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ARTICLE

Understanding Recreational Angler Diversity and Its Potential Implications on Promoting Responsible Fishing Practices in a Multispecies Gulf of Maine Fishery

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Abstract

Recent work in the Gulf of Maine multispecies recreational fishery has established responsible fishing practices that anglers can use to reduce bycatch and the discard mortality of three key groundfish species. However, anglers represent a diverse stakeholder group whose backgrounds and experiences may influence how they receive, support, and adopt responsible fishing practices that aim to sustain catch-and-release angling opportunities. We therefore surveyed Gulf of Maine recreational anglers who target groundfish, including Atlantic Cod *Gadus morhua*, Haddock *Melanogrammus aeglefinus*, and Cusk *Brosme brosme*, to assess whether differences among anglers influenced how likely anglers were to voluntarily adopt or consider adopting responsible fishing practices and which information channels they used to obtain such information. By broadly sampling Gulf of Maine recreational fishing license holders via an online survey, we collected responses from 306 respondents who targeted groundfish in some capacity; several topics, including fishing activity and experience, responsible fishing practices, information channels, and sociodemographics, were addressed in the survey. A latent class cluster analysis found that respondents who participate in this

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regional fishery can be broadly categorized into three distinct classes (Striped Bass [*Morone saxatilis*] Enthusiasts, All-rounders, and Offshore Groundfishers) from their primary fishing mode and target species. Despite the presence of these latent classes, class membership did not affect how likely respondents were to voluntarily adopt or consider adopting species-specific fishing practices from previous scientific investigations. However, class membership was observed to influence how respondents used information channels to receive angling information, with Offshore Groundfishers relying more often on captains and crew than the other classes. Therefore, to promote responsible fishing practices alongside regulations, we recommend that fishery managers use a mixed outreach program to effectively communicate and engage with this portion of the community until more directed studies can be conducted.

Recreational fishing (i.e., angling) is a popular outdoor activity worldwide that yields numerous socioeconomic benefits to its participants (FAO 2012; Tufts et al. 2015). Despite these gains, fishing mortality from recreational fisheries is increasingly recognized as a major source of mortality for many freshwater and coastal marine fish stocks (Post et al. 2002; Cooke and Cowx 2004; Brownscombe et al. 2019). In an effort to reduce their impact, recreational anglers often release fish, either voluntarily or in accordance with management regulations, in a practice called catch-and-release angling (Cooke and Wilde 2007). However, the utility of catch-and-release angling as a management tool relies on the premise that released fish survive. Although fish may appear healthy and vigorous upon release, the capture, handling, and release process may cause mortality (i.e., discard mortality) or reduced biological fitness from physical injuries and physiological disturbances (reviewed by Arlinghaus et al. 2007). As such, directed investigations on catch-and-release angling are often conducted to identify which factors influence discard mortality and to establish responsible fishing practices that anglers can adopt to (1) reduce the incidental capture of nontarget species (i.e., bycatch); or (2) if bycatch is unavoidable, reduce the discard mortality of and associated impacts on nontarget species (Cooke and Suski 2005; Brownscombe et al. 2017).

The true value of catch-and-release angling depends not only on estimated discard mortality rates for a given species or fishery and the development of responsible fishing practices for reducing such mortality but also on how effectively these fishing practices are disseminated and then adopted by recreational anglers (Nguyen et al. 2012; Cooke et al. 2013). Although they are capable of negatively impacting the health of individual fish and populations as well as aquatic ecosystems (Cooke and Cowx 2004), anglers can be instrumental in achieving fishery sustainability if they are properly informed and open to changes in angling behavior (Cooke et al. 2013; Elmer et al. 2017). Anglers, however, are a diverse stakeholder group whose members come from different sociodemographic and angling backgrounds and express a range of beliefs and attitudes (Shafer 1969; Fisher 1997; Salz and Loomis 2004) that can influence how likely they are to voluntarily adopt or consider responsible fishing practices (e.g., Nguyen et al. 2013; Scyphers et al. 2013; Curtis et al. 2019). Moreover, even if they are likely to voluntarily adopt such practices, anglers use a variety of channels (e.g., online and print media; word of mouth) to receive angling-related information, which complicates effective outreach efforts (e.g., Nguyen et al. 2012). Therefore, if management agencies aim to engage with this stakeholder group and promote the use of responsible fishing practices alongside regulations, it is critical to first understand angler views toward voluntarily adopting responsible fishing practices and then effectively target them through strategic communication (Arlinghaus et al. 2007; Cooke et al. 2013).

This is especially relevant for recreational fisheries in which responsible fishing practices have been recently generated or refined to sustain catch-and-release angling opportunities. For instance, in the U.S. Gulf of Maine multispecies recreational fishery for "groundfish," which primarily targets Atlantic Cod *Gadus morhua* and Haddock *Melanogrammus aeglefinus*, anglers frequently release fish in compliance with strict size, possession, and seasonal regulations. Consequently, directed catch-and-release studies were recently conducted to derive discard mortality rate estimates and identify responsible fishing practices for several ecologically important stocks, including Atlantic Cod (Capizzano et al. 2016, 2021), Haddock (Capizzano et al. 2019), and Cusk *Brosme brosme* (Capizzano 2020). These recommended fishing practices were then widely disseminated to the Gulf of Maine angling community through various information channels operated by federal, state, academic, and nonprofit organizations. Given the critically depleted state of Gulf of Maine Atlantic Cod (NEFSC 2017) and the Cusk's designation as a species of concern (NOAA 2007), the use of these responsible fishing practices is crucial to mitigating the threat of discard mortality in this fishery. However, no study to date has evaluated the likelihood that Gulf of Maine anglers would voluntarily adopt these fishing practices or the most effective channels through which to reach these individuals.

The goal of this study was to explore diversity among anglers in the Gulf of Maine groundfish fishery and understand whether such differences can be used to derive and disseminate effective educational materials on responsible

catch-and-release fishing practices. To this end, we conducted a study as part of a larger survey to query Gulf of Maine anglers who target groundfish, specifically on (1) how likely they are to voluntarily adopt or consider species-specific responsible fishing practices and (2) what channels they use to receive information about fisheries. Because distinct types of anglers can exist in a fishery (e.g., Nguyen et al. 2012, 2013), we used latent class cluster analysis to identify and characterize anglers into distinct "classes" based on differences in their fishing behavior and ultimately to determine whether class membership influenced responses to survey questions on responsible fishing practices and information channels. Our results will guide management and sustainability efforts when promoting responsible fishing practices to the Gulf of Maine angling community.

METHODS

Online survey.— The Gulf of Maine recreational angling community was broadly sampled via an online survey to query anglers who catch groundfish. We sought e-mail addresses for recreational anglers who held fishing licenses in 2019 from the marine resources division of each U.S. state bordering the Gulf of Maine—specifically, Massachusetts (MA), New Hampshire (NH), and Maine (ME). We obtained records and e-mail addresses for 118,653 recreational anglers from MA ($n = 118{,}003$) and ME ($n = 504$). E-mail addresses could not be obtained for NH recreational anglers due to information sharing restrictions. To adequately sample a representative portion of the angling community that targeted groundfish, a two-wave phased approach was used to send online survey invitations to over 20,000 anglers with valid e-mail addresses. The first wave randomly subsampled 1,000 MA anglers to pilot the survey's format and content and examine the prevalence of groundfish anglers among this subsample. Based on the observed response rate for anglers who target groundfish (~2%), the second wave randomly subsampled 19,000 additional MA anglers and all 504 ME anglers. To incentivize participation, survey recipients could enter in a gift card raffle (US$25 value) to Bass Pro Shops. Each survey wave was active for a 2-week period between February and March 2020, and four e-mail reminders were sent to invitees throughout each wave to promote responses. Our survey was approved by the University of MA Boston's Institutional Review Board (Number 2020005) and administered online by using Qualtrics Survey Software Research Suite.

All survey participants were asked a series of questions spanning four general categories: (1) fishing characteristics, (2) responsible fishing practices, (3) information channels, and (4) sociodemographics (Table 1; see the Appendix for the survey instrument). In section 1 of the survey, fishing activity and experience questions described an angler's participation in the Gulf of Maine recreational fishery, years of fishing experience, average number of days fished per year (i.e., avidity), primary fishing mode via percent time on various modes (i.e., private = shore and private vessels; for-hire = party and charter vessels; or no preference), and targeted species and group (e.g., groundfish, highly migratory species, etc.). We used responses in this section to screen out anglers who did not target groundfish in the Gulf of Maine (similar to Murphy et al. 2015). Section 2 (responsible fishing practices) evaluated the extent to which participants would adopt or consider tools and tactics designed to reduce mortality risk for Atlantic Cod, Haddock, and Cusk. Participants were first informed of findings from recent Gulf of Maine catch-and-release studies—specifically which factors influence bycatch and discard mortality and what recommendations were established to reduce mortality risk in each species. Next, on a five-point Likert scale, participants were asked how likely they were to voluntarily adopt or consider adopting three species-specific practices that were recommended by recent studies: (1) using baited hooks for Atlantic Cod (Capizzano et al. 2016, 2021); (2) fishing during cooler times of year for Haddock (Capizzano et al. 2019); and (3) using descending devices to release Cusk (Capizzano 2020). Section 3 assessed which information channels anglers typically use to receive angling-based information. The survey concluded with a set of sociodemographic questions (section 4) to record the gender, age, highest level of education, total household income, and state of residence (via ZIP code) of the participants. Although participants were asked other questions as part of a larger project, only this subset of questions is presented given the study's objectives.

Data analysis.— Following the procedures outlined by Nguyen et al. (2012, 2013), we carried out a two-step analysis to explore heterogeneity among anglers in this fishery and to understand whether such differences could impact views toward sustainable fishing practices and the use of information channels. We first used the latent class cluster analysis to characterize distinct angler typologies with respect to their fishing attributes and behaviors. Latent class cluster analysis is an exploratory statistical technique that has become increasingly popular among researchers for its ability to identify and describe latent classes, or "hidden groups," within a population by using responses from two or more categorical variables (Nylund-Gibson and Choi 2018). In comparison to other cluster analysis techniques, like k-means clustering, latent class cluster analysis is model based, where cases are classified into mutually exclusive classes using membership probabilities (Vermunt and Magidson 2002). Therefore, because managing fish involves managing people and their behaviors (Hilborn 2007), fisheries researchers have begun using latent class cluster analysis to distinguish angler typologies and understand how such heterogeneity impacts angler responses to

TABLE 1. Summary of survey questions by general category.

Category	Question	Response
1. Fishing activity and experience	1. Participation in Gulf of Maine fishing	Multiple choice
	2. Port/state of origin	Multiple choice
	3. Fishing experience (years)	Numeric entry
	4. Avidity (d/year)	Numeric entry
	5. Percent time on fishing mode	Numeric entry
	6. Target species/groups	Select all
	7. Primary target species/groups	Multiple choice
2. Responsible fishing practices	How likely to *[practice]* to reduce impacts in [species]	
	1. *Fish at times of the year with cooler temperatures*; Haddock	Multiple choice
	2. *Use baited hooks*; Atlantic Cod	Multiple choice
	3. *Use descending devices*; Cusk	Multiple choice
3. Information channel use	1. Current information channels	Select all
4. Sociodemographics	1. Age	Multiple choice
	2. Gender	Multiple choice
	3. Highest level of education	Multiple choice
	4. Total household income	Multiple choice
	5. ZIP code	Numeric entry

management actions and sustainability efforts (e.g., Morey et al. 2006; Nguyen et al. 2012, 2013; Tingley et al. 2019).

We estimated latent classes of anglers based on their fishing characteristics using maximum likelihood via the expectation maximization algorithm in the software package Latent GOLD version 5.1 (Vermunt and Magidson 2016). However, before selecting the most appropriate model from the latent class cluster analysis, we first had to decide on the number of classes and then had to decide on the form of the model given the number of classes (Vermunt and Magidson 2002; Nylund-Gibson and Choi 2018). Therefore, to determine the number of mutually exclusive classes and which variables to include, we initially analyzed latent class models with one to five classes as well as five variables of fishing experience and activity (1.3–1.7; Table 1) that were converted into nominal variables with broad groupings (see Table 2). Based on recommendations by Nylund et al. (2007), we used the Bayesian information criterion (BIC) to guide model selection given its ability to penalize overfitting and yield the most parsimonious model (Schwarz 1978). Model fit was then evaluated using the bootstrapped likelihood-ratio chi-square statistic (L^2), where, in this case, a P-value greater than 0.05 indicated an adequate fit. If, however, the model with the number of classes that minimized the BIC did not provide the "best" fit, we compared the fit of neighboring class models (i.e., comparing $k - 1$ and k-class models) using the bootstrapped likelihood-ratio test. In addition to global measures of model fit, we inspected the assumption of local independence between variables by using bivariate residuals (BVRs). Generally, significant BVRs ($x^2 > 3.84$, df = 1, $P < 0.05$) indicate that the model does not provide a good fit to the data because correlations between variable pairs have not been adequately explained (Vermunt and Magidson 2003). As such, we eliminated significant local interactions by sequentially removing variables with the highest number of significant BVRs until resulting values were less than 2 units (Nguyen et al. 2012, 2013; Schreiber 2017). Finally, we assigned individual anglers to their most probable class by using posterior probabilities of membership from the final latent class model.

The second step of the analysis used univariate statistical tests to explore relationships among angler classes and the remaining survey questions (similar to Nguyen et al. 2013). Specifically, we used a series of Pearson's chi-square frequency tests to evaluate the influence of angler class on how likely the anglers were to voluntarily adopt or consider adopting responsible fishing practices (2.1–2.3; Table 1) and the use of specific information channels for receiving information (3.1; Table 1). When appropriate, Bonferroni-adjusted pairwise comparisons were applied to further determine which angler classes statistically differed in their response to specific questions. All frequency and subsequent pairwise comparisons were conducted in R version 4.0.2 (R Core Team 2020). Unless otherwise stated, data were considered statistically significant at $P < 0.05$ for all analyses.

RESULTS

Survey Response and Sample Descriptive Statistics

We collected a total of 1,938 responses across both survey waves. Although a pool of 20,500 survey invitations was sent to recreational license holders from MA and ME,

TABLE 2. Responses of Gulf of Maine survey participants who targeted groundfish ($n = 306$). Response frequencies (n) and percentages (%) only refer to sociodemographic and fishing activity and experience questions (see Table 1). The fishing activity and experience questions were then used in a latent class cluster analysis to identify angler classes.

Question	n	%	Question	n	%
Sociodemographics					
Gender ($n = 283$)			Education level ($n = 284$)		
Male	265	93.6	High school or less	33	11.6
Female	18	6.4	Some college	59	20.8
			2-year college degree	27	9.5
Age ($n = 287$)			4-year college degree	99	34.9
18–29	17	5.9	Postgraduate	66	23.2
30–39	48	16.7			
40–49	67	23.3	Household income (US$; $n = 248$)		
50–59	71	24.7	<$20,000	0	0
60–69	65	22.6	$20,000–39,999	10	4.0
≥70	19	6.6	$40,000–59,999	18	7.3
			$60,000–79,999	37	14.9
Gulf of Maine resident[a] ($n = 275$)			$80,000–99,999	33	13.3
Yes	261	94.9	$100,000–149,999	73	29.4
No	14	5.1	≥$150,000	77	31.0
Fishing activity and experience					
Fishing experience ($n = 306$)			Primary fishing mode[b] ($n = 306$)		
<5 years	36	11.8	Private modes	246	80.4
5–9 years	35	11.4	For-hire modes	27	8.8
10–19 years	78	25.5	No primary mode	33	10.8
≥20 years	157	51.3			
			Primary target species ($n = 306$)		
Avidity ($n = 306$)			Groundfish species	95	31.0
<10 d/year	75	24.5	Striped Bass	164	53.6
10–29 d/year	143	46.7	Other species	47	15.4
≥30 d/year	88	28.8			
			Other target species ($n = 306$)		
			None	12	3.9
			Single other species	41	13.4
			Multiple other species	253	82.7

[a]Gulf of Maine residents included respondents who lived in Massachusetts, New Hampshire, or Maine. Respondents residing outside of the Gulf of Maine states included those from Arizona, Florida, Maryland, Michigan, New York, Pennsylvania, and Rhode Island.

[b]Private modes included shore/pier and private vessels.

only 7,558 e-mail invitations were opened, resulting in an adjusted response rate of 26%. Only 6% ($n = 452$) of anglers who responded to the survey indicated that they targeted groundfish in the Gulf of Maine to some extent. Of these survey participants, a final sample of 306 respondents was retained given that the latent class cluster analysis could only assess records with complete information. As such, all results presented herein relate to this sample of 306 respondents.

Respondents were overwhelmingly similar across various sociodemographics and fishing characteristics (Table 2). Nearly 95% of survey respondents resided in states surrounding the Gulf of Maine (i.e., MA, NH, and ME), 94% were male, and 71% were between the ages of 40 and 69. Many of these respondents possessed a 4-year college degree or higher (58%) and had a total household income of over $100,000 (60%). With respect to fishing activity and experience, over 80% of respondents indicated that they primarily fished from private modes (i.e., shore and private vessels) and averaged 28 years of fishing experience and 25 d of fishing per year. Furthermore, while all respondents targeted groundfish in some capacity, only 31% ($n = 95$) primarily targeted groundfish, while the remainder primarily targeted other species, including Striped Bass *Morone saxatilis* (54%), Atlantic Mackerel *Scomber scombrus* (5%), Bluefish *Pomatomus saltatrix* (2%), and Black Sea Bass *Centropristis striata* (2%), or groups of species, such as regionally specific flatfish (4%) and highly migratory species (3%).

Latent Class Cluster Analysis

The latent class cluster analysis was conducted using data on fishing activity and experience—specifically, years of experience, avidity, primary fishing mode, number of target species, and primary target species. Based on these variables, we initially chose a model with three classes for segmenting Gulf of Maine anglers who target groundfish (Table 3). Although a two-class model produced the lowest BIC value, the bootstrapped likelihood-ratio test indicated that a three-class model provided a statistically better fit to the data, which was supported by the decreasing L^2 statistic and associated nonsignificant P-value. Calculated BVRs were well below the conservative threshold of 2, and so the final, three-class model retained all five variables of fishing activity and experience.

Using posterior probabilities of class membership from the final three-class model, we labeled respondents as "Striped Bass Enthusiasts" (53%), "All-rounders" (35%), or "Offshore Groundfishers" (12%; Table 4; Figure 1). Striped Bass Enthusiasts typically fished from shore and private vessels (i.e., private modes) and targeted multiple species but indicated Striped Bass as their primary target species. All-rounders similarly fished from private modes but were more split on their primary target species, focusing somewhat equally on Striped Bass, groundfish, and other species. Although respondents in this group targeted multiple species other than groundfish, the All-rounders class also included respondents that focused their fishing effort on groundfish and a single other species. Finally, the majority of Offshore Groundfishers fished using for-hire modes (e.g., party and charter vessels) and primarily targeted groundfish species. Striped Bass Enthusiasts fished at least 30 d/year, while the remaining classes were less avid, fishing less than 29 d/year on average. All classes were mainly composed of respondents with over 20 years of fishing experience, but All-rounders had the greatest percentage of respondents with less than 5 years of fishing experience.

Responsible Fishing Practices

Most Gulf of Maine respondents from each class in the latent class analysis were likely to voluntarily adopt or consider adopting responsible fishing practices for Atlantic Cod and Cusk and, to a lesser extent, Haddock. For instance, over 88% of respondents said that they were likely to use baited hooks to reduce Atlantic Cod bycatch, while nearly 70% said that they were likely to use descending devices to mitigate Cusk discard mortality. Although 53% of respondents were likely to consider fishing at times of the year with cooler temperatures to reduce Haddock discard mortality, roughly 44% indicated that they were indifferent toward this information. Pearson's chi-square frequency tests concluded that angler classes did not significantly influence how likely the respondents were to voluntarily adopt or consider adopting responsible fishing practices for Atlantic Cod ($P = 0.24$), Haddock ($P = 0.25$), and Cusk ($P = 0.78$).

Information Channels

We found that respondents used a variety of channels to receive angling-related information. When asked whether they used a specific information channel or not, 79% of respondents indicated that they used online Web sites. The next most popular information channels included other members of the angling community (53%), tackle shops (50%), friends and family (46%), e-mail blasts/listservs (35%), newspapers and magazines (32%), social media (30%), for-hire captains and crew members (21%), television and YouTube (16%), and podcasts and radio talk shows (4%). Frequency test analyses determined that angler classes significantly differed only in their use of captains and crew members for information ($\chi^2 = 44.7$, df = 2, $P < 0.001$; Figure 2). Offshore Groundfishers used captains and crew members significantly more than did Striped Bass Enthusiasts ($P < 0.001$) and All-rounders ($P < 0.001$), whereas usage rates did not statistically differ between these latter two classes.

DISCUSSION

Angler Classes

Our results suggest that respondents who participate in the Gulf of Maine recreational groundfish fishery display fishing behaviors that can be categorized into three classes

TABLE 3. Fit statistics of latent class cluster models with one to five classes (LL = log-likelihood; BIC = Bayesian information criterion; N_{par} = number of parameters; L^2 = likelihood-ratio chi-square statistic; df = degrees of freedom; P = significance value from L^2; Class Err = classification error). The model with the lowest BIC value is presented in italics, while the final selected model is shown in bold.

Model	LL	BIC	N_{par}	L^2	df	P	Class Err
1 class	−1,351.8233	2,766.6061	11	319.7235	295	0.15	0.0000
2 classes	*−1,275.7471*	*2,683.1367*	*23*	*167.5711*	*283*	*1.00*	*0.0862*
3 classes	**−1,261.1587**	**2,722.643**	**35**	**138.3944**	**271**	**1.00**	**0.1944**
4 classes	−1,251.7477	2,772.5039	47	119.5723	259	1.00	0.1682
5 classes	−1,243.9079	2,825.5074	59	103.8927	247	1.00	0.1595

TABLE 4. Response percentages for Gulf of Maine survey participants belonging to three angler classes. The latent class membership of respondents who targeted groundfish ($n = 306$) was dictated by fishing activity and experience (see Table 1)—specifically, primary fishing mode and target species.

Variable or indicator	Class 1: Striped Bass Enthusiast	Class 2: All-rounder	Class 3: Offshore Groundfisher
Class size (%)	53.1	34.6	12.3
Indicators			
Fishing experience			
<5 years	5.6	22.5	8.4
5–9 years	12.3	10.9	9.2
10–19 years	28.8	18.8	30.1
≥20 years	53.4	47.8	52.4
Avidity			
<10 d/year	8.9	38.3	53.1
10–29 d/year	37.7	60.6	46.6
≥30 d/year	53.4	1.1	0.3
Primary fishing mode			
Private mode	99.1	73.7	18.3
For-hire mode	0.0	6.3	53.9
No primary mode	0.9	20.0	27.8
Primary target species			
Groundfish species	12.7	35.4	98.2
Striped Bass	74.0	40.9	1.2
Other species	13.4	23.7	0.6
Target species other than groundfish			
None	0.0	0.0	31.8
Single other species	3.9	23.3	26.7
Multiple other species	96.1	76.7	41.5

based on their primary fishing mode and target species. In general, we found that Striped Bass Enthusiasts and All-rounders preferred to target Striped Bass from shore and on private vessels, whereas Offshore Groundfishers primarily targeted groundfish by using for-hire vessels. Although all respondents targeted groundfish in some capacity, it is interesting that each class consisted of individuals who opportunistically caught other species aside from their preferred target species. Such opportunistic fishing behavior was also observed by Salz et al. (2001), as MA anglers primarily targeting Atlantic Cod aboard for-hire (e.g., party) vessels often targeted other species, like Striped Bass and Bluefish. However, while Salz et al. (2001) surmised that these anglers placed greater emphasis on catching any fish as a condition for a successful fishing trip, we are unable to confirm or deny these observations given our survey instrument and responses.

Responsible Fishing Practices

Despite the existence of distinct classes, most respondents were likely to voluntarily adopt or consider adopting alternative terminal tackle types to reduce Atlantic Cod bycatch and descending devices to reduce Cusk discard mortality. Although this trend may be partly attributable to the sample of anglers surveyed (see "Survey Limitations" section below), we speculate that this result may be due to anglers' beliefs about which factors threaten fish survival (i.e., threat perceptions). For instance, responses to a supplementary question on fish survival indicated that many respondents had varying beliefs on which factors are harmful (i.e., likely to impact survival) to groundfish during fishing. When asked to select all factors that were harmful to groundfish, most respondents indicated that time out of water (77%), injuries sustained by fish (70%), and depth of capture (65%) are of principal concern for fish survival, followed by angler experience (53%) and the type of tackle used (49%). Such findings are similar to those of Scyphers et al. (2013); in that study, anglers who were most likely to use venting tools and techniques to release offshore reef fish were those who perceived these practices to benefit the survival of fish experiencing pressure-induced injuries (barotrauma).

Such threat perceptions could also suggest why a large portion of respondents (44%) were indifferent or much less inclined to consider fishing at times of the year with cooler water temperatures to reduce Haddock discard mortality. For example, in the same multiple selection question on factors that were harmful to groundfish, only a small

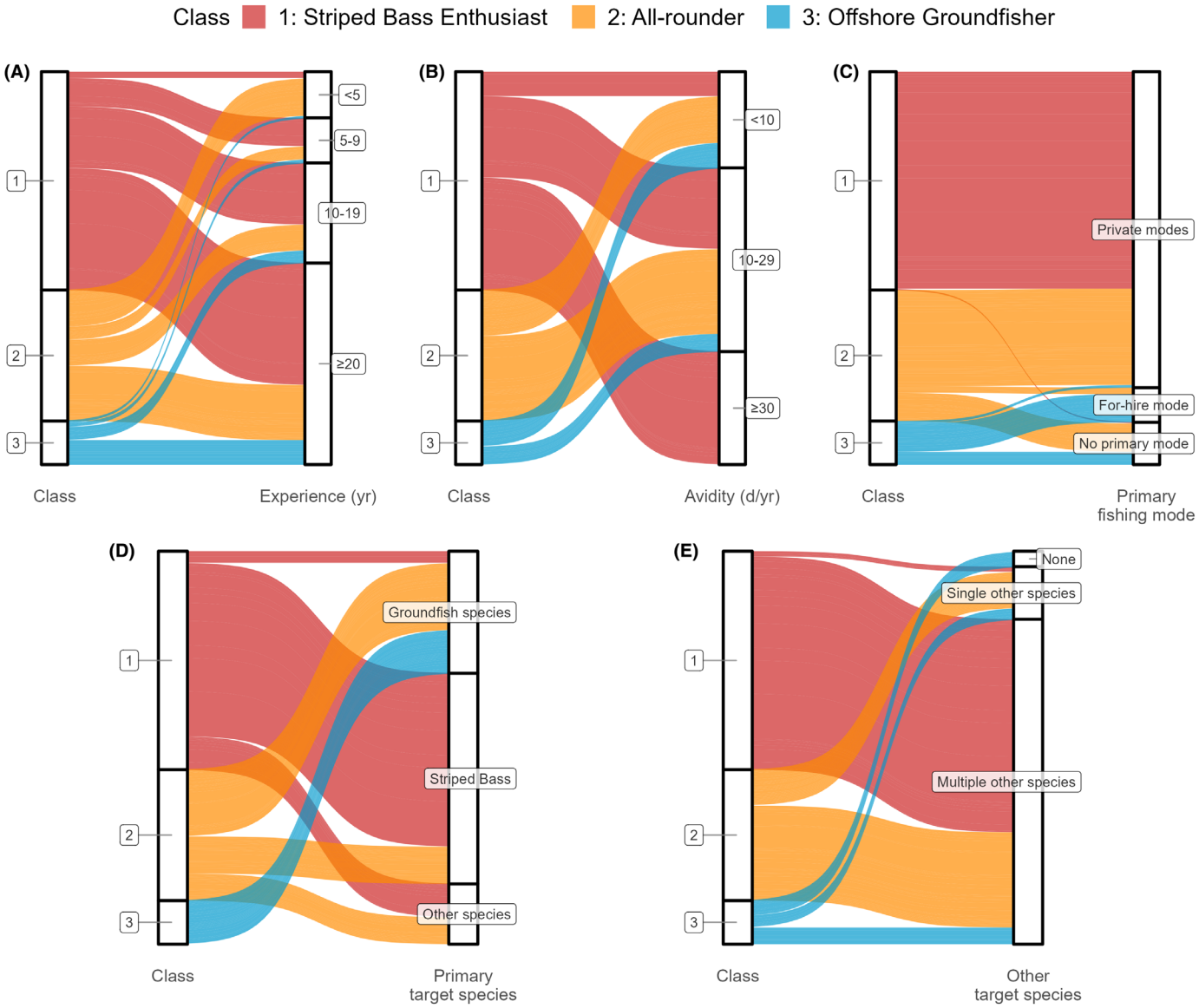

FIGURE 1. Latent class membership of Gulf of Maine survey participants ($n = 306$) based on their **(A)** years of angling experience, **(B)** average number of days fished per year (i.e., avidity), **(C)** primary fishing mode, **(D)** primary target species, and **(E)** number of target species other than groundfish. The width of horizontal splines (i.e., alluvia) depicts the frequency of respondents in each of the three classes (i.e., Striped Bass Enthusiast, All-rounder, and Offshore Groundfisher).

number of respondents believed that the size of the fish (16%), water temperature (8%), or sea conditions (3%) could impact fish survival. Although multiple factors are known to influence discard mortality, temperature has long been termed the "master factor" in fish biology due to its influence over physiological processes (Brett 1971), with elevated water temperature causing a series of physiological disruptions that threaten internal homeostasis and fish survival (reviewed by Gale et al. 2013). However, while this is widely known in the scientific community, our survey revealed that only 8% of respondents believed that water temperature was harmful to fish survival, which is similar to survey responses in other recreational fisheries (e.g., Nguyen et al. 2013). These results suggest that respondents may not understand the influence of water temperature or possibly how oceanographic processes influence environmental conditions and the fate of released fish. For example, despite its historic reputation as a cold-water environment, the Gulf of Maine can experience large annual ranges in sea surface temperatures as stratification of the water column creates dramatic differences from seafloor temperatures. Consequently, even if anglers believe that the Gulf of Maine is cold throughout the year, extreme water temperature differentials during the

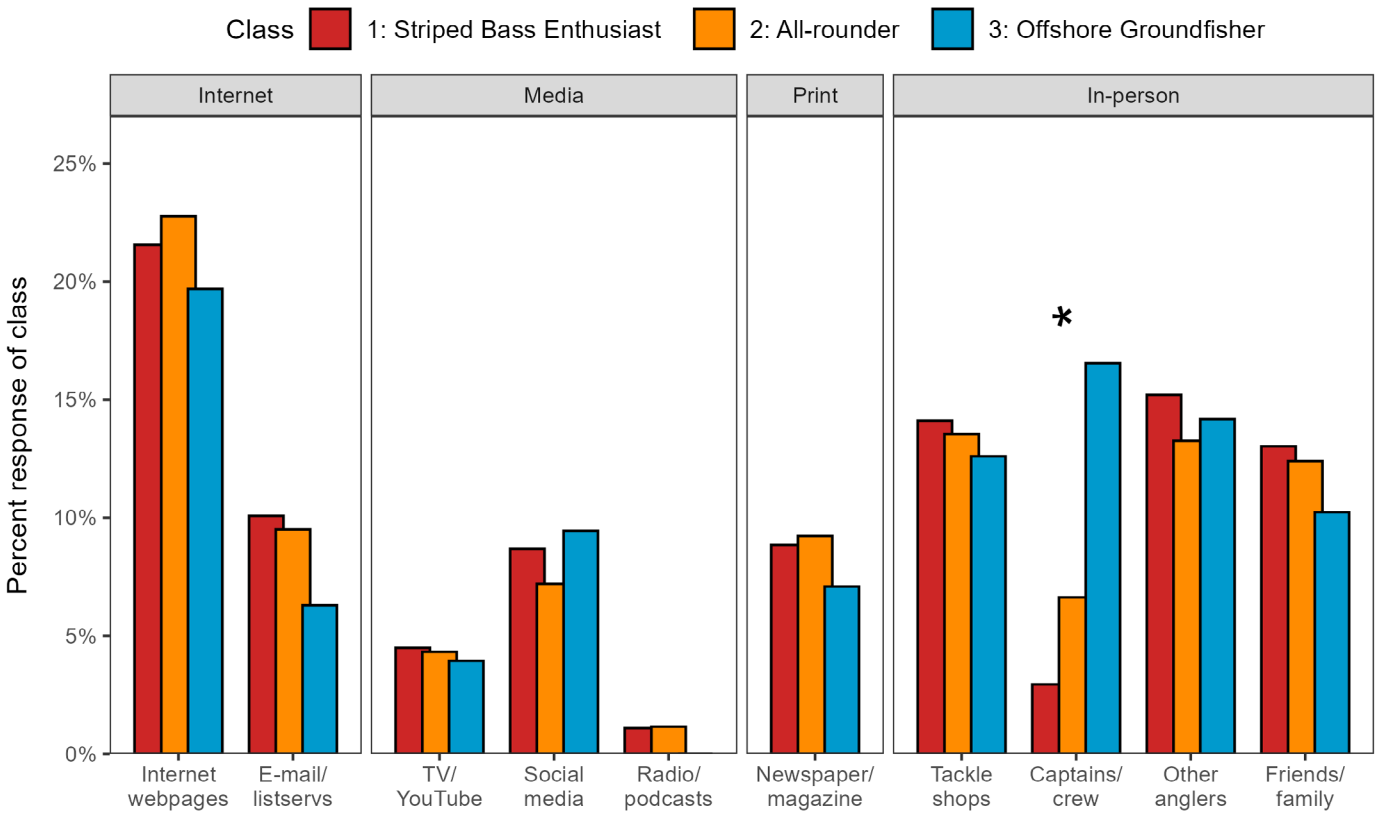

FIGURE 2. Responses of Gulf of Maine survey participants toward using various information channels according to their latent class membership in one of three angler classes (i.e., Striped Bass Enthusiast, All-rounder, and Offshore Groundfisher). Calculated percentages refer to the proportion of responses for each class (i.e., displayed percentages per class sum to 100%). Asterisks indicate significantly different usage rages between angler classes for a particular channel.

boreal summer can influence discard mortality of fishes, especially Haddock and other regional groundfish that are acclimated to colder seafloor conditions.

The potential influence of threat perceptions, while not a primary objective in the present study, is thought provoking and highlights the importance of a well-rounded angler education program when attempting to promote responsible fishing practices. However, it is unclear whether respondents' beliefs about the effect of water temperature on fish survival are from a lack of knowledge and experience or are displaced by the desire to fish during seasons with favorable conditions. For instance, when asked during which season they prefer to fish for groundfish in the Gulf of Maine, nearly 82% of respondents indicated that they preferred fishing during the summer (June–August) and autumn (September–November). Although such trends could suggest that respondents prefer this time of year due to the availability of their preferred groundfish, the boreal summer in the United States —especially Gulf of Maine states—often brings pleasant weather and presents opportunities for people to vacation and participate in this fishery. Survey participants could have also selected answers that would result in the least amount of impact to their fishing activities if additional regulations were established (e.g., Gallagher et al. 2015). For example, the Newfoundland recreational fishery for Atlantic Salmon *Salmo salar* enforces in-season closures to reduce discard mortality when temperatures exceed 20°C (Breau and Caissie 2013). Given that such controls fully restrict fishing activities as compared to other less-restrictive harvesting regulations (e.g., size and possession limits), respondents may not acknowledge the influence of water temperature on discard mortality due to the potential impact of regulations on fishing opportunities.

Understanding threat perceptions to fish survival is important if managers hope to gauge how likely anglers are to (1) adopt or consider adopting specific responsible fishing practices or (2) comply with regulatory measures related to catch-and-release angling (Sturgis and Allum 2004; Arlinghaus et al. 2007; Cooke et al. 2012). Although likelihood does not equal the voluntary adoption of a practice, this information can assist with identifying knowledge gaps among the angling community and developing/crafting outreach efforts for groups of anglers to

improve fish welfare and survival (Nguyen et al. 2013). Our results suggest that respondents, while supportive of groundfish health, either are unaware of the threat of water temperature on fish survival or purposefully avoid acknowledging this relationship due to the desire to circumvent severe fishing restrictions (e.g., Gallagher et al. 2015). Future studies should continue to explore the underlying beliefs of this angling group to better understand whether education and outreach can shift such threat perceptions and potential attitudes toward recommended fishing practices.

Information Channels

Although our findings suggest that respondents are supportive of responsible fishing practices from scientifically validated investigations, previous research indicates that anglers in general are unlikely to consult peer-reviewed literature for this information (Pelletier et al. 2007). Indeed, we found that survey participants who target groundfish often consult several channels to receive angling-related information. Nearly 80% of respondents, for instance, indicated that they used online Web sites to find information, followed by interpersonal communication with other anglers in the community (53%), tackle shops (50%), and friends and family (46%). Nguyen et al. (2012) observed similar trends in information channel use by recreational anglers on the lower Fraser River, British Columbia; those anglers primarily used Web sites (55%), talking with anglers at fishing sites (12%), and word of mouth with family and friends (12%), among other sources. Studies by Cardona-Pons et al. (2010) and Gray and Jordan (2010) similarly reported a diverse use of information channels by marine anglers, but the anglers in those studies consulted printed media and word-of-mouth exchanges more often than consulting online sources. Such differences in the use of online resources could owe to those studies being conducted in 2010, when Internet access and specialized Web sites were limited relative to the present day. Nevertheless, the results from the current study and those previously mentioned highlight the need for diverse outreach strategies when dispersing responsible fishing practices to increase the likelihood that they are both accepted and adopted by recreational anglers. In the context of this Gulf of Maine fishery, outreach campaigns should prioritize the dissemination of information on Web sites and should target industry members, such as tackle shops and for-hire captains and crew, who will serve as conduits of information among the angling community.

Interestingly, the influence of angler heterogeneity, while seemingly absent in influencing how likely respondents were to adopt or consider responsible fishing practices, was evident in the use of specific information channels. Offshore Groundfishers, for example, consulted with captains and crew members far more than other classes who target groundfish. These results are not surprising given that Offshore Groundfishers are most likely to target groundfish aboard for-hire vessels, where captains and crew members are often accessible and regarded as resident experts. However, simply because an information channel is easily accessible for anglers does not mean that it is their most preferred channel (e.g., Gray and Jordan 2010; Nguyen et al. 2012), which can impact dissemination efforts (Wilkins et al. 2018). Such impacts can be inflated by the fact that some people do not always feel that their most preferred information channel was the most credible (Westley and Severin 1964; Kiousis 2001). Therefore, when considering the observed usage trends among anglers, differentiating which channels anglers use out of convenience and preference is important to maximize message dissemination (Wilkins et al. 2018).

As reviewed by Gray and Jordan (2010), the source of information will likely determine how—or even if—a message is properly received (Giffin 1967). Results from Peters et al. (1997), for example, demonstrated that trust and credibility are key factors in environmental risk communication and could influence an angler's decision to ultimately accept or reject a message (Trettin and Musham 2000). Whereas trust is sometimes defined as a function of credibility (e.g., high credibility of a source positively impacts the trust in the source), distrust toward a source can impact the degree to which people accept information even if the source is credible (Frewer 2004; Wilkins et al. 2018). Given that relations of trust facilitate cooperation between people, which is critical for sustainability (Pretty 2003), identifying which sources (and channels) are trusted by anglers may be valuable when conveying the importance of responsible fishing practices to the angling community (Gray and Jordan 2010).

Survey Limitations

Despite yielding valuable insights into anglers who target groundfish in the Gulf of Maine, our results may not be representative of the greater fishery level due to sampling limitations. First, in contrast to a mail survey or face-to-face interviews, we solicited responses using an online survey via e-mail invitation given its convenience and ability to quickly obtain a large survey sample at minimal cost (reviewed by Evans and Mathur 2005). Online surveys, however, inherently exclude a portion of invitees without Internet connectivity, computer access, or e-mail addresses (Murphy et al. 2015), possibly skewing results toward anglers who favor the Internet as a resource. Second, we only focused on anglers who held valid recreational licenses in MA and ME. Surveying recreational license holders could have biased our results toward more avid and experienced anglers given the average years of experience and days fished per year for the respondents in our study (e.g., Murphy et al. 2015; Curtis et al. 2019). Additionally, we

were unable to survey anglers from all Gulf of Maine states (i.e., NH) as well as nonlicensed anglers who can legally fish on for-hire platforms, like charter boats and party boats. Because anglers who fish on for-hire operations, both licensed and nonlicensed, can differ from those who fish using private modes (Salz et al. 2001), the responses of nonlicensed anglers would likely shift our results, but the direction of that shift is uncertain. Finally, our survey instrument did not require respondents to answer all questions, which promoted nonresponse from survey participants and reduced sample sizes for various analyses.

Implications and Conclusions

Our results are likely not scalable to all members of the Gulf of Maine groundfish angling community because our chosen sampling approach did not give all anglers an equal chance of being surveyed. However, even if our sample of respondents represents a portion of the available population, we observed distinct classes of anglers whose responses to questions on responsible fishing practices and information channels cannot be ignored. For example, despite being characterized into distinct classes based on their fishing behavior, we observed that these differences among respondents did not influence their views toward responsible fishing practices, as most respondents were likely to voluntarily adopt or consider adopting them. This inclination of respondents toward responsible fishing practices is promising; Cooke et al. (2013) noted that voluntary behaviors, such as adopting responsible fishing practices, have the potential to achieve management objectives without the transactional costs associated with more formal regulations, but they rely far more heavily on communication and participation among the angling community. This information sharing, however, could be complicated by the fact that respondents were observed to use a vast array of channels, including online Web sites and interpersonal communication, that differ among classes. Given the impact that angling communities can have by informally communicating and disseminating information among their members (e.g., Cardona-Pons et al. 2010), the use of key industry members in the fishery, such as tackle shop owners and the captains and crew members of for-hire party and charter boats, may be pivotal in networking with the community (reviewed by Hall-Arber et al. 2009), as they can potentially aid in building social capital (Pretty 2003) that leads to greater resilience and sustainability.

In conclusion, this study advanced our understanding of how differences among anglers can potentially impact the promotion of responsible fishing practices in the Gulf of Maine recreational groundfish fishery to reduce the impact of catch-and-release angling. Our results support the old adage that "the average angler does not exist" (Shafer 1969), as survey participants who target groundfish can be separated based on their fishing experience into groups who vary in their views toward voluntarily adopting responsible fishing practices and using specific information channels. Based on our results, we recommend that managers employ a mixed outreach program that capitalizes on popular information channels to promote and encourage the voluntary adoption of responsible fishing practices alongside regulations. Although we acknowledge the potential limitations of our chosen sampling approach, our results are valuable nonetheless, as we still observed distinct angler classes and differences in survey responses when querying even a subsample of the population. As such, we hope that this work encourages others to conduct more comprehensive studies using a suite of additional survey methods (e.g., in-person interviews, mail, and phone) to obtain a more complete sample of this regional fishery. These studies should continue to investigate the role of angler beliefs and attitudes, including the relationship between threat perceptions and responsible fishing practices as well as angler communication preferences and trust toward information sources, to craft better outreach materials for anglers who are unaware of the impact of catch-and-release angling on fish. Although these findings are not anticipated to be a panacea for addressing issues related to stock rebuilding in the Gulf of Maine, they highlight the importance of establishing effective education and outreach programs to help meet stewardship and management goals.

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Appendix: Survey Instrument

Below is the online instrument that was sent out to recreational license holders from Massachusetts and Maine in 2019 (summarized in Table 1). Due to the online format and functionality of Qualtrics Survey Software, respondents were either advised (e.g., check all that apply) or restricted on how to answer specific questions (e.g., only capable of selecting one response). Questions in section 2 on responsible fishing practices were scored on a five-point Likert scale so respondents could rate their response to the presented question; the score for selecting a specific response can be found in brackets (not visible to respondents).

Because this study was part of a larger survey to query the Gulf of Maine groundfish angling community, only a subset of the questions is provided given the aims of the present study.

Section 1: Fishing characteristics

Q1.1 Do you participate in recreational saltwater fishing in the Gulf of Maine?

- ☐ Yes
- ☐ No

Q1.2 If so, which state do you most commonly sail or fish from when recreational fishing in the Gulf of Maine?

- ☐ Massachusetts
- ☐ New Hampshire
- ☐ Maine

Q1.3 Roughly how many years have you recreationally fished in the Gulf of Maine?

	0	20	40	60	80	100
Number of years						

Q1.4 On average, how many days each year do you recreationally fish in the Gulf of Maine?

	0	20	40	60	80	100
Number of days/year						

Q1.5 What percentage of your fishing in the Gulf of Maine last year was conducted from the following modes (total must sum to 100)?

Shore/ pier :	%
For-hire vessel (i.e., party/ charter boat) :	%
Private vessel :	%
Did not fish last year :	%
Total	**100%**

Q1.6 What species/groups of fishes do you generally target during your recreational fishing trips in the Gulf of Maine? Check all that apply.

- [ ] Black sea bass
- [ ] Bluefish
- [ ] Groundfish species - Roundfish (e.g., Atlantic cod, haddock, pollock)
- [ ] Mackerel
- [ ] Tuna and swordfish
- [ ] Sharks
- [ ] Striped bass
- [ ] Groundfish species - Flatfish (e.g., winter flounder, halibut)

Q1.7 Of the species you selected previously, which species/group do you primarily target when recreational fishing in the Gulf of Maine?

- [ ] Black sea bass
- [ ] Bluefish
- [ ] Groundfish species - Roundfish (e.g., Atlantic cod, haddock, pollock)
- [ ] Mackerel
- [ ] Tuna and swordfish
- [ ] Sharks
- [ ] Striped bass
- [ ] Groundfish species - Flatfish (e.g., winter flounder, halibut)

Section 2: Responsible fishing practices

Over the past several years, there have been numerous studies in the Gulf of Maine to investigate the mortality of groundfish released by recreational anglers, an event known as **discard mortality**. By working with local captains and using electronic tags, research efforts determined the factors that influence the discard mortality of groundfish differ by species.

Q2.1 Haddock experience greater discard mortality during autumn (September - November) when waters are warmer than in the spring (March - May). Based on this information, to what extent would you consider discard mortality rates in your decision of when to fish for haddock?

☐	Much more	[5]
☐	Somewhat more	[4]
☐	About the same	[3]
☐	Somewhat less	[2]
☐	Much less	[1]

Groundfish anglers can catch Atlantic cod when fishing for haddock since these species aggregate on similar fishing grounds. With the critically depleted status of the Gulf of Maine Atlantic cod stock, it is important to avoid catching cod in high numbers to reduce the overall number of discarded and dead fish.

The use of different terminal tackle rigging is an effective way to reduce Atlantic cod discards in the Gulf of Maine. For instance, recent studies determined that groundfish anglers fishing with baited hooks on high-low rigs were 1.3 – 1.9 times more likely to catch haddock than cod in comparison to jigs.

Q2.2 Given these findings, how likely would you be to use baited hooks when fishing to reduce cod bycatch?

☐	Extremely likely	[5]
☐	Somewhat likely	[4]
☐	Neither likely nor unlikely	[3]
☐	Somewhat unlikely	[2]
☐	Extremely unlikely	[1]

Fish can also suffer pressure-related injuries called **barotrauma** when they are reeled up from deep depths and gases in their body expand. Such events can cause internal injuries and

bleeding and positive buoyancy that can lead to immediate mortality or prevent the fish from swimming down, which increases its chances of dying at the surface or being eaten by sharks or birds.

To reduce such discard mortality, anglers in other regions have adopted the use of tools to quickly get fish down to the seafloor, potentially reducing pressure symptoms and the risk of being stuck at the sea surface. These devices can be generally grouped as venting tools ([image]; remove excess gas with a hollow needle) and descending devices ([image]; return fish to depth without needles).

Cusk is a species that is particularly susceptible to barotrauma. A recent study found that cusk returned to the seafloor with descending devices had increased survival, from 26% at the surface to 74% with descending devices.

Q2.3 Given these recent findings, would you be inclined to voluntarily use descending devices to safely release cusk?

- ☐ Extremely likely [5]
- ☐ Somewhat likely [4]
- ☐ Neither likely nor unlikely [3]
- ☐ Somewhat unlikely [2]
- ☐ Extremely unlikely [1]

Section 3: Use of information channels

Q3.1 How do you typically receive news about recreational fishing in the Gulf of Maine? Check all that apply.

- ☐ Online (webpage, forum, blog)
- ☐ TV and YouTube
- ☐ Social media
- ☐ Podcasts and radio talk shows
- ☐ E-mail blast/ listserv
- ☐ Newspaper and magazine
- ☐ Tackle shops
- ☐ For-hire captains and crew
- ☐ Members of the angling community
- ☐ Friends and family
- ☐ Other _____

Section 4: Socio-demographics

The following questions are meant to get a better idea of the recreational anglers that make up the Gulf of Maine fishing community.

Q4.1 Please indicate your age.

- ☐ Under 18
- ☐ 18 - 29
- ☐ 30 - 39
- ☐ 40 - 49
- ☐ 50 - 59
- ☐ 60 - 69
- ☐ 70 - 79
- ☐ 80 or older
- ☐ Prefer not to say

Q4.2 Please indicate your gender.

- ☐ Male
- ☐ Female
- ☐ Prefer not to say

Q4.3 Please indicate your highest level of education.

- ☐ Less than high school
- ☐ High school graduate
- ☐ Some college
- ☐ 2 year degree
- ☐ 4 year degree
- ☐ Professional degree
- ☐ Doctorate
- ☐ Prefer not to say

Q4.4 Please indicate your household income bracket.

- ☐ Less than $20,000
- ☐ $20,000 - $39,999
- ☐ $40,000 - $59,999
- ☐ $60,000 - $79,999
- ☐ $80,000 - $99,999
- ☐ $100,000 - $149,999
- ☐ More than $150,000
- ☐ Prefer not to say

Q4.5 Please enter the zip code where you reside 6 or more months of the year.

_____