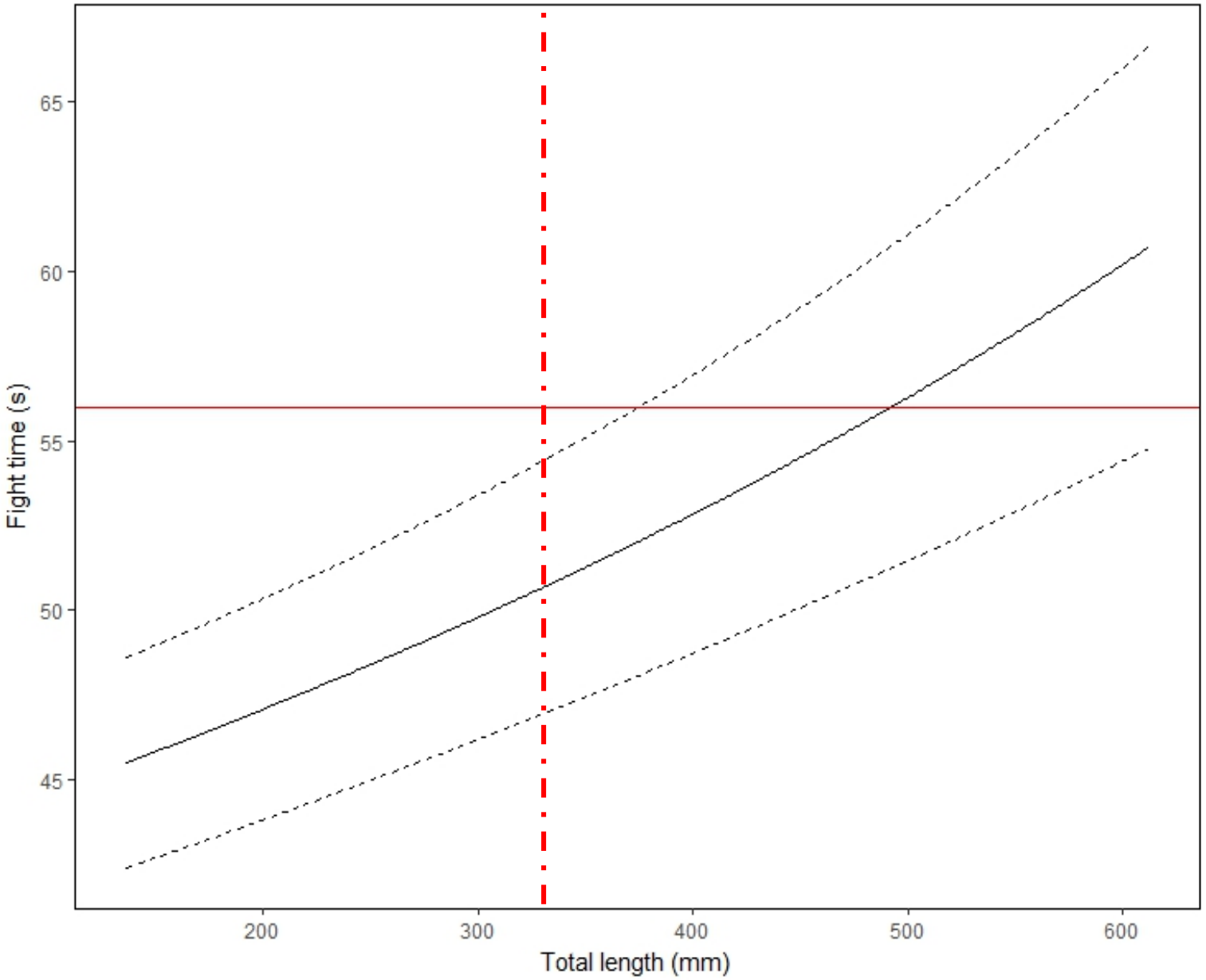
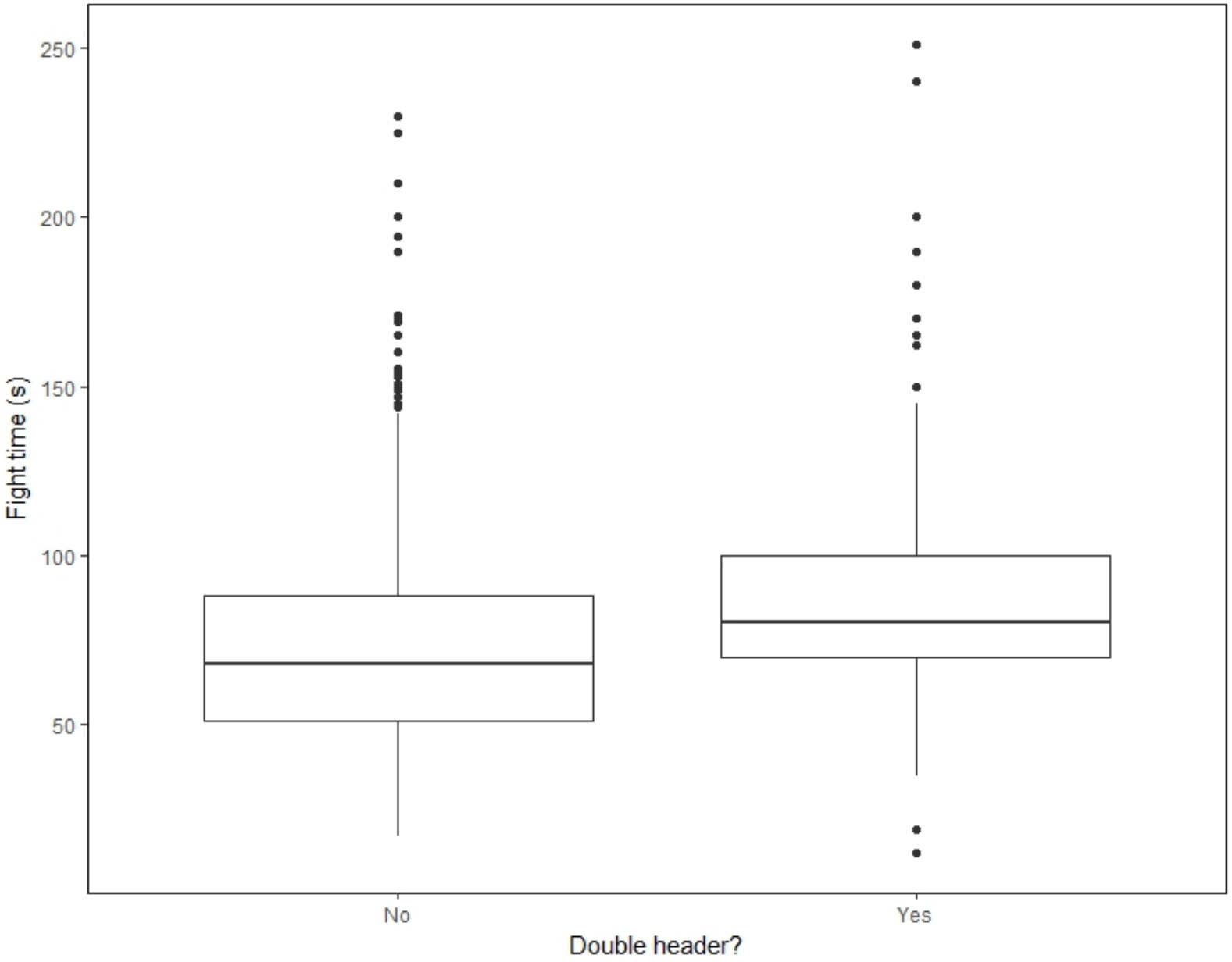
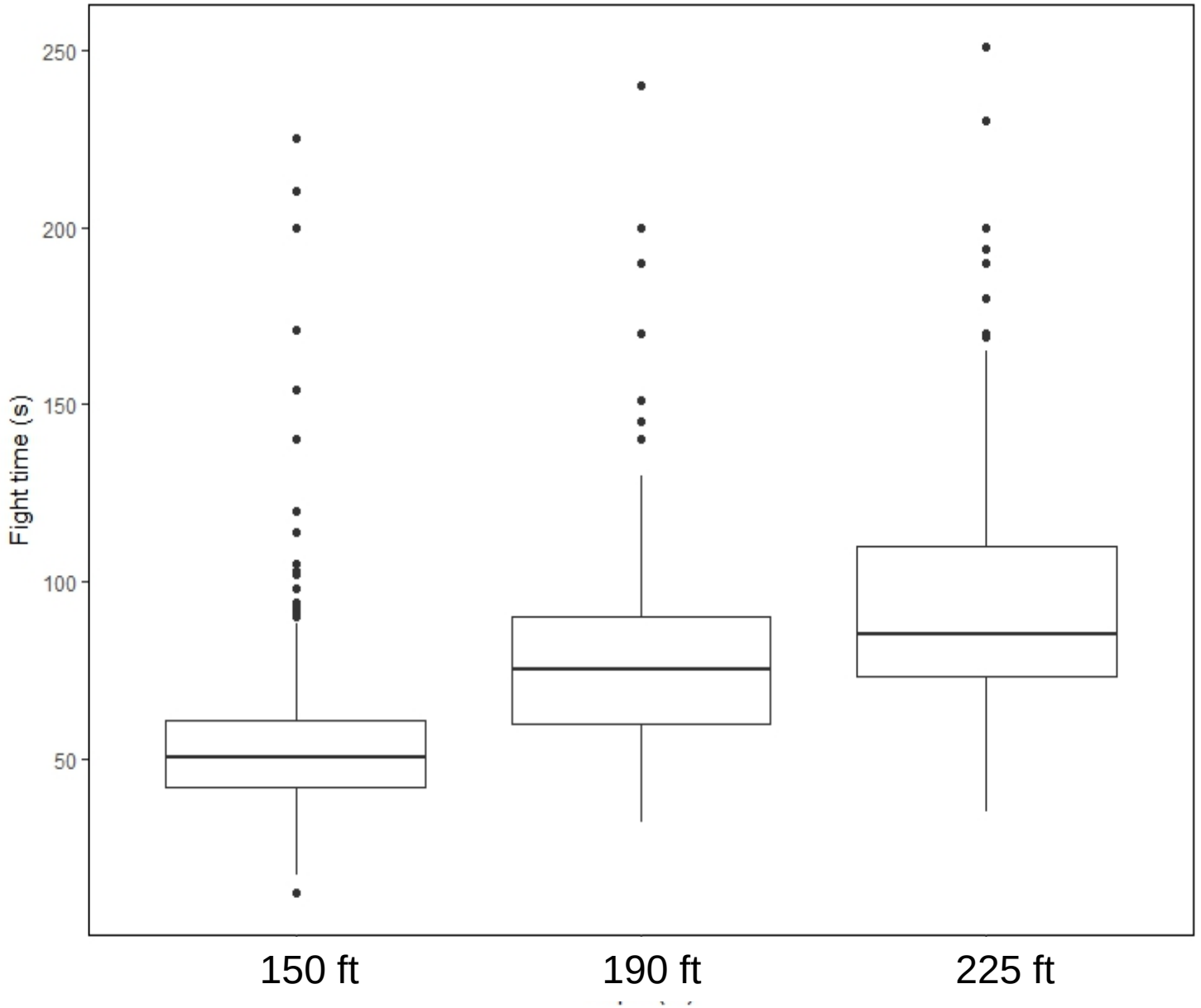
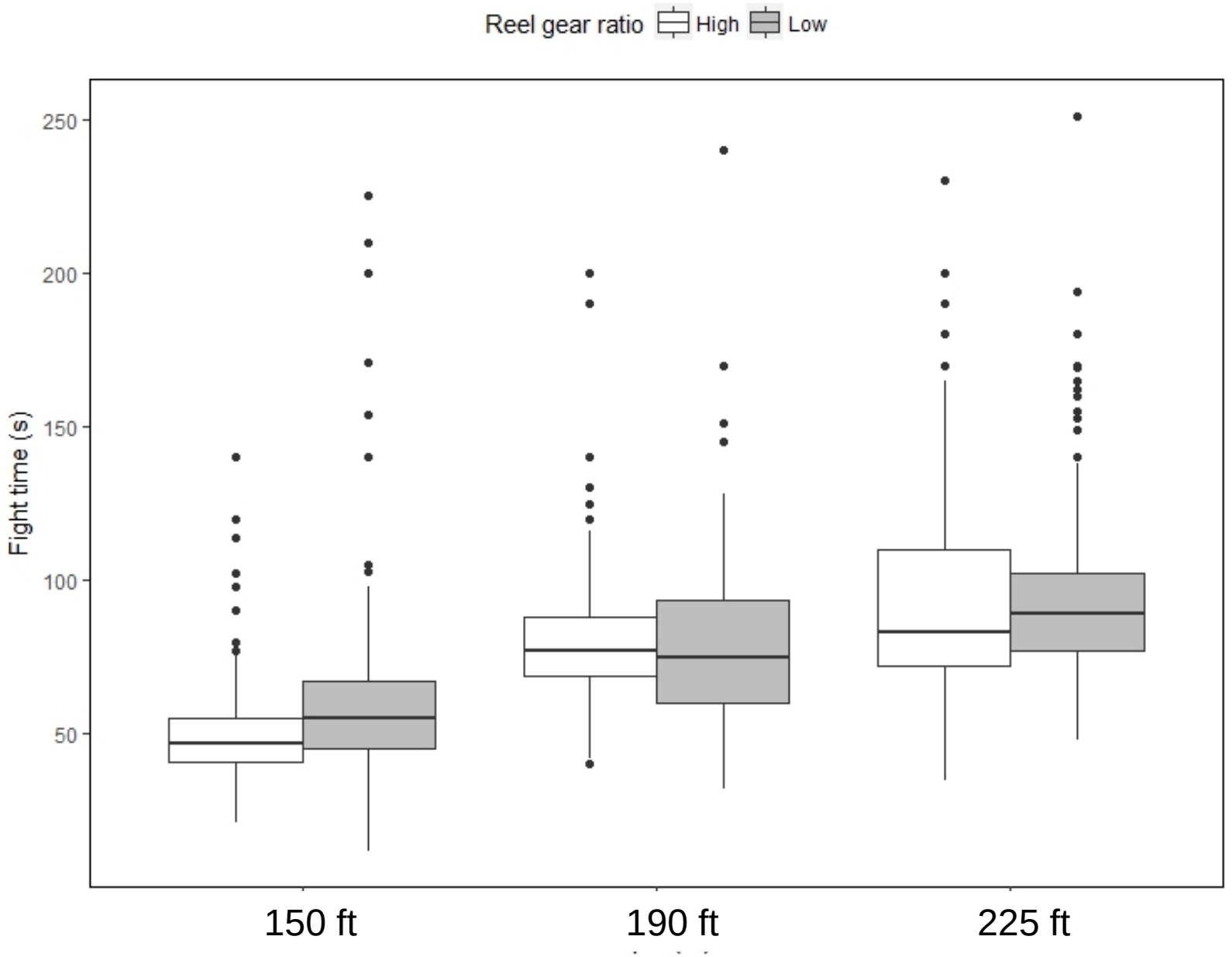

65
60
55
50
45
Fight time (s)
200
300
400
500
600
Total length (mm)

Table 9 – Model selection results for the generalized additive mixed effect model examining the relationship of each variable on fight time. The model with the lowest Akaike Information Criterion (AIC) value is in bold. TL=total length; DH=double header

Model	Estimated degrees of freedom	Deviance explained	AIC	ΔAIC
Fight time ~ s(TL) + Depth + DH+Reel_gear	**51.52**	**64.3%**	**15088**	**0**
Fight time ~ s(TL) + Depth + DH	50.64	64.0%	15102	14
Fight time ~s(TL) + DH + Reel_gear	50.22	55.5%	15480	392
Fight time ~ s(TL) + Depth+ Reel_gear	50.37	63.4%	15132	43
Fight time ~s(TL) + DH	49.29	55.5%	15479	391
Fight time ~ s(TL) + Depth	49.46	63.1%	15147	58
Fight time ~s(TL) + Reel_gear	49.23	54.2%	15530	441
Fight time ~s(TL)	48.29	54.2%	15528	440
Fight time ~ 1	47.32	49.9%	15685	597


250
200
150
100
50
Fight time (s)
No
Yes
Double header?


Fight time (s)
250
200
150
100
50
150 ft
190 ft
225 ft


Reel gear ratio
High
Low
Fight time (s)
250
200
150
100
50
150 ft
190 ft
225 ft

Tag Recapture Locations