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SEDAR94-DW-16

18 July 2025

Please cite this document as:

Eguia, Leonardo, Zachary Siders, Debra Murie. 2025. Recreational For-Hire Trends in Release Methods and Barotrauma Assessment of Hogfish (*Lachnolaimus maximus*) using a Fisheries-Dependent At-Sea Observer Program. SEDAR94-DW-16. SEDAR, North Charleston, SC. 28 pp.

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using a Fisheries-Dependent At-Sea Observer Program

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In preparation for

SEDAR 94 Florida Hogfish

July 28, 2025

INTRODUCTION

Historically, hogfish (*Lachnolaimus maximus*) have been primarily harvested by private recreational spearfishers until recent years (Davis 1976; McBride 2001; SEDAR 2013; Collins and McBride 2015, NOAA 2025) and for this reason, previous stock assessments (SEDAR 06, SEDAR 37, SEDAR 37 Update) did not have sufficient recreational hook-and-line data to inform a dedicated fishery within the model. Additionally, due to the shallow depths where hogfish are caught on hook-and-line, it was assumed that discard mortality would likely be low (McBride 2001), and hogfish were therefore assumed to have a 10% discard mortality rate (SEDAR 2017). Since SEDAR 37, hook-and-line catch and effort of hogfish have increased substantially, according to angler reports (Eguia, pers. obs.), as well as state and federal surveys (Florida Fish and Wildlife Conservation Commission (FWC) 2024b, NOAA 2025). Despite this emerging fishery, there has been no published research that describes the effect that hook-and-line fishing has on hogfish.

Since 2009, the Fish and Wildlife Research Institute's (FWRI) Fisheries Dependent Monitoring (FDM) group initiated an at-sea observer program (FWC 2024a), which collects data while aboard participating for-hire vessels (headboats and private charter boats). At-sea observer data eliminates recall bias, which is common in dockside surveys done at the end of a fishing day. The primary focus of the at-sea observer program, therefore, is to collect accurate discard data, including numbers and species caught, whether fish were harvested or released, length measurements, barotrauma assessment, release condition (if discarded) as well as location, water depth, and bottom type at each fishing site. In addition, certain discarded reef fish, including hogfish, are opportunistically tagged with conventional dart tags statewide to estimate unique discard mortality rates. In an effort to better understand discards from the for-hire fleet, the at-sea observer program began collecting barotrauma data in July of 2022, using an ordered numerical coding system, ranging from 0 (absent) to 4 (catastrophic), based on external symptoms present (Table 1).

Since 2009, 650 discarded Hogfish have been tagged in the at-sea observer program, but only 16 recaptures have been reported. Of the 15 recaptures, seven were reported as Red Grouper (*Epinephilus morio*) and one was smaller than when initially tagged; therefore, only 7 recaptures provided usable data. Only one hogfish was recaptured while an observer was onboard. Discard mortality rates have been estimated for other reef fish species using a conventional tag-recapture method when tag return rates are adequate (Sauls 2014; Ayala 2020; Vecchio et al. 2022), but a reliable and robust discard mortality rate for hogfish cannot be estimated from only seven tag returns. However, due to the comprehensive nature of the data collected by the at-sea observer program, it is possible to analyze the general disposition of hogfish and the degree of barotrauma associated with the emerging hook-and-line fishery.

Our specific objectives were to summarize trends in the for-hire fleet targeting hogfish and to determine environmental variables that influence the degree of observed barotrauma symptoms. Frequencies of discard methods, depth of capture, and barotrauma scores were summarized to provide insight into effort and angler behavior towards barotrauma mitigation. A Bayesian ordinal regression model was conducted to estimate barotrauma based on several predictor variables collected by the at-sea observer program. These estimates can provide insight into the nature of catching hogfish on hook-and-line and, in combination with frequencies of discard methods and barotrauma observed, can inform the discard mortality model for this species.

METHODS

At-Sea Observer Trends

Data collected by the FWRI at-sea observer program were summarized for trends in discard disposition, barotrauma assessment, and depths fished. All observed hogfish were scored as to whether they were kept or discarded, vented/not vented, and recompressed/not recompressed. Specifically, for the at-sea observer field data recording for all discarded hogfish, surface released fish were given a vent code of “N” and release condition that was not “R”; vented fish had a vent code of any value other than “N” and a release condition that was not “R”; and recompressed fish had a release condition of “R” and a vent code of “N”. Finally, vented and recompressed fish had a release condition of “R” and a vent code of any value other than “N”. Venting tools consisted of primarily hollow needles, but there were two hogfish vented with knives, and one vented with a different tool, likely a hook. Venting primarily occurred through the ventral region of the fish, but there was one observation of venting through the anus occurring. Descending devices (brand SeaQualizer) were used in almost every recompression event, but one hogfish was recompressed with a cage. Due to only one observation of a vented and recompressed hogfish in 2024, this field was included with the recompressed category. All hogfish were released using the method that was usually employed by the charter boat or headboat crews and at-sea observers did not recommend nor interfere with the method used to release fish. Release methods were then summarized by year and by depth of capture.

Hogfish were also scored for external signs of barotrauma when possible. Barotrauma assessment included: Score = 0 included fish that exhibited no visible barotrauma symptoms; Score = 1 included fish that had visible bloating in the ventral region; Score= 2 included fish that had extruded organs outside the mouth or less than 1 inch of intestinal extrusion; Score = 3 included fish that had any combination of lower scores and/or stomachs extruding through operculum, exophthalmia (but still in contact with eye socket), and/or greater than 1 inch of intestinal extrusion; and a Score = 4 included fish that exhibited any symptoms from lower scores as well as severe exophthalmia (full eyeball extrusion past eye socket), scales raised, and blood leaching from body (Table 1). Barotrauma scores of 9 (or not checked) were omitted. Observer data that were filtered for observations of hogfish that included barotrauma assessment reduced the total observations from 1,928 to 612. Depth of capture was binned into four 10-m depth categories, including ≤ 10 m, 10-20 m, 20-30 m, and > 30 m. A frequency table was created of barotrauma assessment score as a function of depth of capture using SAS (SAS Institute Inc. 2004).

Sea Temperature Alignment

The at-sea observer program does not collect water temperature data aboard observed trips. Therefore, sea surface temperature (SST) and bottom temperature (BT) were incorporated from the HYbrid Coordinate Ocean Model (HYCOM). HYCOM is a high-resolution ocean circulation model developed by NOAA in collaboration with the Naval Research Laboratory and academic peers (Halliwell 2004; Chassignet et al.

2007). Using the HYCOM-TSIS GOMb0.01 reanalysis product, temperature estimates were incorporated into the at-sea observer dataset by date, location (latitude and longitude to the nearest whole minute), and hour. This product has been validated with temperature data recorded in situ (Thorr et al. 2025) and contains temperature estimates at 1 km^2 resolution (HYCOM 2024).

Bayesian Mixed Effects Ordinal Regression Model

We used a Bayesian mixed effects ordinal logistic regression to predict barotrauma based on parameters collected from the at-sea observer survey and HYCOM. Due to the overlap between absent and minor barotrauma codes (Table 1) and low observations in each condition (Table 3), these codes were pooled into an absent/minor category (denoted by Barotrauma = 1) leaving us with four barotrauma scores. Small sample sizes in the regions other than Tampa Bay (SW = 2 observations, SE = 5 observations, and KY = 22 observations) were dropped, reducing total sample size to 580 observations.

Due to the sample size of hogfish observed in Fall and Winter (75% of observations with barotrauma assessment), temperature anomalies were calculated using the following formulae:

$$SST\ anomaly = SST - mean(SST\ per\ season)$$

$$BT\ anomaly = BT - mean(BT\ per\ season)$$

Seasons were denoted as follows: Spring consisted of March, April, and May, Summer consisted of June, July, and August, Fall consisted of September, October, and November, and Winter consisted of December, January, and February.

Predictor variables other than Depth were standardized using the *bestNormalize* package (Peterson and Cavanaugh 2020, Peterson 2021) in R (R Core Team, 2023). Capture depth was log transformed. We trialed several model structures (not included) using parameters described in Table 5, but arrived at a model (Equation 1) with fixed effects for capture depth (X_{Depth}), fork length (X_{FL}), capture season (X_{season}), interactions between SST $(X_{SSTanom})$ and BT anomalies (X_{BTanom}) with capture season. We controlled for the repeated measures nature of the dataset with a random effect for at-sea sampler $(X_{sampler})$ and a nested random effect of vessel (X_{vessel}) within vessel type (X_{type}).

$$S_i \sim \log(X_{i,Depth}) + X_{i,FL} + (X_{i,SSTanom} * X_{i,season}) + (X_{i,BTanom} * X_{i,season}) + (1|X_{i,sampler}) + (1|X_{i,vessel}/X_{i,type}) \quad \text{Eq. 1}$$

The model was implemented using the *brms* package (Bürkner 2017, 2018, 2021) using default priors, which set flat priors for parameters and a mean of 3 and standard deviation of 2.5 for intercepts and random effects. We ran the model with eight chains that had 4000 warmup iterations and 1000 sampling iterations each. Posterior samples from individual chains were combined and assessed using an $\hat{R}$ below 1.1 (Gelman and Rubin, 1992) and with effective sample sizes over 2000. Parameter significance was assessed at an $\alpha = 0.1$. Marginal effects were calculated using the conditional effects function in *brms*.

RESULTS

At-Sea Observer Trends

The majority of discarded hogfish (~80%) were discarded with no barotrauma mitigation, as observed through the at-sea observer program (Table 2). Vented hogfish accounted for approximately 13% of discards and the remaining 7% were recompressed. One hogfish in 2024 was vented prior to recompression and was included in the recompression category. While surface releases accounted for the majority of discards, annual rates of venting and recompression increased slightly after 2020 (Table 2).

Nearly 90% of hogfish were captured in 10-20 m, and <1% were captured in depths > 30 m (Table 3). Despite being captured primarily in 10-20 m depth, catastrophic symptoms of barotrauma were being observed in more than half of the hogfish caught on for-hire trips (~53%). Severe barotrauma symptoms were observed nearly 24% of the time, intermediate symptoms ~15% of the time, and approximately 8% of observed hogfish did not exhibit any barotrauma or only minor barotrauma symptoms. In the primary depth range of capture (10-20 m) almost 56% of hogfish exhibited catastrophic barotrauma symptoms, 23% exhibited severe barotrauma, 15% exhibited intermediate symptoms, and the remaining ~6% exhibited minor or no symptoms of barotrauma.

Despite severe and catastrophic barotrauma symptoms present in approximately 77% of observed hogfish, 69% of sampled hogfish in the primary depth range (10-20 m) were released with no barotrauma mitigation (Table 4). Sample sizes for discarded hogfish outside of this depth range were low but may indicate increased barotrauma mitigation in greater depths. Despite only ~5% of hogfish sampled having been caught in 20-30 m, 25% of discarded hogfish were vented, as opposed to ~15% in the primary depth range (Table 4). Sample sizes in depths >30 m were too low to confidently describe any trends regarding barotrauma mitigation for discarded hogfish.

Bayesian Mixed Effects Ordinal Regression Model

The Bayesian mixed effects ordinal logistic regression converged with all parameters having $\hat{R}$ values of less than 1.002 and effective sample sizes over 4000 samples. Fork length, SST Anomaly, Summer, Winter, BT Anomaly, the interaction between SST Anomaly and Spring, and the interaction between BT Anomaly and Spring all had probability of directions greater than 0.98 indicating strong positive or negative effects (Table 6). Interactions between SST Anomaly and Season, and BT Anomaly and Season had mixed results. Summer and Winter interactions were not significant, but Spring was (Table 6).

Capture depth had a median posterior parameter estimate close to zero as well as confidence intervals that overlapped 0 indicating it was not a significant predictor of barotrauma score (Table 6, Figure 1). This stands in contrast to other species as depth is frequently a factor contributing to barotrauma in reef fishes (Drumhiller et al. 2014, Rudershausen et al. 2014, Ayala 2020). In Tampa Bay-caught Hogfish, the most likely barotrauma scoring is catastrophic regardless of depth and makes up ~50% of the expected barotrauma scores (Figure 1). Fork length was estimated to have an inverse relationship with the probability of catastrophic barotrauma for hogfish (Figure 2). At the minimum size limit in the Gulf, 14 inches or 356 mm fork length (NOAA Fisheries 2017), the model predicts roughly a 45% probability of catastrophic barotrauma symptoms, 35% probability of severe barotrauma, 15% probability of intermediate barotrauma, and a probability of less than 5% of absent or minor barotrauma symptoms.

Estimates of the SST anomaly effect indicated that small temperature changes may influence barotrauma severity (Figure 3). Strong negative SST anomalies were estimated to curtail the probability of catastrophic barotrauma (Figure 3). But even with moderate negative SST anomalies of -1ºC, Hogfish were expected to have higher rates of catastrophic barotrauma than other barotrauma outcomes. Bottom temperature anomalies have inverse effects on barotrauma predictions (Figure 4). Higher BT anomalies predict lower barotrauma scores have higher probabilities but by 1˚C, severe and catastrophic scores have higher probabilities than other outcomes. By -5˚C BT anomaly, the probability of catastrophic barotrauma is 95%. Across seasons, summer was estimated to have the lowest probability of severe or catastrophic barotrauma, with intermediate having the highest estimated probability at 39%. Winter was estimated to be dominated by catastrophic barotrauma with a probability of 71%. Spring and fall exhibit similar trends with each barotrauma score. Given the strong correlation between season and hook-and-line fishing effort (almost all in the winter), it is very likely these seasonal fixed effects are confounded in part by this phenomenon.

Negative SST anomalies in spring influence higher probabilities of absent/minor barotrauma, while positive SST anomalies influence catastrophic (Figure 6). In fall, strong negative SST anomalies influence lower barotrauma scores, otherwise catastrophic barotrauma has the highest probability. SST anomalies with summer and winter had high uncertainty (93% and 431% respectively, Table 5). Spring and fall BT anomalies had the opposite relationship of SST anomalies. In spring, negative anomalies generated higher probabilities of catastrophic barotrauma and positive anomalies generated high probability of absent/minor barotrauma (Figure 7). Fall BT anomalies also had the opposite relationship from SST anomalies with an increasing chance of catastrophic barotrauma with decreasing anomaly (Figure 7). Again, summer and winter BT anomalies had high uncertainty similar to the SST anomalies (76% and 229% respectively, Table 5).

ACKNOWLEDGEMENTS

We would like to thank Sean Wilms and the samplers of the at-sea observer survey for coordinating and collecting the data utilized in this analysis. We'd also like to thank Alexander Hyman, Chloe Ramsay, and Luiz Barbieri for assistance with data filtering and analysis. Additionally, we'd like to thank all of the captains, crew, and anglers that allowed observers on trips and cooperated/assisted in data collection. Lastly, thanks to Oscar (Butch) Ayala for his fishery expertise, and inspiration in conducting this analysis. This research is funded with the help of the Fish & Wildlife Foundation of Florida via proceeds from the Koons-Ayala Marine Fisheries Research and Conservation Endowment by providing a scholarship for graduate studies at the University of Florida.

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Table 1. Barotrauma score code and corresponding symptoms as determined by FWRI’s At-Sea observer survey. Barotrauma codes are assigned to every fish measured at sea. Photos taken by L. Eguia.

<table>
<tr><th>Barotrauma Code</th><th>Definition</th><th>Example</th></tr>
<tr><td>Absent (0)</td><td>No external symptoms such as popeye, stomach extrusion or intestinal eversion. Ventral area does not feel inflated and firm to the touch, it is soft and pliable.</td><td rowspan="2"></td></tr>
<tr><td>Minor (1)</td><td>Ventral region tight or swollen (bladder/stomach), No Externally visible stomach extrusion (there may be slight stomach extrusion inside the mouth).</td></tr>
<tr><td>Intermediate (2)</td><td>Ventral region tight or swollen (bladder/stomach), Stomach extruded and visible outside mouth and/or minor intestinal extrusion, defined as less than one-inch intestines visible.</td><td></td></tr>
<tr><td>Severe (3)</td><td>Ventral region tight or swollen (bladder/stomach), Stomach extruding from mouth and/or out gill raker/plate, Exophthalmia visible-orbit still in contact with eye socket and/or major intestinal extrusion, defined as greater than one-inch of intestines visible.</td><td></td></tr>
<tr><td>Catastrophic (4)</td><td>Severe Exophthalmia-hanging by optic nerve, Scales raised, air and/or blood leaching from body, Intestinal extrusion-not required, Tight belly, and/or stomach fully extruded - may not be present, swim bladder ruptured.</td><td></td></tr>
</table>

Table 2. Release methods for Hogfish *Lachnolaimus maximus* reported by FWRI At-Sea observers in the Tampa Bay region during 2009-2024. Surface release meant that no barotrauma mitigation tools were used when releasing the fish, venting involved puncturing the gas bladder prior to release, and recompressed was for fish that were descended using various devices. *One discarded Hogfish in 2024 was vented prior to recompression. Percentages for release methods represent annual percent, while total percent represents total percent of entire time series.

	Surface Released		***Vented***		***Recompressed***		***Total***	
Year	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
2009	1	100	0	0	0	0	*1*	*0.09*
2010	0	0	0	0	0	0	*0*	*0*
2011	1	100	0	0	0	0	*1*	*0.09*
2012	2	66.67	1	33.33	0	0	*3*	*0.28*
2013	7	100	0	0	0	0	*7*	*0.66*
2014	42	93.33	3	6.67	0	0	*45*	*4.23*
2015	38	95	2	5	0	0	*40*	*3.76*
2016	42	95.45	2	4.55	0	0	*44*	*4.14*
2017	39	86.67	6	13.33	0	0	*45*	*4.23*
2018	78	96.3	3	3.7	0	0	*81*	*7.62*
2019	94	92.16	8	7.84	0	0	*102*	*9.60*
2020	8	88.89	1	11.11	0	0	*9*	*0.85*
2021	110	78.01	30	21.28	1	0.71	*141*	*13.3*
2022	185	73.71	26	10.36	40	15.94	*251*	*23.6*
2023	87	73.73	19	16.1	12	10.17	*118*	*11.1*
2024	119	68	36	20.57	20*	11.43	*175*	*16.5*
Total	**853**	**80.24**	**137**	**12.89**	**73**	**6.87**	**1063**	**100**

Table 3. Barotrauma score as a function of depth of capture of Hogfish reported by FWRI's at-sea observers in 2022-2024. Barotrauma score was based on ranked scores described in Table 1.

	Depth of Capture (m)									
	0-10		**10-20**		**20-30**		**>30**		**Total**	
Barotrauma	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Absent	6	26.09	2	0.37	0	0.00	0	0.00	***8***	***1.31***
Minor	6	26.09	33	6.03	2	5.26	0	0.00	***41***	***6.70***
Intermediate	6	26.09	81	14.81	6	15.79	1	25.00	***94***	***15.36***
Severe	3	13.04	127	23.22	14	36.84	2	50.00	***146***	***23.86***
Catastrophic	2	8.70	304	55.58	16	42.11	1	25.00	***323***	***52.78***
Total	**23**	**3.76**	**547**	**89.38**	**38**	**6.21**	**4**	**0.65**	***612***	***100***

Table 4: Release method as a function of depth of capture of Hogfish reported by FWRI's at-sea observers with barotrauma assessments in 2022-2024. Release methods are grouped the same as Table 2. *One discarded Hogfish in 2024 was vented prior to recompression. Percentages for release methods represent depth bin percent, while total percent represents total percentage of release methods.

	Depth of Capture (m)									
Release Method	**0-10**		**10-20**		**20-30**		**>30**		**Total**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Surface Released	14	66.67	276	68.66	14	58.33	0	0	***304***	***67.56***
Vented	7	33.33	60	14.93	6	25.00	1	33.33	***74***	***16.44***
Recompressed*	0	0	66	16.42	4	16.67	2	66.67	***72***	***16.00***
Total	**21**	**4.67**	**402**	**89.33**	**24**	**5.33**	**3**	**0.67**	***450***	***100***

Table 5. Parameter variables used as predictors in the barotrauma estimation model. Data came from the At-Sea Observer Program (2022-2024) and HYCOM for temperature.

Parameters	Parameter Type	Definition	Parameter Source
		Response Variables	
Barotrauma (BTC)	Categorical	**1.** Absent/Minor **2.** Intermediate **3.** Severe **4.** Catastrophic *See Table 1 for detailed definitions*	At-Sea
		Predictor Variables	
Season	Categorical	**Spring:** March, April, May **Summer:** June, July, August **Fall:** September, October, November **Winter:** December, January, February	At-Sea
Depth	Continuous	Depth in meters (m) collected by At-Sea Observers at every location	At-Sea
Fork Length (FL)	Continuous	Measurement recorded by observers to the nearest millimeter (mm) of the base of the mouth to the fork of the caudal fin	At-Sea
Sea Surface Temperature (SST)	Continuous	Temperature recorded at 0m depth to the nearest date, hour, latitude, and longitude)	HYCOM
Bottom Temperature (BT)	Continuous	Temperature recorded at bottom depth to the nearest date, hour, latitude, and longitude)	HYCOM
SST Anomaly	Continuous	Calculated by subtracting the mean SST from each season from the observed SST	HYCOM
BT Anomaly	Continuous	Calculated by subtracting the mean BT from each season from the observed BT	HYCOM
		Random Effect Variables	
FDMSamplerID	Categorical	Sampler ID assigned to every At-Sea Observer to distinguish source of data collection	At-Sea
FDMVesselID	Categorical	Unique 7-digit code to identify individual vessels on which observers collect data	At-Sea
VesselType	Categorical	**H:** Headboat – includes multi day trips (typically denoted as **M**) **C:** Private charter	At-Sea

Table 6. Posterior parameter estimates of fixed and random effects from Bayesian Mixed Effects Ordinal Regression Model. For each parameter, we report the median, lower and upper 95% credible interval (CI), the probability of direction (PD), the percent of the 95% credible interval in the region of practical equivalence (-0.18,0.18; ROPE), the $\hat{R}$ statistic, and effective sample size (ESS). Probabilities of direction close to one indicate the posterior is strongly negative or positive. High percent in ROPE indicates posteriors are poorly distinguishable from an effect size of zero.

Parameter	Median	Lower CI	Upper CI	PD	ROPE	$\hat{R}$	ESS
Intercept[1]	-2.869	-6.211	0.451	0.951	1.93%	1.001	8717
Intercept[2]	-1.080	-4.430	2.215	0.741	7.14%	1.001	8827
Intercept[3]	0.538	-2.823	3.823	0.629	8.83%	1.001	8851
Log(Depth)	0.249	-0.933	1.406	0.664	23.55%	1.001	9058
Fork Length	-0.575	-0.771	-0.388	1.000	0.00%	1.000	8701
SST Anomaly	1.353	0.316	2.624	0.996	0.00%	1.000	4560
Spring	-0.138	-1.308	1.061	0.592	23.93%	1.000	6894
Summer	-2.353	-3.431	-1.357	1.000	0.00%	1.000	4483
Winter	0.754	0.244	1.267	0.998	0.00%	1.001	7407
BT Anomaly	-1.087	-2.309	-0.100	0.985	1.53%	1.000	4483
SST Anomaly: Spring	11.863	4.519	19.882	1.000	0.00%	1.001	4567
SST Anomaly: Summer	-3.674	-10.645	2.957	0.860	2.57%	1.000	4157
SST Anomaly: Winter	0.652	-4.717	5.867	0.602	5.22%	1.001	4848
BT Anomaly: Spring	-12.839	-21.504	-4.986	1.000	0.00%	1.001	4470
BT Anomaly: Summer	4.820	-2.239	12.353	0.908	1.82%	1.000	4118
BT Anomaly: Winter	-1.248	-6.697	4.318	0.677	5.00%	1.001	4902

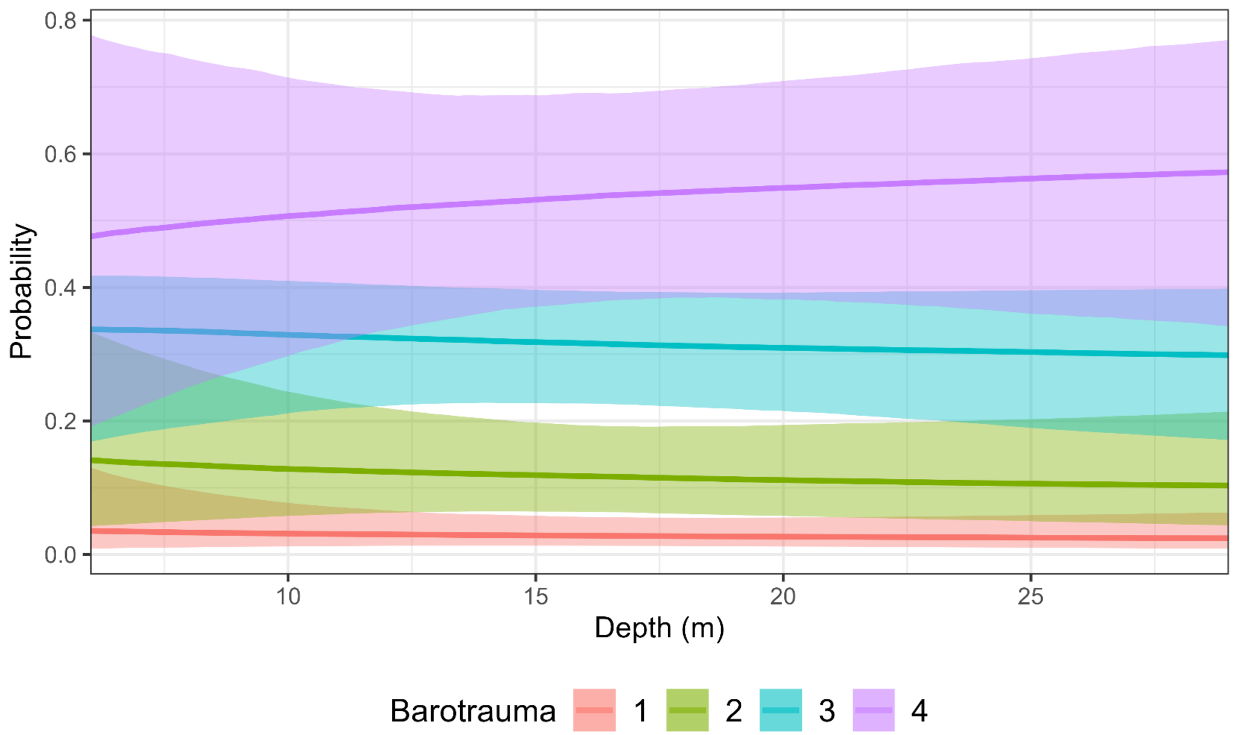

Figure 1: Bayesian Mixed Effects Ordinal Regression Model prediction of probability of barotrauma score as a function of depth.

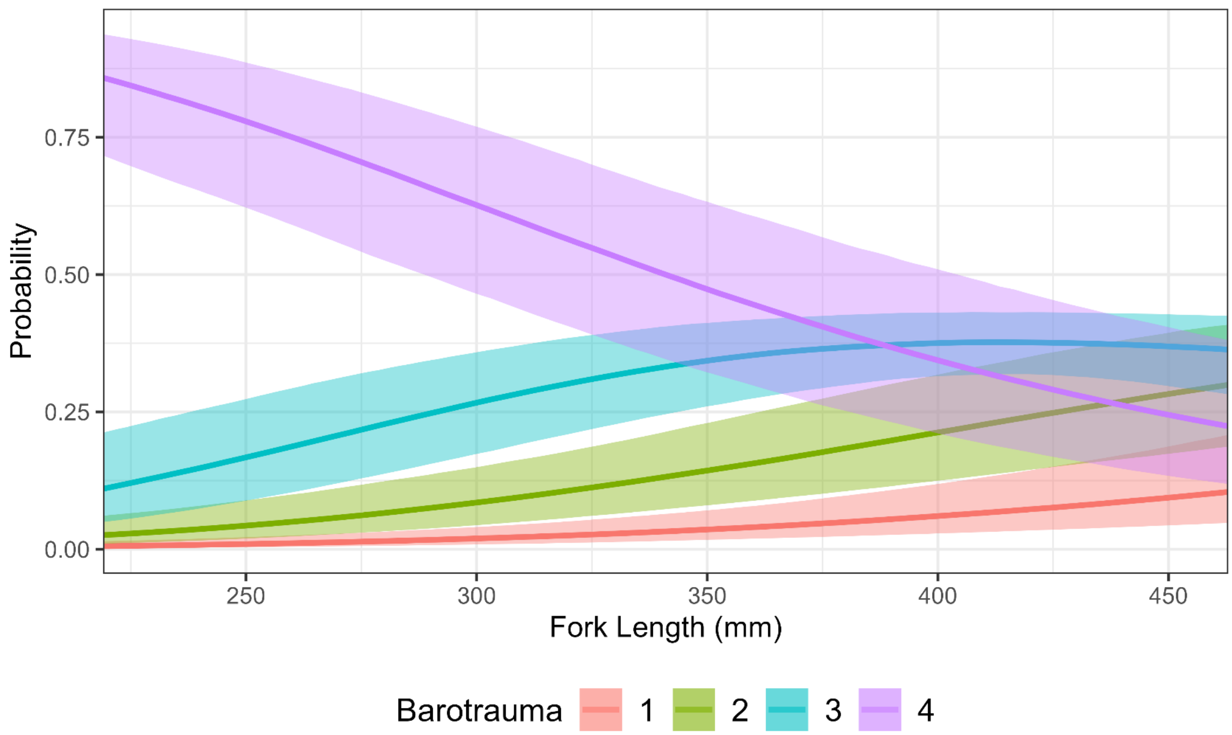

Figure 2: Bayesian Mixed Effects Ordinal Regression Model prediction of probability of barotrauma score as a function of fork length.

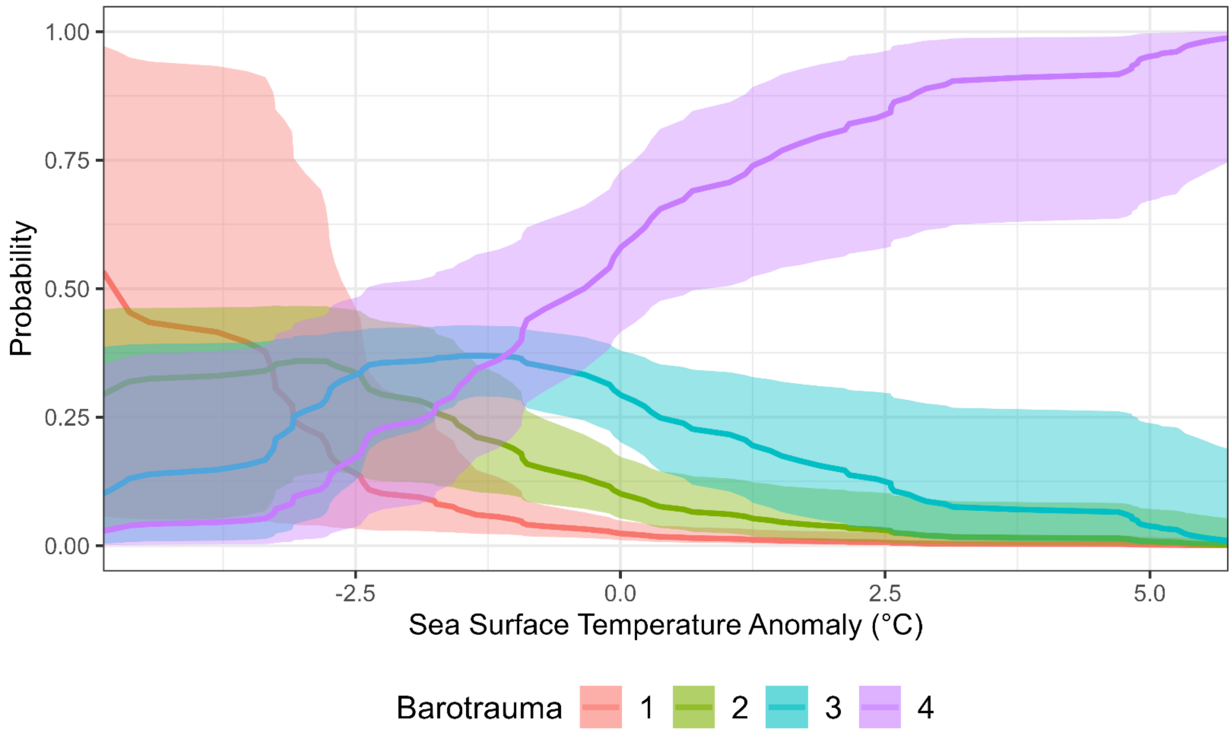

Figure 3: Bayesian Mixed Effects Ordinal Regression Model prediction of probability of barotrauma score as a function of sea surface temperature anomaly.

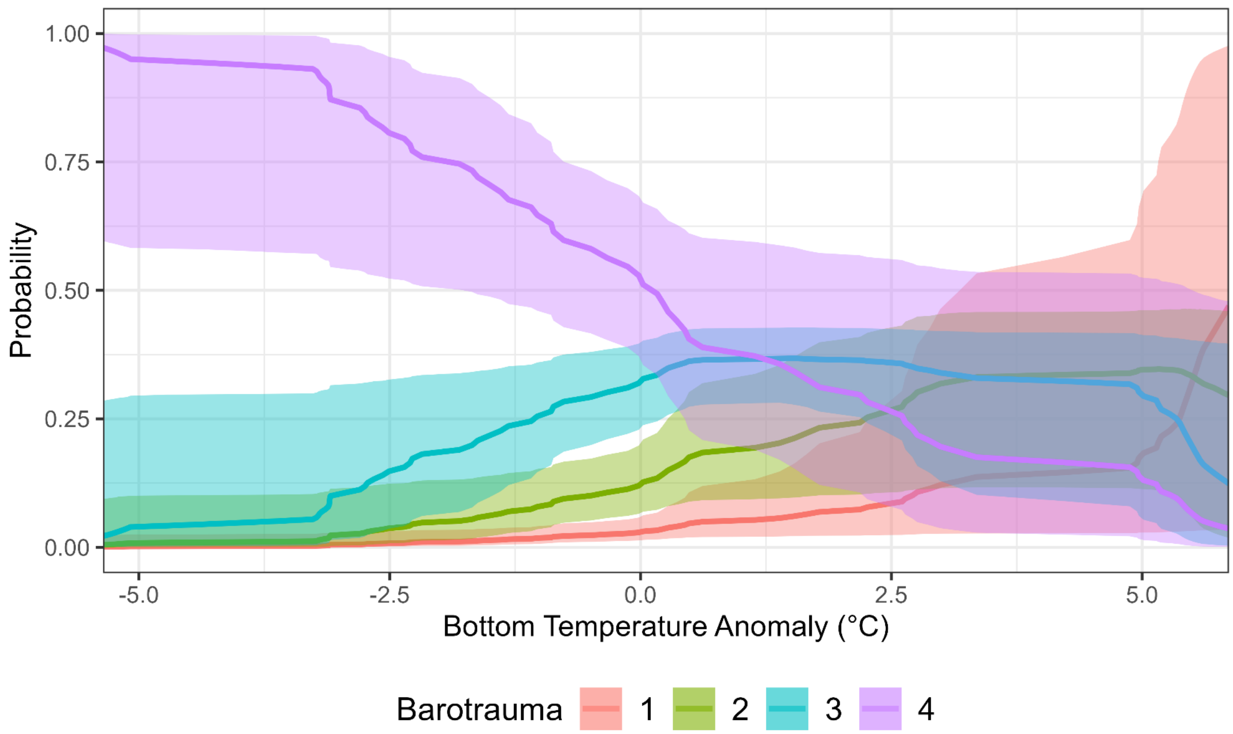

Figure 4: Bayesian Mixed Effects Ordinal Regression Model prediction of probability of barotrauma score as a function of bottom temperature anomaly.

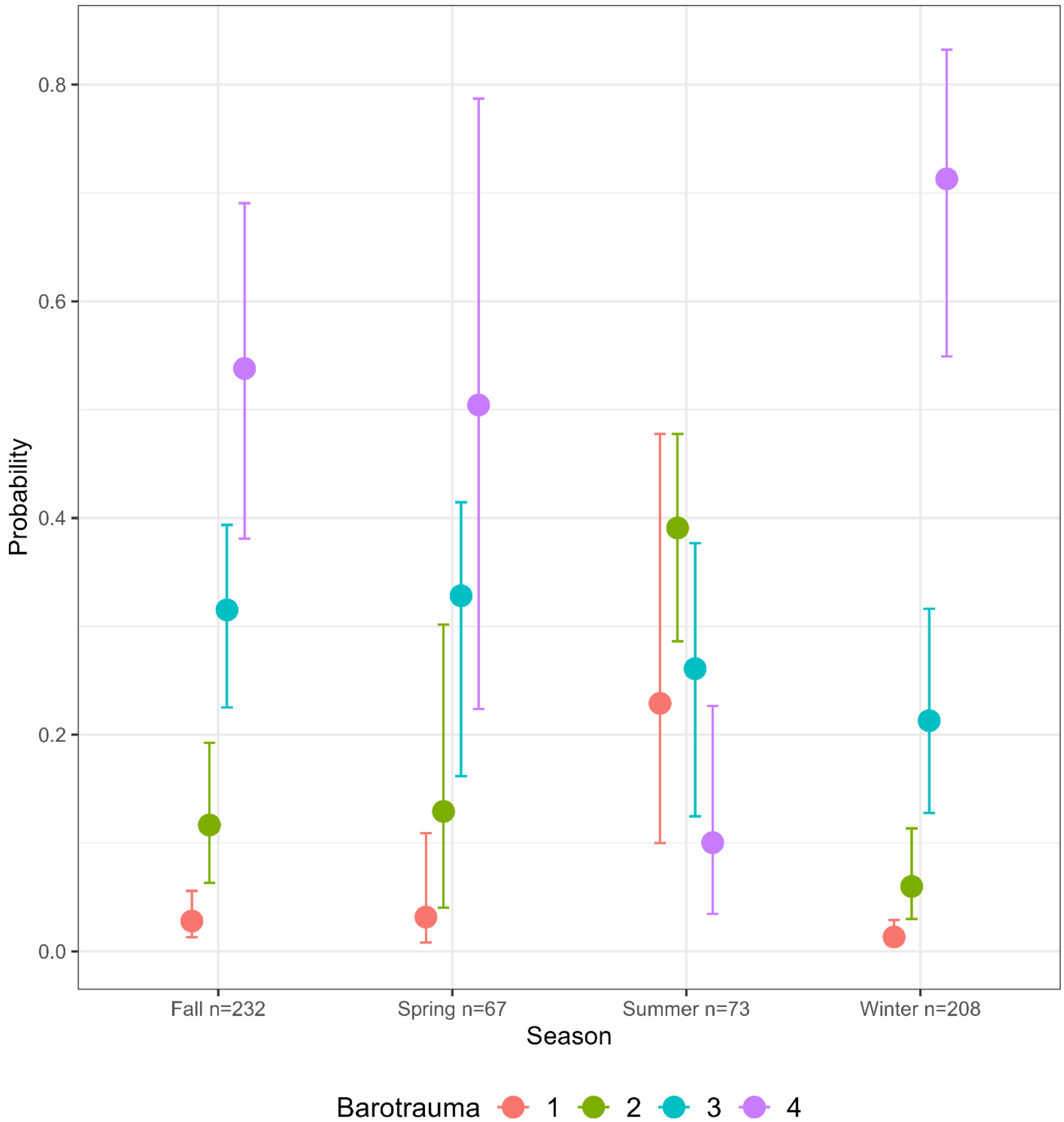

Figure 5: Bayesian Mixed Effects Ordinal Regression Model prediction of probability of barotrauma score as a function of season.

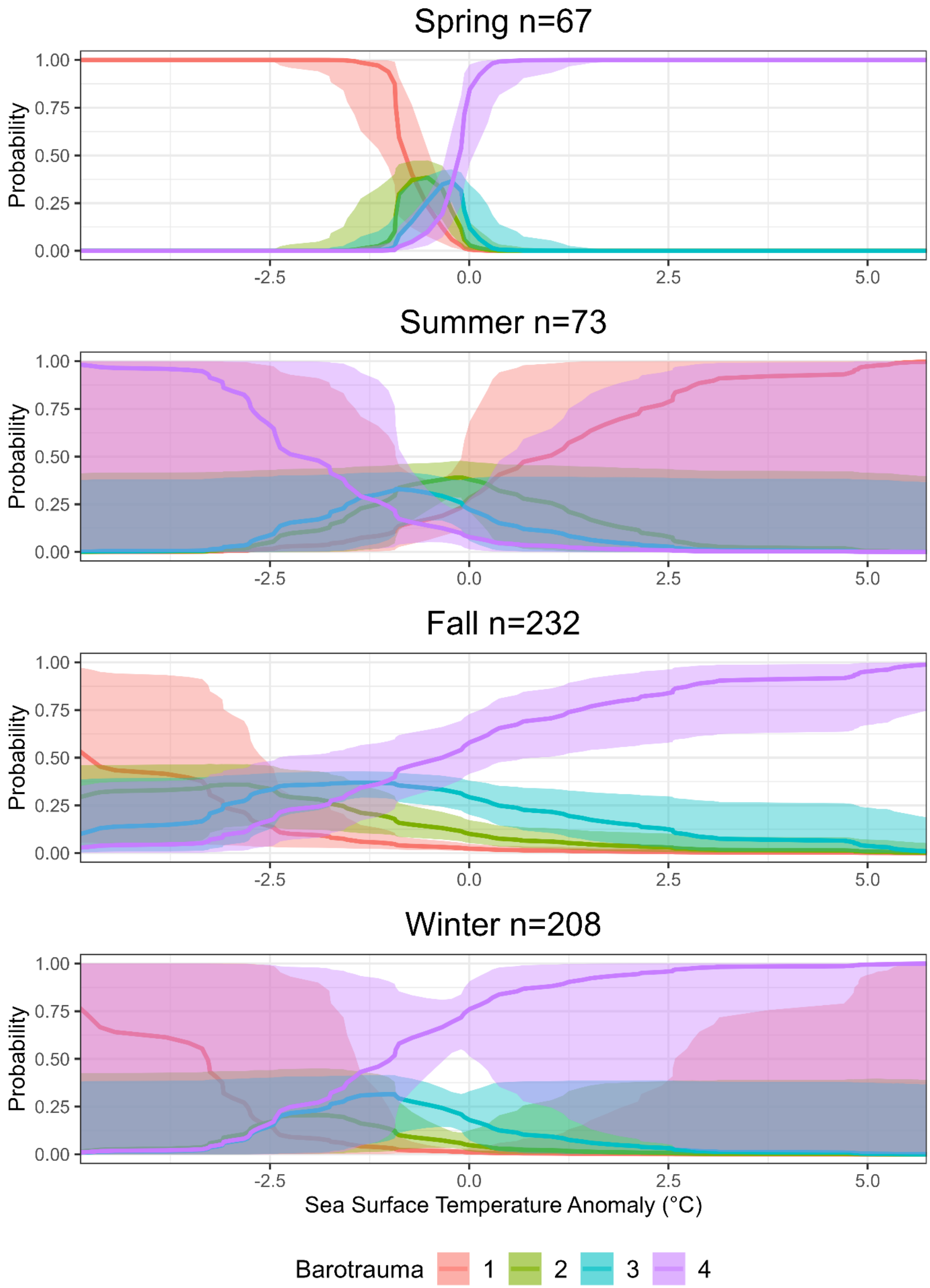

Figure 6: Bayesian Mixed Effects Ordinal Regression Model prediction of probability of barotrauma score as a function of sea surface temperature in each season.

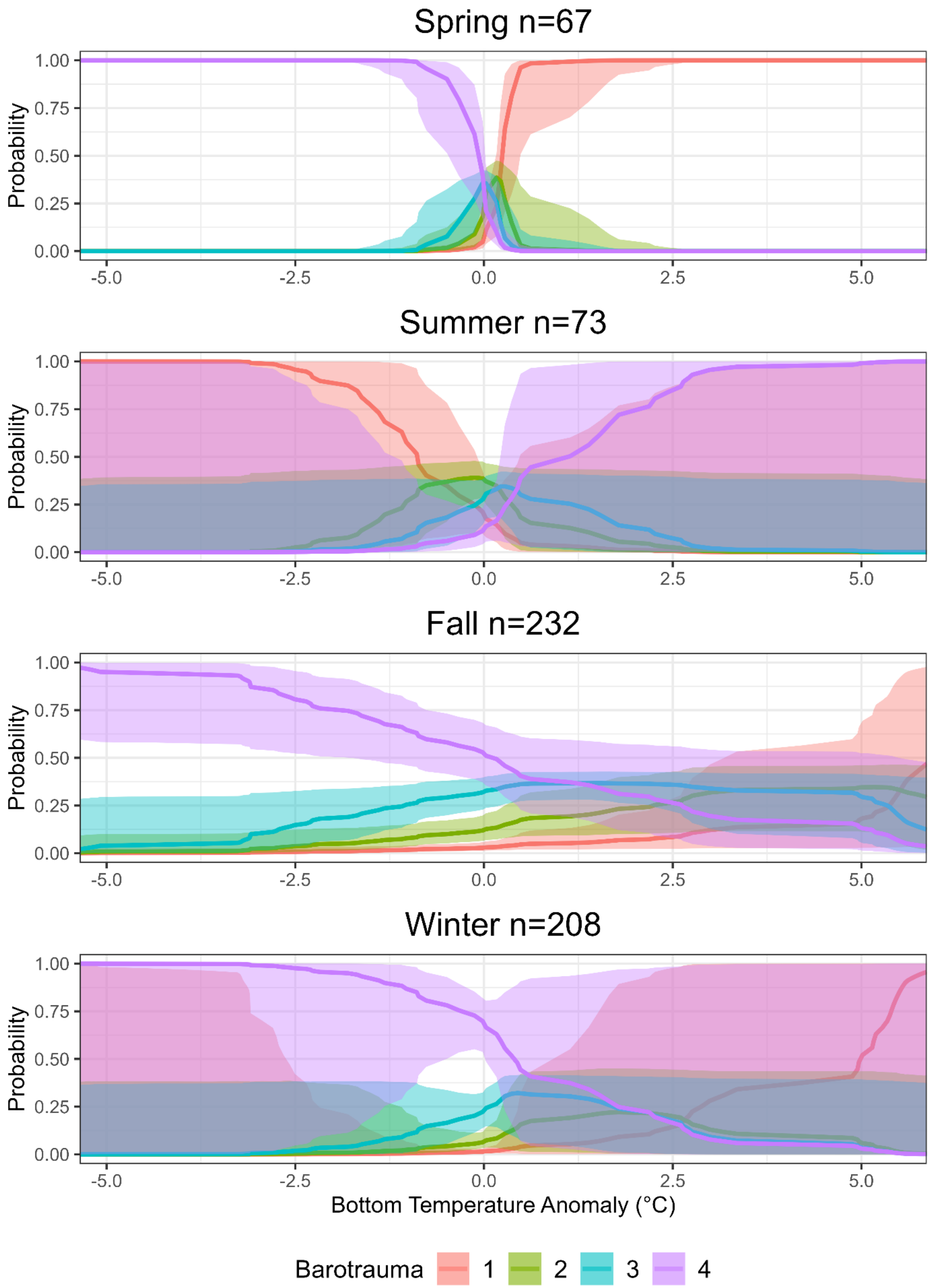

Figure 7: Bayesian Mixed Effects Ordinal Regression Model prediction of probability of barotrauma score as a function of bottom temperature in each season.