A Multi-Disciplinary Approach for Assessing Catch-and-Release Impacts and Angler Beliefs in the Striped Bass (Morone saxatilis) Recreational Fishery

A MULTI-DISCIPLINARY APPROACH FOR ASSESSING CATCH-AND-RELEASE IMPACTS AND ANGLER BELIEFS IN THE STRIPED BASS (*MORONE SAXATILIS*) RECREATIONAL FISHERY

A Thesis Presented

by

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ABSTRACT

A MULTI-DISCIPLINARY APPROACH FOR ASSESSING CATCH-AND-RELEASE IMPACTS AND ANGLER BELIEFS IN THE STRIPED BASS (*MORONE SAXATILIS*) RECREATIONAL FISHERY

FEBRUARY 2025

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Recreational angling is a popular leisure activity globally, providing considerable economic and societal benefits. Among the most popular recreational fisheries on the eastern seaboard of North America is that for striped bass (*Morone saxatilis*). Due to management regulations and voluntary conservation efforts, most striped bass caught are released back into the water. The welfare of these fish, however, can be influenced by various stressors related to angler behavior. Research on effects of catch-and-release on striped bass has yet to fully address the range of gear types and techniques used in the recreational fishery. Notably, no study has investigated the impact of air exposure on striped bass. Additionally, little is known about the social norms, perceptions, and attitudes that shape angler behavior in the striped bass recreational fishery. This thesis addresses these gaps by employing a multi-disciplinary approach combining a field assessment to quantify physical and physiological impairment in striped bass following capture and handling, using reflex action mortality predictors and tri-axial accelerometer loggers to measure post-release activity and mortality, alongside an angler survey to investigate social norms, perceptions, and attitudes related to best practices, threats to the stock, and management efforts. Chapter 2 reveals that several factors, including water temperature, fight time, handling time, air exposure, total length, hook location, and gear type, influence striped bass welfare.

Decision tree analysis revealed air exposure as the most important predictor of equilibrium test outcomes, with 50% of striped bass air exposed for 120 seconds losing equilibrium. In addition, delayed recovery following release was observed for striped bass exposed to air for 30 or 120 seconds compared to those without air exposure. Chapter 3 revealed varied awareness in the angler community about the stressors affecting striped bass, although anglers reported frequently engaging in best practices such as limiting handling time. Anglers perceive commercial harvest and juvenile habitat loss as the greatest threats to the fishery and support a range of conservation actions, including management regulations. In the final chapter, I discuss how the findings from Chapters 2 and 3 can inform education and outreach to promote catch-and-release best practices that reduce angler impact.

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CHAPTER 1

GENERAL INTRODUCTION

1.1 Scale and Scope of Recreational Angling

Globally, recreational angling is one of the most popular leisure activities, with average participation rates of about 10% of the adult population in industrialized nations (Arlinghaus et al., 2015). People of all ages and social backgrounds engage in recreational angling, from children to seniors, and from the rich to the poor (Arlinghaus et al., 2008). Equally diverse are the motivations behind recreational angling, including catching for personal consumption, thrill of capture and then release, seeking trophy-sized fish, competition of tournament angling, camaraderie in angling clubs, and connecting with nature (Fedler and Ditton, 1994). In industrialized countries, freshwater recreational fisheries are the most common use of wild fish stocks (Arlinghaus et al., 2007), while coastal marine stocks are often co-exploited for both commercial and recreational purposes (Ihde et al., 2011).

With its scale and scope, recreational angling is a significant contributor to the economy generating approximately $190 billion USD annually (FAO, 2012). Economic capacity provided by recreational angling can come from a wide range of commerce including the production and sales of fishing equipment, tackle, apparel, and boats, to services provided by bait shops, lodges and hotels, fishing guides and through advertising sales associated with fishing magazines, television shows, and tournaments. In many regions, the economic contributions of recreational angling can have a considerable multiplier effect and reach more deeply into local communities compared to that of commercial fisheries (Steinback et al., 2004; Cooke and Cowx, 2006), especially as the importance of recreational fisheries particularly in coastal marine areas is increasing (Ihde et al., 2011). For example, in 2012, it was estimated

that 12 million anglers made 85,000 fishing trips in the United States marine waters that accounted for an overall economic impact of $82 billion (Hughes, 2015). As such, the presence and maintenance of healthy recreational fisheries can have substantial economic and social benefits for regions and communities, underscoring the importance of successful, effective management strategies for recreational fish stocks.

Despite their economic and social importance, recreational fisheries have been recognized as potentially contributing to the decline of fish stocks (Post et al., 2002; Coleman et al., 2004; Cooke and Cowx, 2004; 2006). For example, recreational anglers with the intent to harvest retain an estimated 12% of all fish landed annually worldwide (Cooke and Cowx, 2004). For many species, the harvest from recreational fisheries can even be greater than that for commercial fisheries, even though commercial fisheries are often more quickly implicated in the decline of fish populations (Cooke and Cowx, 2006). For harvest-oriented recreational fisheries and to help control the rate at which fish are removed from a population, management agencies often use input and output controls such as licenses, bag limits, and closed seasons (Hilborn and Walters, 1992). As a result, many fish are often mandatorily released because they do not meet the criteria for harvest or are not the intended target species (i.e., bycatch). A large portion of fish are also released because of a growing conservation ethic among recreational anglers not interested in harvest (Policansky, 2002). Here, management agencies and fisheries conservation organizations rely on guidelines rather than legislation as a means to minimize the impact on fish populations (Arlinghaus et al., 2007; Pelletier et al., 2007).

1.2 Catch-and-Release in Recreational Fisheries

Regardless of whether it is mandated or voluntary, releasing fish back into the water after being angled should provide a fishery management option to offset potential angling-induced impacts on fish populations (Lucy and Studholme, 2002). From a fisheries management and conservation perspective, common sense would suggest that implementing and encouraging release promotes biological, economic, and social sustainability (Policansky, 2002). In practice, however, a proportion of released individuals die as a result of being captured and handled, while others experience sublethal effects such as physical injury, physiological disturbance, behavioral alternations, and fitness impairment (Cooke et al., 2002). Depending on the gear used, the species of fish caught, the skill/intentions of anglers, and a range of environmental factors, the mortality of fish intended to be released can range from less than 1% to >90% (Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005). Factors such as the duration of the fight, hook type and associated physical hook damage, bait type, extent of air exposure, duration and general process of handling, and the environment within which fish are caught, including water temperature, water depth, and the presence of predators, have all been shown to contribute to variation in the fate of fish following catch-and-release (reviewed in Cooke and Suski, 2005; Cooke and Wilde, 2007; Brownscombe et al. 2017). It is this variable mortality rate following release that can lead to population reductions, alter the trophic structure of aquatic systems and fish populations, and, subsequently, negatively impact the resource base of communities and anglers.

Given that recreational anglers release approximately 60% of all fish caught, totaling 31 billion fish annually (Cooke and Cowx, 2004), physical injury, physiological stress, altered behavior, and post-release survival have the potential to

significantly affect fish populations. However, post-release impairment and mortality are often unaccounted for when assessing the impacts of recreational fishing on fish stocks (Cooke and Cowx, 2004; Coggins et al., 2007). Thanks to the growing focus of research on how fish respond to capture and handling, studies have demonstrated that an angling event results in a vast suite of endocrine, energetic, and ionic changes in fish (Gustaveson et al., 1991; Wood, 1991; Kieffer, 2000; Suski et al., 2004). In turn, quantifying fish behavior post-capture can serve as a proxy and indicator of the complex biochemical and physiological changes that occur in response to stress (Schreck et al., 1997). Significant impairment or departures from behavioral norms may indicate altered success of food acquisition, predator avoidance, orientation, migration, and reproduction and may, therefore, be suggestive of a decreased probability of survival (Schreck et al., 1997) and cascading effects on the population. In some cases, even low levels of release mortality can be biologically relevant, particularly in long-lived species with high age at maturation (Schroeder and Love, 2002) or species dealing with a wide range of disturbances.

Improving our understanding of how recreational anglers affect fish they intend to release can help manage recreational fisheries effectively and reduce the impact on valuable fish populations (reviewed in Brownscombe et al., 2017). In the last two decades, a growing body of science has focused on how fish respond to capture and handling, demonstrating that ‘best practices’ to reduce impacts on fish are intuitive and relatively ubiquitous across species (Cooke and Suski, 2005). However, the science has also revealed that species-specific differences in physiology, morphology, and behavioral tendencies, combined with context/environmental differences when and where fish are caught, can present unique conditions that moderate angling stressors and need to be accounted for in management and

conservation frameworks (Cooke and Suski, 2005). Even within a recreational fishery for a given species, post-release mortality can be largely context-specific, with rates being affected by a range of interacting biotic and abiotic factors such as fishing gear, location, seasonality, and the maturation or sex of the fish being targeted (Raby et al., 2015). Understanding the variability in impairment or survival within a given fishery across diverse contexts may be critical to identify since these estimates are needed to shape sound management regulations and best practices guidelines to mitigate the impact (Cooke and Schramm, 2007).

1.3 Striped Bass Recreational Fishery

One of the most popular and valuable recreational fisheries along the eastern seaboard of North America is for striped bass (*Morone saxatilis*). Striped bass in this region are anadromous and highly migratory, with stocks predominately originating in the Chesapeake Bay, Delaware River, and Hudson River undergoing seasonal migrations ranging from North Carolina in the fall and winter to Nova Scotia in the summer months (LeBlanc et al., 2020; Secor et al., 2020). During their life history, Atlantic striped bass also cover a wide range of habitats, including offshore waters where large concentrations of seasonal forage fish occur and nearshore coastal estuaries and embayments. As such, some striped bass stocks in the Atlantic can experience a wide range of environmental conditions (water temperature, salinities, tidal currents) and habitat types (estuaries, open ocean, tidal flats) at certain times during the year. For recreational anglers, this presents a wide range of opportunities to target striped bass, which caters to a wide range of budgets and skills. Striped bass along the Atlantic coast is also the focus of highly popular tournaments such as the Striper Cup and the Cheeky Schoolie tournament (in Cape Cod, MA, the largest flyfishing tournament in the world), bringing a great deal of attention to this species as a desirable and exciting

target for recreational anglers. In 2016, the recreational fishery for striped bass from North Carolina to Maine generated $13 billion USD of economic activity and contributed nearly $8 billion to the region's GDP (Southwick Associates, 2019). In Massachusetts in 2016, 50% of recreational anglers fishing in saltwater were specifically targeting striped bass, making over 20.8 million trips and contributing $1.6 billion to the GPD of the Commonwealth (Southwick Associates, 2019).

The popularity of the striped bass recreational fishery in the Atlantic translates into a large number of striped bass being caught by anglers. In 2017, for example, an estimated total of 45 million striped bass were caught within the Atlantic alone, above the 10-year mean of over 30 million (NMFS, 2018). While considerably more striped bass are harvested in the recreational fishery (over 80%) than in the commercial fishery, many more striped bass are caught, handled, and returned to the water than are harvested (NMFS, 2018). In 2019, in Massachusetts, it was estimated that of the 5.69 million striped bass caught, 5.46 million (or 96%) of these fish were released (Massachusetts Division of Marine Fisheries, 2020). However, due to an increase in recreational fishing activity post-COVID, the number of Atlantic striped bass harvested almost doubled from 2021 to 2022. Additionally, consecutive unsuccessful spawning years and the arrival of a strong recruitment class of 2015 into the current slot limit led to the Atlantic States Marine Fisheries Commission (ASMFC) taking emergency action and decreasing the slot limit across US Atlantic States, resulting in even more striped bass being released. This brings to question the role the recreational fishery plays in the viability of Atlantic striped bass populations, especially since the stock was recently deemed overfished (Northeast Fisheries Science Center, 2019).

Paradoxically, only a relatively small number of studies have attempted to quantify the impacts of capture and handling on the post-release mortality of striped

bass (Harrell, 1988; Hysmith et al., 1994; Diodati and Richards, 1996; Bettoli and Osborne, 1998; Nelson, 1998; Millard et al., 2005; Wilde et al., 2000; Lukacovic and Uphoff, 2002; Thompson et al., 2002; Graves et al., 2009; Griffin et al., 2024; Dean et al., 2024). Also, current recreational post-release mortality estimates for striped bass range between 0-67% (reviewed in Graves et al., 2009), suggesting that environment, angler behavior, or other factors could play a significant role in the fate of striped bass following release. For studies conducted in freshwater systems, such as reservoirs and rivers, higher incidences of post-release mortality were related to hooking location, bait type, and high water temperatures in summer months (Bettoli and Osborne, 1998; Millard et al., 2005; Wilde et al., 2000). In marine systems, there have only been six studies that focused on the impacts of capture and handling for striped bass (Diodati and Richards, 1996; Lukacovic and Uphoff, 2002; Thompson et al., 2002; Graves et al., 2009; Griffin et al., 2024. Dean et al., 2024). For a tributary of Chesapeake Bay, Thompson et al. (2002) found that angling time and water temperature influenced the physiological response and mortality of striped bass, however the scope of parameters they assessed was limited and mortality was assessed for fish held in pens. Pens were also used for studies Lukacovic and Uphoff (2002) and Millard et al. (2005) that examined post-release mortality of striped bass, meaning that fish were not exposed to potential predators and other natural environmental conditions that could influence survival. Moreover, holding fish in pens could confound the results of studies examining the impacts of angling on fish because of unaccounted for sources of physical and physiological stress related to confinement (Cooke et al., 2002).

To overcome some of these methodological challenges, Graves et al. (2009) employed pop-up satellite archival tag technology to gain insights into the post-release survival of striped bass released following recreational angling during winter

pre-spawning aggregation near the mouth of Chesapeake Bay. The use of pop-up archival tags allowed for the measurement of temperature, pressure as a surrogate for water depth, and light levels as an indicator of geographic location to assess the movement patterns and potential mortality of striped bass following release (Graves et al., 2009). Although all striped bass whose tags transmitted data for 30 days prior to their detachment from the fish survived, a limited sample size (n=8) precluded any statistical analyses that could test for differences in the post-release response of striped bass to different hook types and handling practices used in the study. In addition, the study by Graves et al. (2009) was conducted only during the winter, potentially not accounting for temporal differences in angling stress related to greater physiological demands at higher water temperatures (Thompson et al., 2002), especially when striped bass have migrated north for the summer months.

Of all the studies to date, the most frequently referenced by management agencies is one by Diodati and Richards (1996) who conducted a study in Massachusetts that estimated hooking mortality for striped bass held in an enclosed saltwater pond. Their study revealed that hooking mortality ranged from 3-26% depending on hooking location and bait type, with a mean hooking mortality being 9%. In fact, the 9% mean hooking mortality generated by Diodati and Richards (1996) is used as the discard mortality estimate for recreational fisheries in Atlantic striped bass stock assessments. However, their study only focused on relatively small (27-57 cm) striped bass and fish caught and released in an impoundment (artificial environment). Diodati and Richards (1996) even state directly in their paper that “our present model would not be sufficient for estimating coastwide hooking mortality of striped bass, as it does not include effects of such factors as fish size and environmental variables on mortality”.

None of the studies on striped bass catch-and-release mortality—whether in freshwater or saltwater—have specifically examined the effects of air exposure on their physiology and survivorship, despite air exposure being a common aspect of catch-and-release angling and its known impact on other recreationally targeted species (Brownscombe et al., 2015; Ferguson and Tufts, 1992). This gap limits our understanding of how capture and handling influence the post-release survival of striped bass, particularly since air exposure may exacerbate stress levels associated with capture and handling. Consequently, current estimates may either overstate or underestimate the effects of catch-and-release angling on striped bass stocks. A more comprehensive assessment of the potential impacts of catch-and-release on the Atlantic striped bass stock remains critical for informing stock assessment models as well as for the development of science-based best practices that anglers can employ to minimize their effect on striped bass intended for release. This becomes especially critical in situations where active government monitoring in catch-and-release fisheries is limited, and the safeguarding of fish stocks is dependent on the individual angler behavior.

Previous research highlights the significant role that recreational anglers can play in the conservation of fish populations by adopting behaviors such as self-imposed gear limitations, active advocacy, and voluntary catch-and-release (Granek et al., 2008; Cooke et al., 2013; Guckian et al., 2018). Studies on human dimensions have identified predictors of anglers' willingness to engage in catch-and-release practices rather than catch-and-keep methods, with key factors including social norms and awareness of consequences (Sutton, 2003; Arlinghaus, 2007; Stensland et al., 2013). However, there has been limited research on how individuals perceive and adopt catch-and-release practices in conjunction with ongoing efforts to identify best

practices. Given that the effectiveness of science-based best practices fundamentally depends on the receptivity of recreational anglers to accept and adopt them, there is an acute need to investigate the factors influencing such behavior within the context of the Atlantic striped bass recreational fishery. To further foster social acceptability of conservation strategies for recreational fisheries (Ajzen, 1985; Bruskotter and Fulton, 2007) and shift prevailing social norms toward adopting conservation behaviors, it is crucial to assess perceptions and attitudes within the recreational fishery regarding threats to the fishery and management efforts, including fishing regulations. This knowledge is essential for developing educational and outreach programs aimed at disseminating best practices and closing knowledge action gaps (Nguyen et al., 2017; Cooke et al., 2020) within the broader recreational angling community, ultimately promoting conservation-oriented angler behavior.

1.4 Purpose Statement

The overarching purpose of my thesis is to fill knowledge gaps related to 1) the cumulative effect of angling stressors, including air exposure, on striped bass welfare and survivorship and 2) the social norms, perceptions, and attitudes of anglers in the striped bass recreational fishery along the Atlantic coast of the United States. Specifically, in Chapter 1, I assessed the physical injury and physiological impairment of striped bass following catch-and-release using reflex action mortality predictors across gear types (conventional versus fly) and five air exposure treatments (0 s, 10 s, 30 s, 60 s, and 120 s). Additionally, for a subset of fish caught on conventional gear and double treble hook lures, I assessed short-term post-release activity and mortality using tri-axial accelerometer biologgers across three air exposure treatments (0 s, 30 s, and 120 s). The results of my field study can be used to inform targeted education campaigns, utilizing workshops and social media outreach to provide guidelines to

anglers on how they can make subtle changes to their fishing practices to reduce their impact on striped bass.

In Chapter 2, I distributed an angler survey through a broad network of fishing organizations, industry partners, and nonprofits to assess perceptions and attitudes related to catch-and-release best practices, threats to the fishery, and support for conservation strategies, including management regulations. The insights derived from my survey provide a more profound understanding of the factors that shape motivations and willingness to adopt best practices, thereby enabling me to inform effective communication and design behavior change strategies that will help foster cooperation and responsible angling in the striped bass recreational fishery.

In my third and final chapter, I synthesize my findings and discuss how they can be used to promote more effective catch-and-release practices and conservation behaviors through both management strategies and grassroots initiatives. I revisit each data chapter to highlight the direct implications of my research and outline future research directions. Collectively, the two main body chapters of my thesis not only provide essential insights into impacts of capture and handling on striped bass, but also contribute to informing strategies for changing social norms in the fishery towards more conservation-minded behaviors, ultimately fostering self-management among anglers through improved conservation practices.

CHAPTER 2

ASSESSING THE RESPONSE OF STRIPED BASS (*MORONE SAXATILIS*) TO CAPTURE AND HANDLING IN THE MASSACHUSETTS RECREATIONAL FISHERY

2.1 Abstract

Striped bass (*Morone saxatilis*) are a highly valued species in the recreational fishery along the eastern coast of North America, with most fish being released voluntarily or to comply with regulations. Understanding how striped bass respond to capture and handling in this diverse recreational fishery is essential for informing both management decisions and angler practices aimed at maximizing the survival of released fish. In this study, we evaluated the physical and physiological condition of striped bass (n = 521) subjected to catch-and-release angling across gear types (conventional versus fly) and five air exposure treatments (0 s, 10 s, 30 s, 60 s, and 120 s) using reflex action mortality predictors (RAMP). For a subset of fish (n = 37) caught on conventional gear and double treble hook lures, we assessed post-release activity and behavior using tri-axial accelerometer biologgers across three air exposure treatments (0 s, 30 s, and 120 s). Physical injury resulting from foul hooking was more frequent with conventional gear and double hook lures, while deep hooking occurred more frequently with fly gear and single hook lures. Assessments showed that reflex impairment of striped bass increased with rising water temperatures, longer fight and handling times, increased air exposure, and hooking in locations other than the jaw. Moreover, striped bass caught on conventional gear demonstrated greater physiological impairment than those caught on fly gear. Post-release activity was significantly influenced by time following release, with higher overall dynamic body acceleration observed in striped bass that were not air exposed compared to those air

exposure for 30 s and 120 s. Within 20 minutes of observation, the overall survival rate of striped bass in this study was 100%, indicating their resilience to the tested factors in the context of this study. Our findings suggest that anglers can minimize the sublethal effects of catch-and-release by reducing fight and handling times, limiting air exposure, avoiding high temperatures, and using single hooks. Our study highlights the importance of best angling practices to minimize stress particularly for larger fish. These insights can guide management decisions and inform the development of species-specific best practices for catch-and-release of striped bass.

Keywords: catch-and-release, best practices, post-release mortality, recreational fisheries, reflex impairment

2.2 Introduction

Recreational fishing ranks among the most popular leisure activities globally and often represents the primary use of fish stocks (Arlinghaus et al., 2015; Coleman et al., 2004; FAO, 2012). Fish that are caught recreationally are sometimes harvested for food, although it is estimated that up to 60% of fish caught worldwide are released back into the water (Cooke and Cowx, 2004). Motivations behind releasing fish include compliance with slot or bag limits, seasonal closures, or bycatch (Cooke and Schramm, 2007). Increasingly, however, many anglers are motivated by a conservation ethic, leading to a large number of fish being voluntarily released (Policansky, 2002). While catch-and-release serves as a tool to minimize impacts on individual fish (Adams, 2017; Arlinghaus et al., 2007; Cooke and Philipp, 2004), its broader success is largely dependent upon the contribution of released fish to the maintenance of the population (Aas et al., 2002; Quinn,1996).

Over the past few decades, a growing body of science has focused on the physical, physiological, and behavioral responses of fish to capture and handling (reviewed in Bartholomew and Bohnsack, 2005, Arlinghaus et al. 2007), with the outcome of these studies being used as the basis of 'best practices' to reduce negative impacts of angling on fish (Cooke and Suski, 2005; Brownscombe et al., 2017). For instance, fish subjected to catch-and-release experience varying levels of physical injury and physiological stress that can reduce post-release survival or have a range of sublethal impacts, including impaired swimming performance, reduced feeding ability, and diminished fitness (Cooke et al., 2002; Arlinghaus et al., 2007; Cooke and Cowx, 2004; Cooke and Philipp, 2004; Bartholomew and Bohnsack, 2005). The responses to catch-and-release can be specific to gear type (Cooke et al., 2003b, 2003a), angling and handling practices (Brownscombe et al., 2017), target species,

and environmental conditions (Cooke and Suski, 2005). To maximize the potential of catch-and-release as a conservation tool, it is imperative to quantify physical injury resulting from hooking (Muoneke and Childress, 1994), assess physiological and reflex impairment (Gagne et al., 2017; Brownscombe et al., 2015; McLean et al., 2020), evaluate post-release activity and behavior (Brownscombe et al., 2013; Holder et al., 2020; LaRochelle et al., 2021; Lennox et al., 2018; Griffin et al., 2022) and develop species-specific science-based best practices.

The integration of reflex action mortality predictors (RAMP) and tri-axial accelerometer biologgers has become a reliable method for evaluating the cumulative effects of capture and handling on fish (Brownscombe et al., 2013; Holder et al., 2020; Griffin et al., 2022). Assessment of RAMP involves evaluating the presence or absence of multiple (usually between 2 and 5) reflexes identified to be consistently present in vigorous individuals (Davis, 2010; Raby et al., 2012). Previous studies provide evidence that these tests are often predictive of short-term post-release behavior and/or mortality (Raby et al., 2012; Brownscombe et al., 2013, 2015; Lennox et al., 2024). Tri-axial accelerometer biologgers effectively quantify fine-scale activity, behavior, and short-term mortality of fish after release (Griffin et al., 2022; Holder et al., 2020; LaRochelle et al., 2021). These biologgers are attached to fish in a minimally invasive manner and measure acceleration (g) across three axes (x, y, z). When combined with RAMP assessments, they provide detailed insights into additional aspects of the angling event and environmental conditions, helping to bridge critical gaps in our understanding of how fish respond to capture, handling, and recovery (Brownscombe et al., 2013).

One of the most popular and valuable recreational fisheries along the eastern seaboard of the North America is for striped bass (*Morone saxatilis*). For example, in

2016, the striped bass recreational fishery generated approximately $13 billion USD of economic activity and contributed nearly $8 billion to the region's GDP annually (Southwick Associates, 2019). Striped bass undertake seasonal nearshore migrations typically from North Carolina in the fall and winter to Nova Scotia in the summer months (LeBlanc et al., 2020; Secor et al., 2020), providing anglers with a wide range of opportunities to target this species, resulting in an annual average catch rate of over 30 million fish (National Marine Fisheries Service (NMFS), 2018). Although considerably more striped bass are harvested in the recreational fishery (over 80%) than in the commercial fishery, even more of the striped bass caught by recreational anglers are released (NMFS, 2018; Carr-Harris and Steinback 2020). Despite high release rates in the recreational fishery, striped bass stocks along the Atlantic coast of North America are in decline (Atlantic States Marine Fisheries Commission (ASMFC), 2023). Intense overfishing along with habitat degradation and poor recruitment led to the collapse of the Atlantic striped bass stock in the early 1980s (Richards, 1999; Uphoff, 2023), and although some rebuilding occurred because of subsequent management efforts, including a moratorium, reduced bag limits, quotas, and slot limits, the stock continues to be classified as overfished (ASMFC, 2023). In response to poor recruitment since 2019 (Durell and Weedon, 2023), the Atlantic States Marine Fisheries Commission (ASMFC) enacted an emergency regulation in 2023, decreasing the harvestable slot limit across US Atlantic states to fish between 28 and 31 inches (71.12 – 78.84 cm; ASMFC, 2022), resulting in an even higher number of striped bass mandatorily being released.

Understanding the fate of striped bass following release is imperative for informing management actions and changing social norms in the fishing community (Bruskotter and Fulton, 2007, Guckian et al., 2018; Chapter 3) Current estimates of

post-release mortality for striped bass in recreational fisheries range from 0 to 67% (reviewed in Graves et al., 2009; Dean et al., 2024), reflecting the varied outcomes for fish depending on the range of angling factors that were tested and the duration monitored. Previous research on striped bass identified a wide suite of factors that affect physical injury, physiological stress, and post-release mortality, including hooking location (Diodati and Richards, 1996; Millard et al., 2005; Dean et al., 2024), air temperature (Bettoli and Osborne, 1998), water temperature (Millard et al., 2005; Nelson, 1998; Wilde et al., 2000; Griffin et al., 2024), fight duration (Thompson et al., 2002; Griffin et al., 2024), handling time (Harrel, 1988; Nelson, 1998; Dean et al., 2024), and fish size (Lukacovic and Uphoff, 2002). However, many of these studies (Diodati and Richards, 1996; Nelson, 1998; Millard et al., 2005) held fish in confinement following release, which may have reduced exposure to predators and other natural environmental factors as well as introduced additional stress, potentially confounding results (Cooke et al., 2002). To overcome these methodical challenges, Graves et al. (2009) employed pop-up satellite archival tag technology to assess post-release survival of striped bass released, however the achieved sample size was small (n=8). Dean et al. (2024) used acoustic transmitters to estimate a mortality rate of 10% (n=284) for striped bass caught on single and circle hooks; however, their study focused exclusively on fish captured with bait. Additionally, while fish responses to catch-and-release can vary by gear type (Brownscombe et al., 2017), only one study has investigated the responses of striped bass based on different gear types (i.e., conventional spin versus fly tackle; Griffin et al., 2024). Finally, none of the studies to date have specifically assessed the effects of air exposure despite its significant impact on other recreationally targeted species (Cook et al., 2015; Griffin et al.,

2022). As such, a substantial gap remains in our understanding of the scale and scope of how capture and handling affect the post-release survival of striped bass.

The objective of my study was to quantify the physical and physiological impairment of striped bass across a range of gear types (i.e., conventional spin tackle and fly tackle) and air exposure treatments (0 s, 10 s, 30 s, 60 s, 120 s) using RAMP. Additionally, for a subset of fish, I assessed short-term (20 min) post-release activity and behavior using tri-axial accelerometer biologgers after different durations of air exposure (0 s, 30 s, 120 s). My results can inform management decisions and species-specific science-based best practices that anglers can adopt to minimize their impact on striped bass intended for release.

2.3 Materials and Methods

2.3.1 Capture and Handling

Sampling occurred between May 6 and October 24, 2023 and May 5 and July 3, 2024 along the coast of Massachusetts, United States. Striped bass were caught by volunteer recreational anglers using conventional spin or fly fishing gear with a variety of artificial lures or flies. For each fish, I measured fight time as the duration (in seconds) from hooking to landing, and handling time as the duration (in seconds) from landing to release. To avoid confounding effects, several elements of fish handling were standardized across all treatments. Striped bass were landed by hand by grabbing the lower jaw and always held horizontally. Lip gripping tools were not used to land fish to avoid the risk of injury and potential compounding effects (Danylchuk et al., 2008).

Once landed and before removing the hook, the physical and physiological condition of striped bass was assessed using RAMP (Davis, 2010). Reflex action mortality predictor scoring consisted of assessing: ‘body flex’, the presence of muscle

contraction in the torso when a fish is lifted from the center of its body; ‘tail grab’, the ability to exhibit rapid swimming behavior in an attempt to escape when the fish is grasped by the caudal peduncle; ‘head complex’, the presence of consistent opercular movements; ‘vestibular ocular response’, the ability of the eye to track and adjust with changes in the fish’s orientation; and ‘equilibrium,’ the fish's ability to right itself within three seconds after being turned upside down in the water (Davis, 2010; Brownscombe et al., 2017; Lennox et al., 2024). Each reflex test was scored as 0 (impaired) or 1 (unimpaired), and the cumulative total was converted into a proportional value between 0 and 1. Notably, reflexes were not assessed at the point of landing for fish that were loosely hooked, as these fish were at higher risk of premature release during reflex testing. Following this first reflex assessment (from here on referenced as RAMP 1), hook type (single J or treble hook, and number of hooks per lure) and anatomical hooking location (e.g., jaw or mouth, gills, pharynx, stomach, foul) was noted. Striped bass were measured, hook(s) removed, and subjected to one of five air exposure treatments, 0 s, 10 s, 30 s, 60 s, or 120 s, that were randomly selected. Observations of recreational anglers fishing from boat and from shore showed that air exposure durations predominantly ranged between 30 and 120 sec (O. Dinkelacker, personal observations). Just prior to release, a second RAMP assessment (from here on noted as RAMP 2) was completed to evaluate the cumulative impact of capture and handling. Water temperature (° C) was recorded at the time of release.

2.3.2 Post-Release Activity

To further quantify the effects of capture and handling, the post-release behavior for a subset of striped bass was measured using a tri-axial accelerometer biologger (TechnoSmArt Axy-Depth, Guidonia Montecelio, Italy). Due to logistical

considerations (e.g., interference with shallow water structures), this assessment was limited to fish caught from boats using conventional fishing tackle and with lures outfitted with double treble hooks. Biologgers were temporarily affixed on the ventral side of the body with a Velcro strap (1 cm wide) wrapped between the first and second dorsal fins (LaRochelle et al., 2021) to measure post-release activity. Striped bass affixed with biologgers were randomly assigned to one of three air exposure treatments, 0 s, 30 s, or 120 s. For the 30 s and 120 s air exposure treatments, loggers were secured while the fish was already out of the water to not increase handling time. For 0 s treatment, loggers were attached immediately after the striped bass was measured just prior to release, with logger attachment taking < 20 s.

The Velcro strap with the accelerometer biologger affixed to the striped bass was tethered to a fishing rod with braided Dacron fishing line. Once the logger-attached fish was released, the reel was put in free-spool setting. To ensure minimal line tension and realistic swimming behavior during the post-release monitoring period, the line was also supported by a slip bobber. After a monitoring period of 20 min, the logger package was removed from the striped bass by tightening the drag of the fishing reel and pulling firmly on the line, which undid the Velcro strap allowing the biologging package to be retrieved (Lennox et al., 2018; LaRochelle et al., 2021; Griffin et al., 2022). All accelerometer biologger trials were conducted at a current speed of less than 1.3 km/h.

2.3.3 Data Processing and Analysis

All data processing and analyses were conducted in R (R Core Team, 2024). Values are presented as mean ± 1 standard deviation (SD). Statistical assumptions were evaluated according to Zuur et al. (2010), and if violated, non-parametric tests were implemented, or log transformations were applied prior to analyses. Model selection

was informed by the Akaike Information Criterion (AIC), and all model assumptions were evaluated. For ANOVAs, generalized linear models, and linear mixed models, Tukey tests were implemented via the glht function from the multcomp package (Hothorn et al., 2024) to compare differences among significant predictors. Other R packages for data processing and visualizations included rstatix (Kassambara, 2023), lubridate (Spinu, 2024), ggplot2 (Wickham, 2020), data.table (Dowle et al., 2024), and sjplot (Lüdecke, 2024).

2.3.3.1 Angling Metrics

Differences in total length, fight time, handling time, and water temperature of captured striped bass were tested across gear types and air exposure treatments using a Wilcoxon-rank-sum test and a Kruskal Wallace test, respectively. Spearman's correlation coefficients (ρ) were calculated separately for the relationship between fight time and fish length for striped bass captured via conventional and fly gear. To analyze the distribution of hooking locations across hook types (double hook versus single hook) and gear types, Chi-Squared tests of Independence were used.

2.3.3.2 RAMP Assessment

To identify the best predictors of RAMP 1 and RAMP 2 scores, generalized linear models with a binomial distribution were developed using the glmmTMB function from the glmmTMB package (Magnusson et al., 2017). For RAMP 1 score, candidate models included water temperature, fight time, hooking location, total length, and gear type. These covariates were fitted as singular, additive, and interactive terms. Given that significant differences in total length were observed across gear types, models that incorporated gear type also included total length to account for this effect. A separate set of candidate models was developed for RAMP 2 score, incorporating

water temperature, fight time, handling time, air exposure, hooking location, total length, and gear type. In these models, covariates were similarly fitted as singular, additive, and interactive terms. Due to the observed differences in total length across gear types and variations in handling time across air exposure groups, models including gear type accounted for total length, while those incorporating air exposure also included handling time.

2.3.3.3 Decision Tree Analysis

Decision tree analysis was used to explore the complex, potentially interacting, and non-linear relationships between the physiological impairment of striped bass and a wide range of measured angling and environmental factors (Hothorn et al., 2016; Holder et al., 2020). Decision trees use binary recursive partitioning to construct a hierarchical structure of parent and child nodes, systematically splitting the data based on predictor variables to create an overall tree (Breiman et al. 1984; De'Ath and Fabricius 2000; Olden et al. 2008). Given the observed correlation between the equilibrium test of RAMP 2 and post-release activity values, the decision tree analysis concentrated on this reflex test, using a range of input variables, including fight time, air exposure, handling time, hook location (jaw versus not jaw), water temperature, total length, gear type, and hook type (double versus single hook) to predict reflex outcomes. The dataset was randomly partitioned into a training set (75% of the total data) for constructing the decision trees and a test set (25% of the total data) for evaluating its predictive performance. The decision tree model was created using the C5.0 algorithm (Quinlan, 1992) from the R package C50 (Kuhn and Quinlan, 2021).

Evaluation of tree performance and tree tuning to enhance the predictive accuracy of the test data was done by creating cross tables and confusion matrices (Lantz, 2019) using the gmodels (Warnes et al., 2018) and caret (Kuhn, 2021)

packages. I prioritized identifying factors driving the loss of equilibrium by assigning a penalty three times greater for misclassifications of reflex absence compared to misclassification of reflex presence when constructing the cost matrix (Lantz, 2019). Additionally, to prevent overfitting, I set a threshold that allowed tree splits on nodes with a minimum of eight observations (Lantz, 2019).

2.3.3.4 Post-Release Activity

To prepare the raw acceleration data for analysis, static acceleration (gravity) values were calculated using a 2 second box smoother (Shepard et al. 2008; Brownscombe et al., 2018) with the *rollmean* function in the R package zoo (Zeileis et al., 2023). Subsequently, dynamic acceleration (fish movement) values were derived by subtracting the static acceleration values from the raw detection data. Overall dynamic body acceleration, an index of locomotor activity (Gleiss et al., 2011; Brownscombe et al., 2013), was then calculated using the absolute sum of the dynamic acceleration from all three axes (x, y, and z; Gleiss et al. 2011), and the mean was calculated at each minute post-release. Spearman correlation tests were employed to explore the relationship of RAMP 2 and individual reflexes that were most frequently failed in the study with ODBA. Additionally, T-tests were conducted to evaluate differences in ODBA values between striped bass with present and absent equilibrium.

A linear model via the lm function in base R was used to assess the effects of water temperature, fight time, handling time, air exposure, and total length on post-release activity. Additionally, I fitted linear mixed models using the lmer function from the lme4 package (Bates et al., 2015) to explore the effect of these angling factors as well as time following release on averaged ODBA values, which were aggregated at two-minute intervals to account for short-term fluctuations. Candidate models included covariates as singular, additive, and interactive terms, and Trial ID

was always included as a random effect. Given that significant differences in handling time were observed across air exposure groups, handling time was incorporated in all candidate models including air exposure. To further explore the relationship of air exposure and ODBA across the monitoring period, I fitted separate linear models for each air exposure group with minutes post-release (two-minute intervals) as the only covariate and trial ID as a random effect. Lastly, ANOVAs were used to identify differences in ODBA across air exposure groups at two-minute intervals.

2.4 Results

2.4.1 Angling Metrics

A total of 521 striped bass were captured for this study: 332 on conventional gear and 189 on fly gear. Data on RAMP 1 score was collected for 402 (conventional: n = 263, fly: n = 139) striped bass, all of which were retained for analysis of RAMP 1. These striped bass were caught in water temperatures ranging from 10°C to 24.4°C (15.5°C ± 2.1°C) with no significant difference in temperature across gear types ($W = 15916$, $p > 0.05$). Fight time ranged from 5 s to 558 s (137 s ± 79 s) with no significant difference across gear types ($W = 15916$, $p > 0.05$). Fight time was positively correlated with total length for striped bass caught on conventional gear ($\rho(263) = 0.49$, $p < 0.001$) and fly gear ($\rho(139) = 0.59$, $p < 0.001$; Figure 2.1). Total length ranged from 30.5 cm to 101.6 cm, and mean total length was significantly higher for striped bass caught on conventional gear (70.8 cm ± 9.8 cm) than those caught on fly gear (63 cm ± 9.7 cm; $W = 23956$, $p < 0.001$). Gear type and total length were incorporated into analysis models to account for this effect.

Data on RAMP 2 score was collected for 447 striped bass (conventional: n = 274, fly: n =173), all of which were retained for analysis of RAMP 2. For these fish, water temperature ranged from 10°C to 24.4°C (15.3°C ± 2.2°C) with no significant

difference in temperature across gear types (W = 23542, p > 0.05) or across air exposure groups (H(4) = 4.68, p > 0.5). Further, fight time ranged from 5 s to 558 s (137 s ± 82 s) and there was no significant difference in fight time for these fish across gear types (W = 21009, p > 0.05) or air exposure groups (H(4) = 2.01, p > 0.5). Handling time ranged from 4 s to 434 s (176 s ± 76 s), and there was no significant difference across gear types (W = 22182, p > 0.05). Handling time for striped bass in the 120 s air exposure treatment was significantly higher (241 s ± 66 s; H(4) = 70.53, p < 0.001), driven by the duration of air exposure, than for striped bass in other air exposure groups (0 s: 175 s ± 80 s, p < 0.001; 10 s: 153 s ± 67 s, p < 0.001; 30 s: 157s ± 69 s, p < 0.001; 60 s: 166 s ± 60 s, p < 0.001). Handling time and air exposure were included in models to account for this effect. Lastly, total length ranged from 25.4 cm to 104.1 cm, and mean total length was significantly higher for striped bass caught on conventional gear (70.8 cm ± 10 cm) than those caught on fly gear (62.3 cm ± 11 cm; W = 30211, p < 0.001). Total length and gear type were included in models to account for this difference.

Data on anatomical hook location was recorded on 500 fish sampled for this study (conventional: n = 318, fly: n =182). Of these, striped bass caught on conventional gear were primarily hooked in the jaw or corner of the mouth (n = 275, 86.5%), followed by foul hooking (e.g., head, eye; n = 22, 6.9%), in the gills (n = 12, 3.8%), and deep hooking in the pharynx or stomach (n = 9, 2.8%). Striped bass caught on fly gear were predominately hooked in the jaw or corner of the mouth (n = 146, 80.2%), followed by deep hooking in the pharynx (n = 27, 14.8%), in the gills (n = 8, 4.4%), and foul hooking (e.g., head, eye; n = 1, 0.6%). Striped bass captured with conventional gear were more often caught with double hooks (n = 193, 60.7%) than single hooks (n = 125, 39.3%), while fish captured on fly gear were more often caught

on single hooks (n= 177, 97.3%) than double hooks (n = 5, 2.7%). First hooks of striped bass caught on conventional gear using double hooks were mostly hooked in the jaw (n = 161, 83.4%), followed by foul hooking (n = 19, 9.9%), gills (n = 7, 3.6%) and deep in the throat (n = 6, 3.1%; X = 353.47, df = 3, $p < 0.001$). Second hooks (trailing hook) of double hook lures were lodged 51.3% of the time, and significantly more often foul hooked (n = 63, 63.6%) than hooked in the jaw (n =24, 24.2%), the gills (n =6, 6.1%), or deep in the mouth (n = 6, 6.1%, X = 87.55, df = 3, $p < 0.001$). Single hooks of striped bass caught on conventional gear were mostly hooked in the jaw (n = 114, 91.2%), followed by the gills (n = 5, 4%), foul hooked (n = 3, 2.4%), or deep in the mouth (n = 3; 2.4%). Fly angled striped bass caught using single hooks were mostly hooked in the jaw (n = 144, 81.3%), deep in the throat (n = 25, 14.1%), the gills (n = 7, 4%), and foul hooked (n = 1, 0.6%). First hooks of striped bass caught on fly gear using double hooks were hooked in the jaw (n = 2, 40%), deep in the throat (n = 2, 40%), and in the gills (n = 1, 20%). The second hook of double hooks of fly angled striped bass were never hooked.

2.4.2 Reflex Indices

Proportional RAMP 1 scores (0: fully impaired, 1: fully un-impaired) ranged from 0.4 to 1.00 (0.82 ± 0.19), and RAMP 2 scores from 0.2 to 1.00 (0.75 ± 0.21) across all treatments and gear types. During RAMP 1 striped bass most commonly failed the equilibrium test (conventional: 36.9%, fly: 15.8%), the tail grab (conventional: 36.9%, fly: 11.5%) and the body flex (conventional: 33.8%, fly: 27.3%). No striped bass failed vestibular ocular response or ventilation during RAMP 1. Similarly, in RAMP 2, striped bass most commonly failed body flex (conventional: 55.8%, fly: 45.7%), tail grab (conventional: 53.7%, fly: 31.8%), and equilibrium (conventional: 31.4%, fly: 23.7%). During RAMP 2, one striped bass caught on conventional gear lost

vestibular ocular response, one lost head complex, and one lost both of these reflexes. In addition, one striped bass caught on fly gear lost vestibular ocular response during RAMP 2. All striped bass that lost vestibular ocular response or head complex experienced air exposure durations of 60 s or 120 s and were either foul or gill hooked. The striped bass losing vestibular ocular response and head complex was air exposed for 120 s, foul hooked, had a fight time of 295 s, handling time of 315 s, and a size of 86.4 cm.

Proportional RAMP 1 score was best modeled by an additive generalized linear model including gear type, fight time, water temperature, total length, and anatomical hook location. Independent of total length, gear type had a significant effect on RAMP 1 score, with striped bass caught on conventional gear exhibiting lower RAMP scores compared to those caught on fly gear ($z = 5.39$, $p < 0.001$; Figure 2.2a). Further, fight time had a significant inverse correlation with fight RAMP 1 ($z = -4.34$, $p < 0.001$; Figure 2.2b). Water temperature, total length and anatomical hook location had no significant effect on RAMP 1 ($p > 0.05$). RAMP 2 was best modeled by an additive generalized linear model, including water temperature, fight time, handling time, air exposure, gear type, total length, and anatomical hook location. Significant negative relationships were revealed between RAMP 2 and water temperature ($z = -2.42$, $p = 0.02$; Figure 2.3a), fight time ($z = -3.76$, $p < 0.001$; Figure 2.3b), and handling time ($z = -5.2$, $p < 0.001$; Figure 2.4a). Striped bass air exposed for 120 s were had significantly lower RAMP 2 scores than those in the 0 s air group ($z = -3.07$, $p = 0.02$), and the 30 s air group ($z = -3.01$, $p = 0.02$; Figure 2.4b). Striped bass captured via fly gear had significantly higher RAMP 2 scores than those caught on conventional gear ($z = 3.05$, $p < 0.01$; Figure 2.5). The effects of total length and anatomical hook location were not significant ($p > 0.05$).

2.4.3 Decision Tree Analysis

For the decision tree analysis, I used the equilibrium reflex test from RAMP 2 as the response variable, as it showed the strongest correlation with ODBA. The decision tree identified air exposure and total length as the most important factors for predicting reflex outcome, with an attribute usage of 100% and 76.75%, respectively. Hook type contributed 49.02%, gear type 39.78%, handling time 34.17%, water temperature 23.53%, anatomical hook location 21.29%, and fight time 19.05% to the model's prediction. The decision tree model achieved a prediction accuracy of 62%, correctly identifying the absence of equilibrium in the test data 22 of 33 times. The data were first split based on air exposure duration (0 s,10 s, 30 s, or 60 s versus 120 s), followed by total length (cm) at 65.41 cm (Figure 2.6). Most failed equilibrium tests were predicted for striped bass air exposed for 0 s, 10 s, 30 s, or 60 s, with a total length over 65.4 cm, caught on single hooks and fly gear, with fight time exceeding 232 s. The second highest number of failed equilibrium tests was predicted for striped bass exposed to air for 120 s, as well as for those air exposed for 0, 10, 30, or 60 s with total lengths exceeding 61.4 cm, caught in water temperatures above 16.6°C.

2.4.4 Post-Release Activity

Thirty-seven striped bass were subjected to accelerometer biologger trials and assigned to air exposure groups of either 0 s (n = 13), 30 s (n = 12), or 120 s (n = 12). The monitoring period was prematurely concluded after 15 minutes on two occasions due to the risk of line entanglement. Striped bass affixed with an accelerometer had total lengths ranging from 68.6 cm to 94.0 cm (76.7 cm ± 7.1 cm), fight times ranging from 70 s to 216 s (132s ± 29 s), handling times ranging from 180 s to 374 s (248 s ± 51 s), and were captured in water temperatures between 12.2°C and 19.4°C (14.4°C ± 1.7°C). There was no significant difference in total length ($H(2) = 1.03$, $p > 0.5$), fight

time ($H(2) = 2.71$, $p > 0.05$), and water temperature: $H(2) = 0.87$, $p > 0.5$) across air exposure treatments. Similar to striped bass not affixed with biologgers, those in the 120 s air exposure group (279 ± 41 s) had significantly longer handling times ($H(2) = 8.99$, $p < 0.01$) driven by air exposure duration compared to striped bass in the 30 s air exposure group (222 ± 43 s, $p = 0.01$) and approached significance compared to those in the 0 s group (242 ± 52 s, $p = 0.08$). Handling time was incorporated in the model that included air exposure as a covariate to account for this effect.

Across trials, ODBA values (averaged across each minute post-release) ranged from 0.03 to 1.55 g (0.24 ± 0.18 g), with individuals demonstrating variable responses in ODBA after release (Figure 2.7). Despite a trend showing increasing ODBA values with increasing RAMP 2 score, there was no significant correlation between RAMP 2 and ODBA ($\rho(35) = 0.17$, $p > 0.05$). Of the three reflexes most commonly lost by striped bass, only equilibrium was significantly correlated with ODBA (equilibrium: $\rho(35) = 0.33$, $p = 0.05$, body flex: ($\rho(35) = -0.12$, $p > 0.05$), tail grab: $\rho(35) = 0.1$, $p > 0.05$). Striped bass that passed the equilibrium test (i.e., righted themselves in three seconds or less) during the second RAMP assessment had significantly higher ODBA values (0.26 ± 0.15 g) compared to striped bass that lost equilibrium (0.18 ± 0.04; $t = -2.81$, $p < 0.01$). Specifically, striped bass that passed the equilibrium test demonstrated significantly higher ODBA at 4:00-5:59 min ($t = -2.3$, $p = 0.03$), 6:00-7:59 min ($t = -3.74$, $p < 0.001$), 8:00-9:59 min ($t = -4.87$, $p < 0.001$), 10-11:59 min ($t = -5.38$, $p < 0.001$), 12:00-13:59 min ($t = -4.33$, $p < 0.001$), and 14:00-15:59 min ($t = -2.03$, $p = 0.05$) compared to those that failed the test (Figure 2.8).

The linear model showed no effect of fight time ($F(1,30) = 0.4$, $p > 0.05$), water temperature ($F(1,30) = 0.01$, $p > 0.05$); total length ($F(1,30) = 0.66$, $p > 0.05$), handling time($F(1,30) = 0.08$, $p > 0.05$), or air exposure ($F(2,30) = 0.37$, $p = 0.05$) on

ODBA. Further, across all trials averaged ODBA values were best modeled by a linear mixed model containing minutes post-release (aggregated by two-minute intervals) as a covariate alone. It revealed a significant positive correlation between time following release and post-release activity ($F(9, 319.07) = 12.31$, $p < 0.001$; Figure 2.9). Specifically, following a significant drop in ODBA from the first two-minute interval (0:00-1:59 min) to the second (2:00-3:50 min, $z = -3.64$, $p = 0.1$), ODBA levels increased over time, reaching significantly higher values at minutes 8:00-9:59 min ($z = 4.94$, $p < 0.1$) and beyond (10:00-11:59 min: $z = 6.63$, $p < 0.01$; 12:00-13:59 min: $z = 6.19$, $p = < 0.01$; 14:00-15:59 min: $z = 6.14$, $p < 0.01$; 16:00-17:59 min: $z = 6.47$, $p < 0.01$; 18:00-20:00 min: $z = 6.73$, $p < 0.01$; 19–20min: $z = 7.96$, $p < 0.01$) compared to the lowest levels during 2:00-3:50 min.

ODBA values changed significantly with minutes post-release (aggregated by two-minute intervals) as a covariate alone for all air exposure treatments (0 s; $F(9, 106.01) = 3.64$, $p < 0.001$, Figure 2.10a), 30 s ($F(9, 99) = 6.78$, $p < 0.001$, Figure 2.10b), 120 s ($F(9, 96.1) = 2.79$, $p < 0.01$, Figure 2.10c). Specifically, striped bass that were not air exposed (0 s) exhibited significantly lower activity levels during 2:00-3:59 min compared to minutes 10:00-11:59 min ($z = 3.45$, $p = 0.01$), 12:00-13:59 min ($z = 3.15$, $p = 0.05$), 16:00-17:59 min ($z = 3.38$, $p = 0.03$), and 18:00-20:00 min ($z = 4.7$, $p < 0.001$). Additionally, their ODBA values during 4:00-5:59 min were significantly lower than those observed during 18:00-20:00 min ($z = 3.5$, $p = 0.02$). Striped bass subject to 30 s air exposure demonstrated significantly reduced activity levels during 2:00-3:59 min compared to subsequent time points starting from minutes 8:00-9:59 min ($z = 3.4$, $p = 0.02$; 10:00–11:59 min: $z = 5.11$, $p = < 0.001$; 12:00-13:59 min: $z = 4$, $p < 0.01$; 14:00–15:59 min: $z = 4.08$, $p < 0.01$; 16:00–17:59 min: $z = 5.15$, $p < 0.01$; 18:00–20:00 min: $z = 5.31$, $p < 0.01$). Furthermore, ODBA

values during minutes 4:00-5:59 min were significantly lower than those recorded during 10:00-11:59 min ($z = 4.32$, $p < 0.01$), 12:00-13:59 min ($z = 3.25$, $p = 0.04$), 14:00-15:59 min ($z = 3.30$, $p = 0.03$), 16:00-17:59 min ($z = 4.36$, $p < 0.01$), and 18:00-20:00 min ($z = 4.53$, $p < 0.01$). Striped bass subjected to air exposure for 120 s also demonstrated significantly lower ODBA levels during 2:00-3:59 min when compared to 12:00-13:59 min ($z = 3.4$, $p = 0.02$), and 19:00–20:00 ($z = 3.73$, $p < 0.01$).

ODBA values in the 2:00-3:59 min interval ($F(2, 71) = 5.81$, $p < 0.01$) and 4:00-5:59 min interval ($F(2, 71) = 4.74$, $p = 0.02$) differed significantly among air groups. Specifically, striped bass that were not air exposed (0 s) exhibited significantly higher activity levels during 2:00-3:59 min than those air exposed for 30 s ($t = -3.07$, $p < 0.01$) or 120 s ($t = -2.78$, $p = 0.02$). Additionally, striped bass in the 0 s air exposure group also had significantly higher ODBA levels at minutes 5-6 compared to those subjected to 30 s of air exposure ($t = -3.02$, $p < 0.01$).

2.5 Discussion

Overall, my assessment of striped bass following capture and handling revealed an immediate post-release survival rate of 100% across all gear types and air exposure treatments. Physical injuries were observed more frequently with conventional gear and lures with two sets of treble hooks, resulting in a higher incidence of foul hooking compared to both conventional and fly gear using single hooks. Conversely, deep hooking was more common with fly gear and single hook lures than with conventional gear, regardless of whether single or double hook lures were used. Reflex assessments indicated an increase in reflex impairment associated with higher water temperatures, prolonged fight times, extended handling durations, and increased air exposure. Additionally, striped bass caught using conventional gear exhibited

greater impairment compared to those caught with fly gear. Short-term post-release activity was significantly influenced by time following release, with quicker recovery observed in striped bass that were not exposed to air compared to those subjected to air exposure for 30 seconds and 120 seconds. To minimize the effects of catch-and-release angling on striped bass, my findings suggest that anglers should limit fight time to under 118 seconds, handling time to under 117 seconds, and air exposure to under 60 seconds. They should also opt for single hooks and avoid fishing at water temperatures above 16.5°C. These measures are especially important for striped bass larger than 65 cm, as these fish were more susceptible to angling stress.

Hooking injuries have a well-documented negative impact on fish and are recognized as a primary cause of angling-related mortality (Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005; Cooke and Suski, 2005; Cooke and Wilde, 2007; Pelletier et al., 2007). In my study, striped bass caught on fly gear with single hook lures were more susceptible to deep hooking than those caught using conventional gear with either single or double hook lures. This susceptibility may be attributed to the smaller size of flies, which can be easily ingested deep within the fish's buccal cavity, in contrast to the larger lures typically used in conventional fishing. Conversely, striped bass caught with conventional gear and double hook lures exhibited higher rates of foul hooking and external tissue damage compared to those captured with either conventional or fly gear using single hooks. The decision tree analysis revealed that hooking location is a significant predictor of outcomes for striped bass, with fish hooked in locations other than the jaw more often losing equilibrium compared to those hooked in the jaw. The greater levels of physical injury in striped bass caught with double hook lures may account for the lower RAMP scores observed in those caught on conventional gear compared to those caught on fly

gear. Although my study did not assess subsequent sub-lethal impacts, foul hooking and associated tissue damage may heighten the risk of parasites, disease, and fungal infections (Meka, 2004; Schramm and Davis, 2006; Teffer et al., 2017).

Anaerobic metabolism during intense exercise, such as when fish fight at the end of a fishing line, elevates lactate levels and disrupts blood chemistry, resulting in metabolic acidosis and impaired physiological functions (Kieffer, 2000). These changes hinder muscle and nerve activity, compromising fish condition and recovery following release (Kieffer, 2000). Consistent with this, my results indicate that fight time significantly affects striped bass, with increased reflex impairment observed as fight duration increased. Moreover, my results demonstrate a significant positive correlation between fight time and total length in striped bass. The decision tree analysis identified total length as the second most important factor in predicting the presence or absence of equilibrium, indicating that striped bass larger than 65.41 cm tend to have poorer outcomes. Research on other recreationally targeted species indicates that larger fish experience greater lactic acid buildup (Meka and McCormick, 2005; Martin et al., 2023) and have slower lactate clearance rates compared to smaller fish (Martin et al., 2023), suggesting that larger fish are more adversely affected by the effects of exhaustive exercise.

The normal physiological response of exhaustively exercised fish involves enhancing oxygen supply to their muscles to meet elevated demands following exertion (Wood 1991; Wang et al. 1994). However, when exposed to air, fish struggle to repay oxygen debt due to gill collapse and adhesion, which disrupts physiological homeostasis and can lead to extracellular acidosis (Ferguson and Tufts, 1992; Cook et al., 2015). In my study, air exposure significantly affected striped bass, with 120 seconds of exposure resulting in significantly lower RAMP 2 scores compared to fish

that were not air exposed or those exposed for only 30 seconds. Moreover, decision tree analysis identified air exposure as the most important predictor of equilibrium impairment, revealing that 50% of striped bass lost equilibrium after 120 seconds of air exposure. These results suggest that prolonged periods of air exposure impose considerable stress on striped bass during catch-and-release angling. Given that air exposure is a common element of catch-and-release angling and the effects have not been previously assessed, this finding is especially crucial for enhancing best practice guidelines for catch-and-release of striped bass. Additionally, RAMP assessments revealed that extended handling times contribute further to angling stress in striped bass. This is consistent with findings from Harrel (1988), which demonstrated that handling time is a critical factor influencing cumulative stress and post-release survival in striped bass.

Physiological processes in fish are closely tied to water temperature, and elevated temperatures can adversely affect their physiological condition and post-release survival (Gale et al., 2013). High water temperatures reduce the availability of dissolved oxygen (Coutant, 1985). Consequently, when fish are already experiencing oxygen depletion due to anaerobic metabolism during angling-induced exercise, elevated temperatures can exacerbate this limitation and intensify physiological stress (Muoneke and Childress, 1994; Davie and Kopf, 2006). My findings support previous research on the catch-and-release of striped bass, demonstrating that water temperature significantly influences their physiological response (Thompson et al., 2002; Griffin et al., 2024). The second RAMP assessment demonstrated a significant reduction in reflex scores with increasing water temperatures. Further, decision tree analysis revealed that temperatures exceeding 16.6 °C have a particularly detrimental impact on striped bass larger than 65.4 cm, particularly those caught with double

treble hooks and exposed to air for 0-60 seconds. Under these conditions, 50% of the fish experienced a loss of equilibrium.

Reflex action mortality predictor scores are well-established indicators of reflex impairment (Davis, 2010; Raby et al., 2012) and often predictive of post-release physiological and behavioral impairment, as well as mortality (Raby et al., 2012; Brownscombe et al., 2013, 2015). The significant relationship observed between the equilibrium test and ODBA supports the notion that reflex tests can effectively capture universal stress responses in fish (Davis et al., 2010). Specifically, striped bass that passed the equilibrium test during the second RAMP assessment exhibited significantly higher ODBA values than striped bass that lost equilibrium. The lack of a significant relationship between overall RAMP score and ODBA in our study could be a product of a small sample size or species-specific differences in morphology, physiology, and behavior that influence the effectiveness of various reflex indicators in assessing physiological impairment.

Physiological disturbances caused by various angling factors can alter routine swimming behavior (Kieffer, 2000; Cooke et al., 2002), and short-term post-release activity patterns often serve as indicators of the long-term fate of fish (Beitinger, 1990; Brownscombe et al., 2014). In our study, no significant influence of water temperature, fight time, handling time, air exposure, or total length on post-release activity was detected. Generalized linear mixed models revealed that the time following release was the only factor influencing activity levels and recovery in striped bass, with fish increasing activity with time after release. However, differences in post-release activity were observed among the various air exposure groups. Striped bass with 0 seconds of air exposure exhibited significantly higher activity levels between 2:00 and 3:59 minutes post-release and demonstrated faster recovery

compared to those exposed for 30 or 120 seconds. Suppressed activity for several minutes after release may indicate the vulnerability of striped bass to post-release mortality if greater physical injury and sub-lethal impacts occur (Bartholomew and Bohnsack, 2005; Raby et al., 2014). In addition, fish with impaired swimming performance may be more susceptible to post-release predation. For instance, Danylchuk et al. (2007) found that bonefish that lost equilibrium, often corresponding to the duration of air exposure, were six times more likely to be preyed upon than those that maintained equilibrium. Although depredation and post-release predation (within 20 min) were not issues during this study, anglers targeting striped bass have reported shark depredation events in the fishery (Casselberry et al., 2022). Interactions between seals and striped bass post-release are also a growing concern (O. Dinkelacker, unpublished data).

Overall, the immediate and short-term survival rate of striped bass following release was high (100%), indicating their resilience to the factors evaluated during this study. However, it is important to note that this study only assessed short-term (20 min) post-release activity and survival, and there may be delayed sub-lethal effects that could lead to post-release mortality days or weeks later. This research adds to the growing suite of studies evaluating how striped bass respond to capture and handling, which is invaluable given the diverse range of gear types used by anglers across various environmental conditions. Although additional research is still warranted to fill in additional knowledge gaps, our study was the first to demonstrate that air exposure can influence striped bass condition and swimming performance after release. With striped bass stocks along the Atlantic coast in decline, my study results can inform targeted outreach programs designed to promote species-specific, science-based best practices that anglers can adopt to reduce their impact.

2.6 Figures

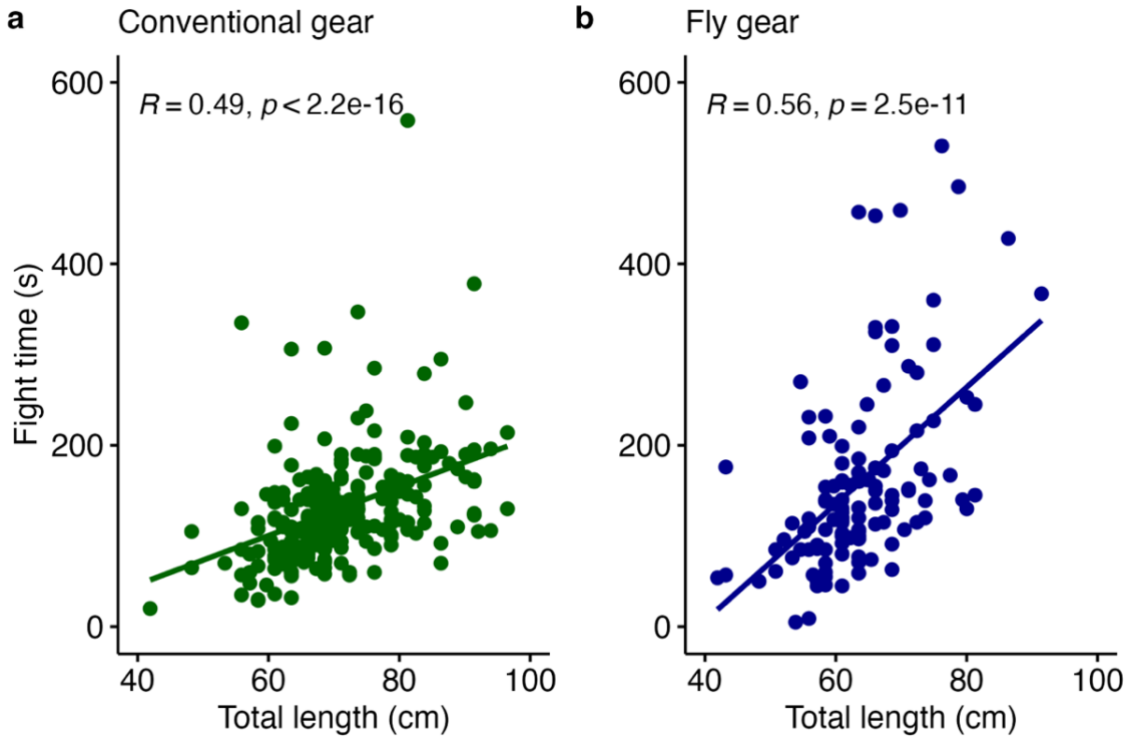

Figure 2.1. Relationship between fight time and total length for striped bass captured via a) conventional gear and b) fly fishing. Spearman's ρ correlation coefficients (R) and corresponding p-values are displayed, along with linear regression lines plotted for each gear type.

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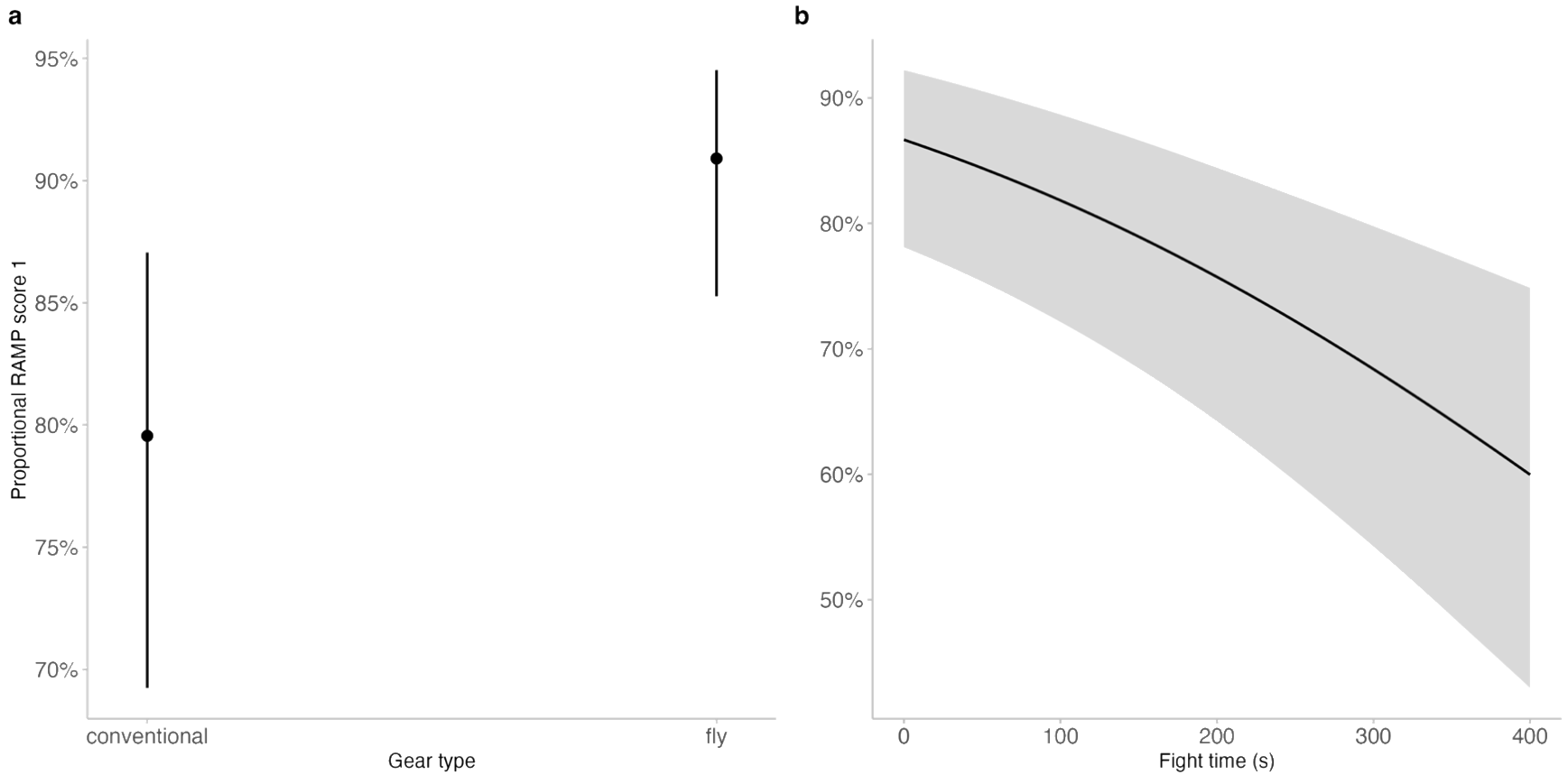

Figure 2.2. Two-part figure presenting (a) proportional RAMP score 1 for different gear types, displaying the expected mean scores and their 95% confidence intervals, and (b) the relationship between proportional RAMP score 1 and fight time, with the shaded area representing the 95% confidence interval around the fitted line.

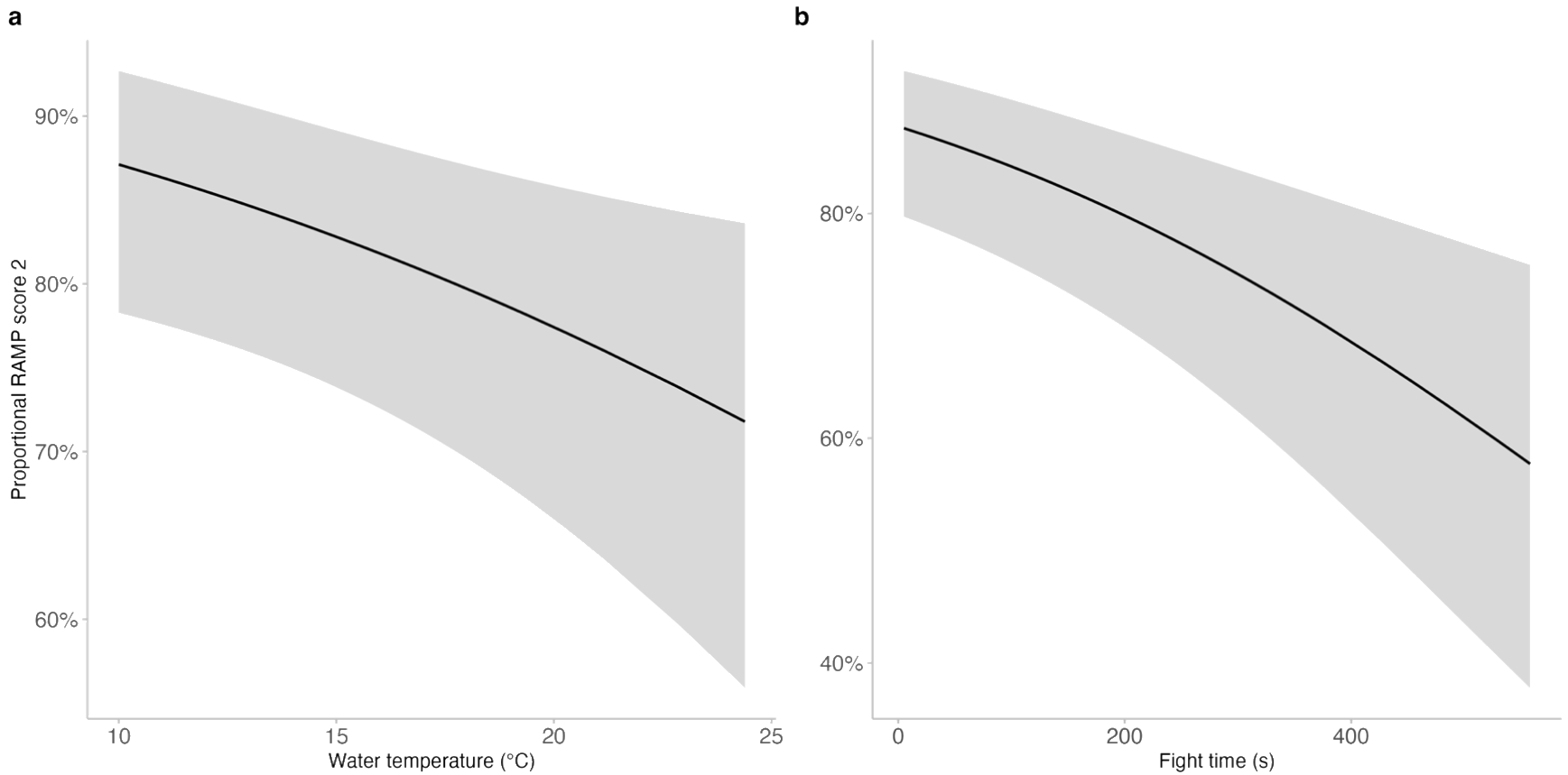

Figure 2.3. Two-part figure presenting the relationship between proportional RAMP score 2 and a) water temperature and b) fight time. Shaded area around the line of best fit represents the 95% confidence interval.

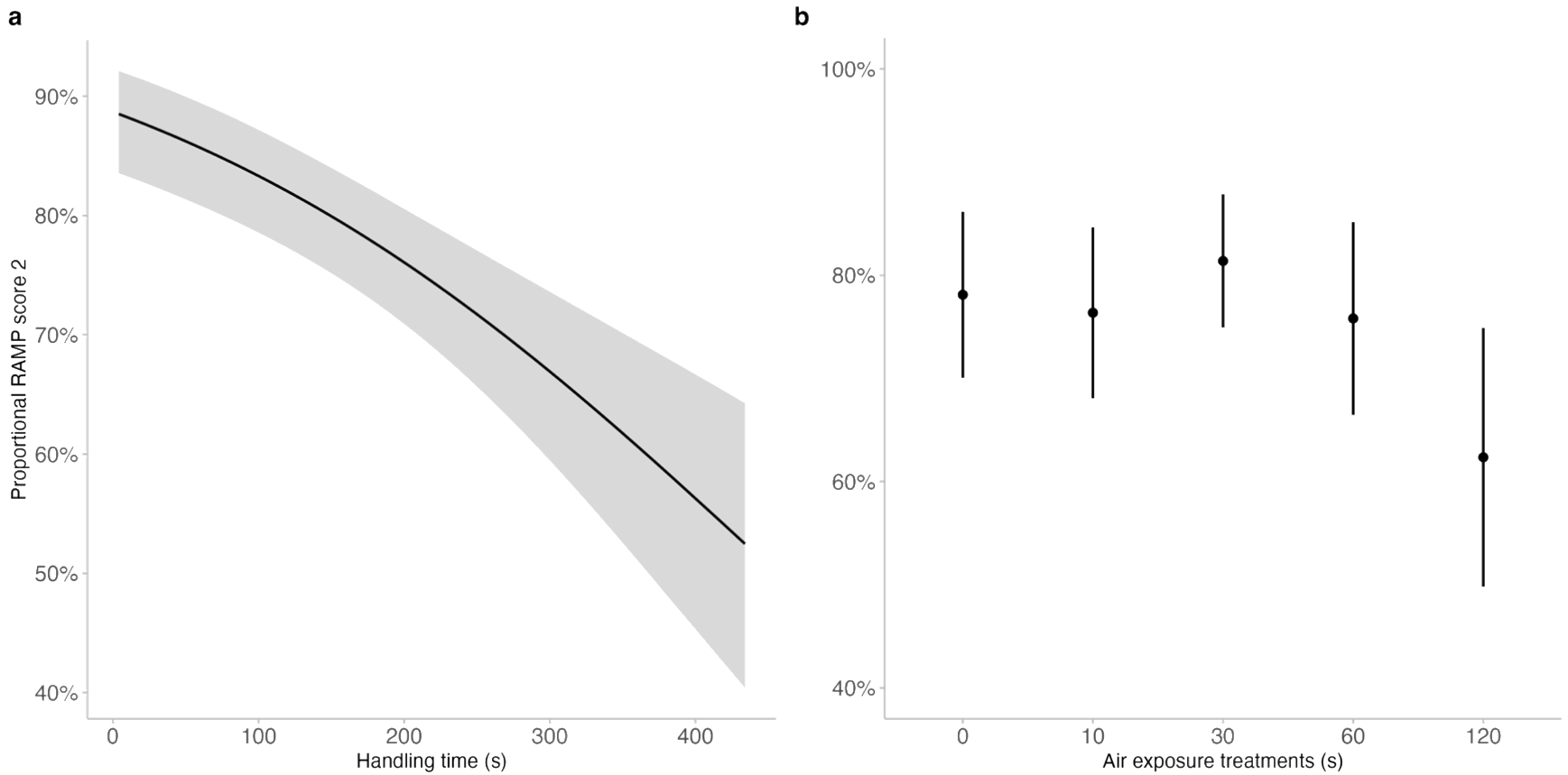

Figure 2.4. Two-part figure presenting a) the relationship between proportional RAMP score 2 and handling time, with the shaded area representing the 95% confidence interval around the fitted line and b) the proportional RAMP score 2 for different air exposure groups.

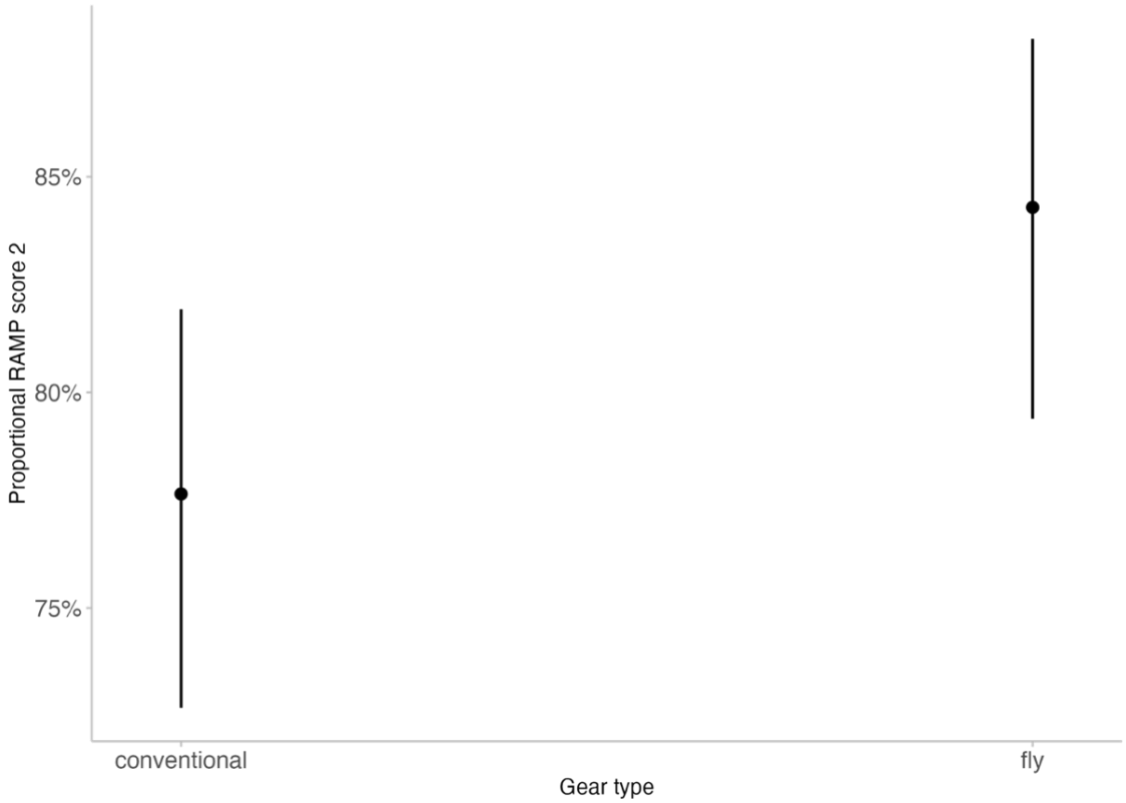

Figure 2.5. Proportional RAMP score 2 for different gear types. Expected mean and 95% confidence intervals are shown.

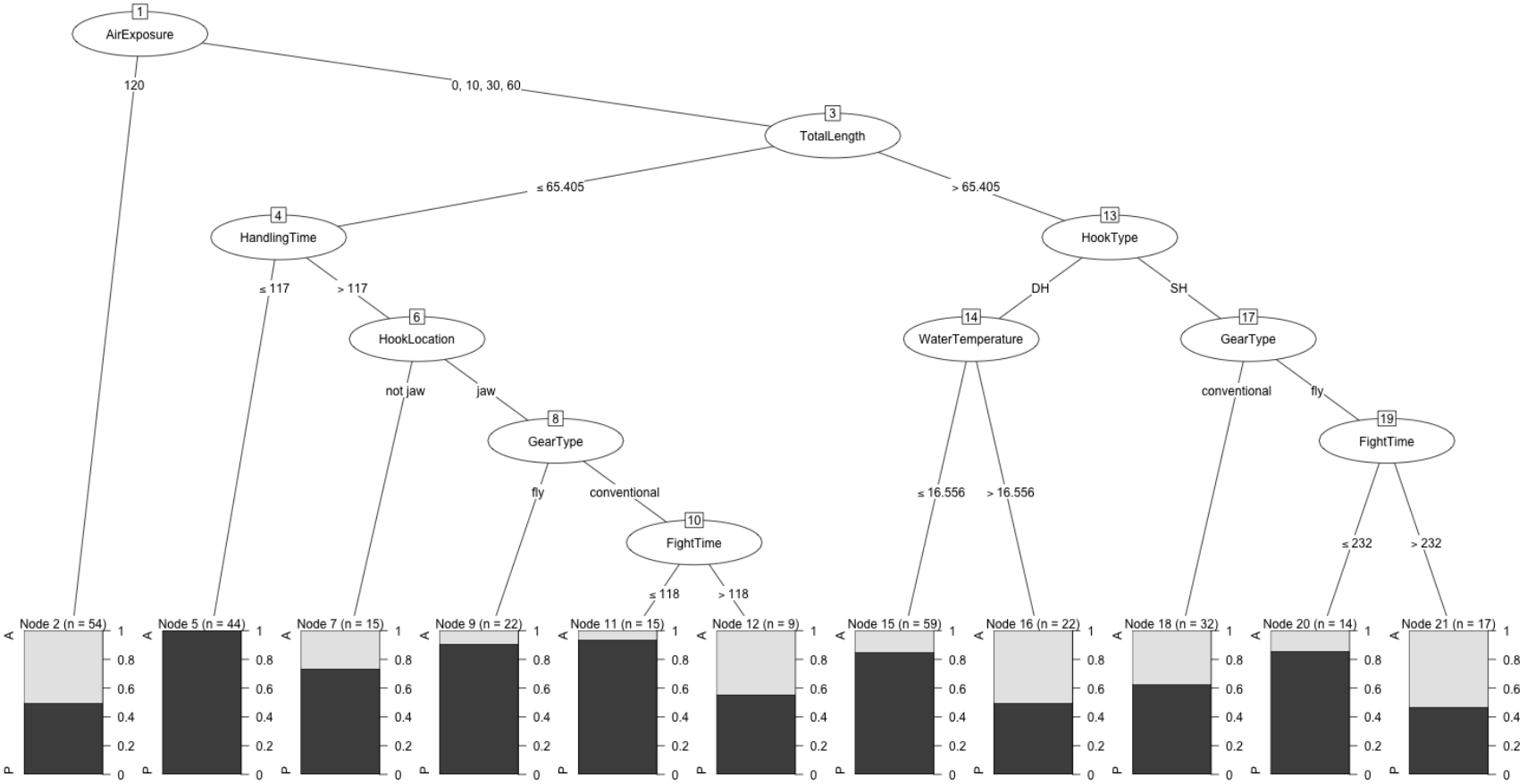

Figure 2.6. Decision tree showing the importance of air exposure, total length (cm), hook type (DH = double hook, SH = single hook), gear type, handling time (s), water temperature (°C), hook location, and fight time (s) in determining the presence or absence of equilibrium in striped bass.

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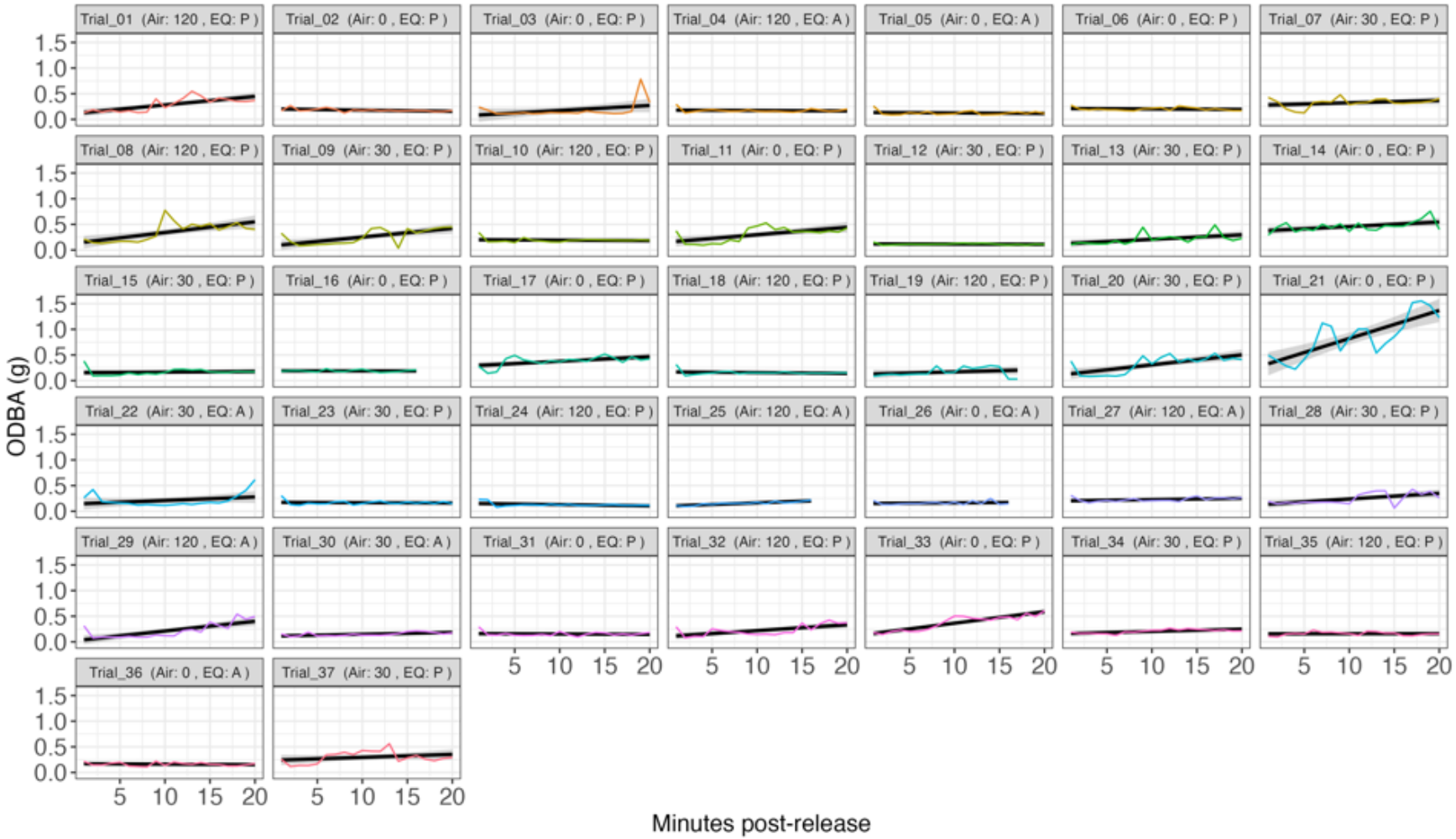

Figure 2.7. Overall dynamic body acceleration (ODBA) for striped bass across minutes post-release for each trial. Air exposure treatment and the result of the equilibrium test (EQ; A = absent, P = present) for each fish are presented in brackets. The color lines connect averaged OBDA per minute values and linear trends are shown via black lines with 95% confidence intervals shaded. The air exposure treatment is shown at the top of each panel for all trials.

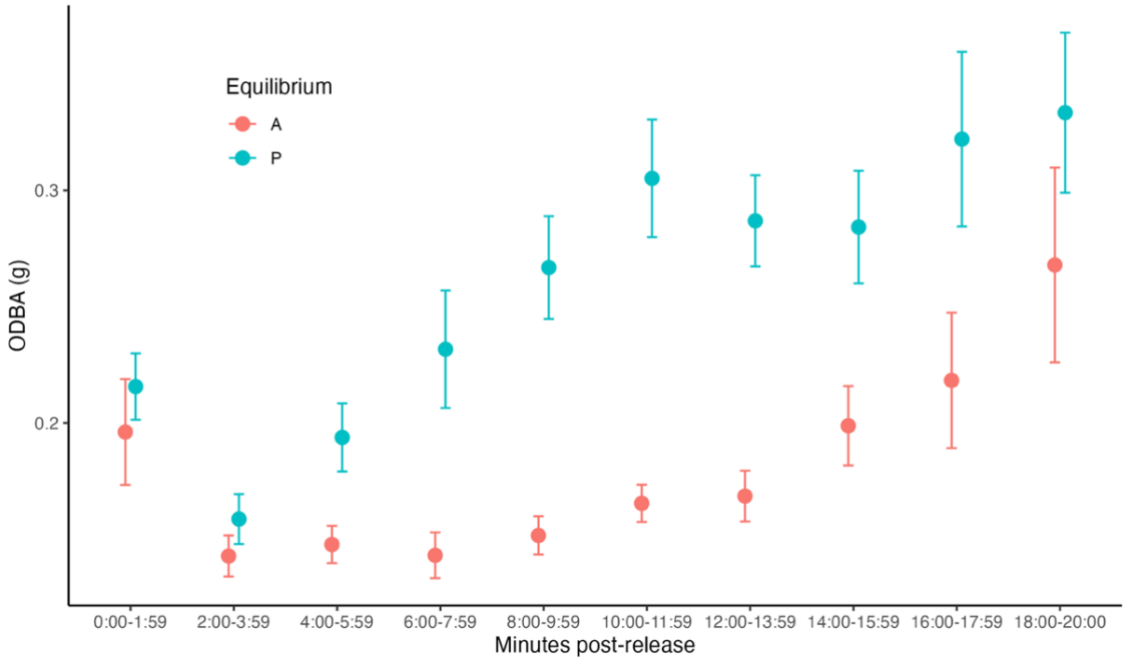

Figure 2.8. Overall dynamic body acceleration (ODBA) across two-minute intervals post-release for striped bass with absent (A) and present (P) equilibrium during the second reflex assessment. Mean and 95% confidence intervals are displayed.

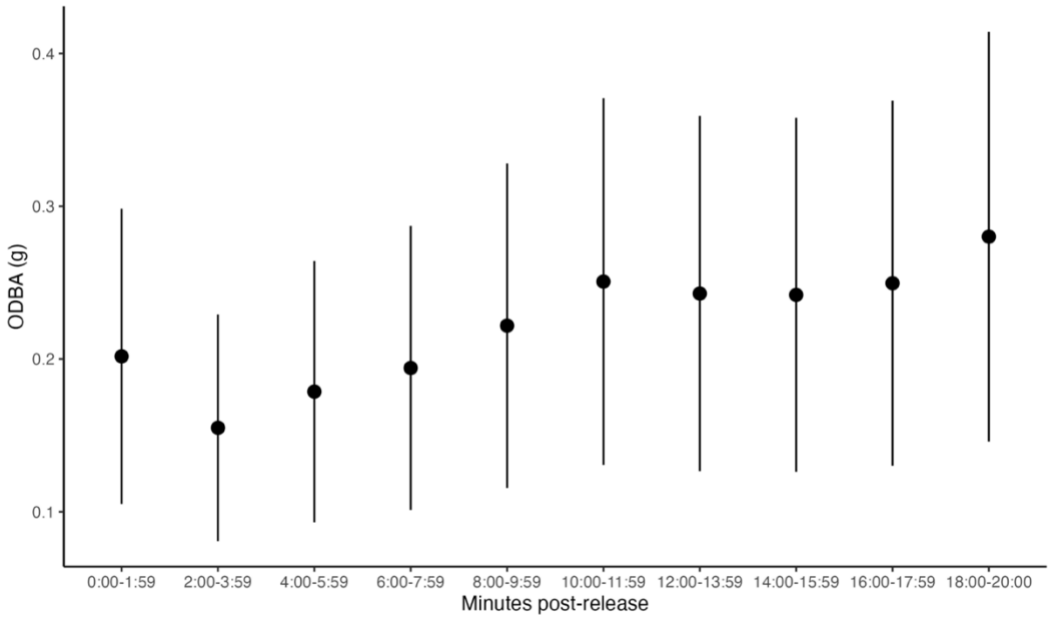

Figure 2.9. Overall dynamic body acceleration (ODBA) of striped bass across two-minute intervals post-release. Mean and 95% confidence intervals are displayed.

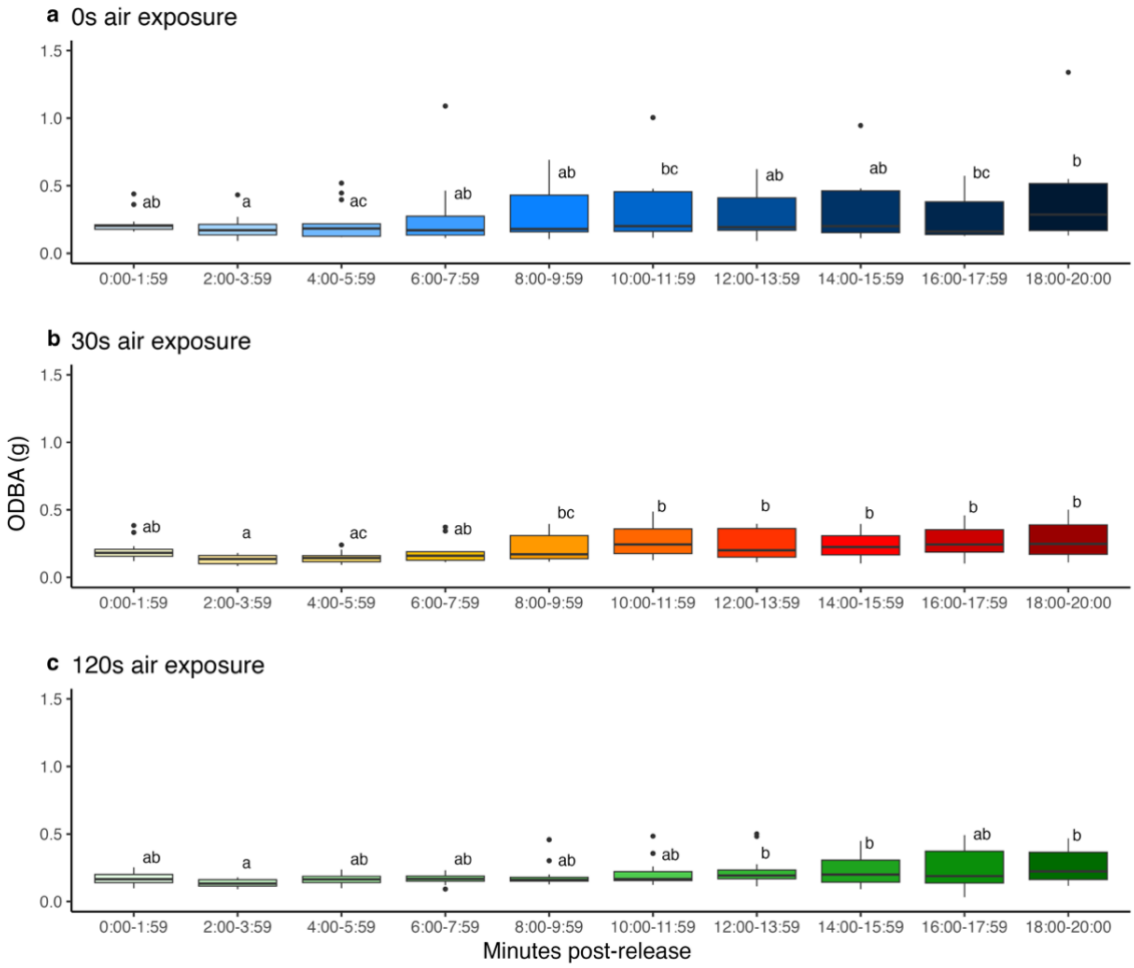

Figure 2.10. Overall dynamic body acceleration (ODBA) across two-minute intervals post-release for striped bass air exposed for a) 0 s b) 30 s and c) 120 s. Boxes indicate 25th and 75th percentiles, with horizontal lines indicating the median and whiskers show upper and lower extremes with outliers as dots. Letters represent the results of a Tukey post-hoc test, with the differing letters denoting significant differences in ODBA at the respective intervals.

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CHAPTER 3

UNDERSTANDING BELIEFS, PERCEPTIONS, AND ATTITUDES OF ANGLERS IN THE STRIPED BASS (MORONE SAXATILIS) RECREATIONAL FISHERY ALONG THE ATLANTIC COAST OF THE UNITED STATES

3.1 Abstract

In recreational fisheries, individual angler choices regarding adherence to regulations and guidelines have the potential to influence management outcomes, emphasizing the need to understand the factors that drive angler behavior. We conducted an online survey of anglers (n = 1651) along the Atlantic coast of the United States focus on the highly popular striped bass (*Morone saxatilis*) recreational fishery to examine anglers' perceptions regarding catch-and-release best practices, angling quality, threats to the stocks, the needs for management actions, and angler support for contemporary fishing regulations. Results reveal high voluntary release rates in the striped bass fishery, along with general understanding of the potential effects of angler behaviors have on fish intended for release and strategies to mitigate impacts. Anglers' perceptions of fishing quality, including a reported decline from the 2000s to the present, mirrored population assessment data on striped bass population trends. Respondents highlighted several threats to striped bass stocks, including pressures from the commercial fishery and the loss of juvenile habitats. They expressed strong support for management regulations and various conservation strategies, including implementation and enforcement of regulations, adoption of best practices for catch-and-release, increased scientific research, and efforts to enhance habitats. Despite broad consensus among respondents, perceptions and attitudes varied depending on gear preference, with fly anglers typically demonstrating stronger conservation-

oriented views. Insights gained from this survey provide important reference points for striped bass management and conservation.

Keywords: Recreational fisheries, conservation, fisheries management, angler specialization, social norms

3.2 Introduction

Globally, recreational angling is one of the most popular leisure activities, with average participation rates of about 10% of the adult population in industrialized nations (Arlinghaus et al., 2015). With its scale and scope, recreational angling is a significant contributor to the economy, generating approximately $190 billion USD globally each year (FAO, 2012). Economic capacity provided by recreational angling can come from a wide range of commerce, including the production and sales of fishing equipment, tackle, apparel, and boats, to services provided by bait shops, lodges and hotels, fishing guides and outfitters, and through advertising sales associated with fishing magazines, television shows, and tournaments. In many regions, the economic contributions of recreational angling can have a considerable multiplier effect and reach more deeply into local communities than commercial fisheries (Steinback et al., 2004; Cooke and Cowx, 2006), especially as the importance of recreational fisheries in coastal areas is increasing (Ihde et al., 2011). For example, in 2012, 12 million anglers made 85,000 fishing trips in US marine waters, accounting for an economic impact of $82 billion (Hughes, 2015).

In addition to their economic and social importance, recreational fisheries are also recognized as contributing to the decline of fish stocks (Post et al., 2002; Coleman et al., 2004; Cooke and Cowx, 2004; 2006). For example, recreational anglers with the intent to harvest retain an estimated 12% of all fish landed annually worldwide (Cooke and Cowx, 2004) such that angled fish support nutritional security in some regions (Lynch et al. 2024). For many species, the harvest from recreational fisheries can be greater than that for commercial fisheries, even though commercial fisheries are often more quickly implicated in the decline of fish populations (Cooke and Cowx, 2006). For harvest-oriented recreational fisheries and to help control the

rate at which fish are removed from a population, management agencies often use input and output controls such as bag limits, size limits, and closed seasons (Hilborn and Walters, 1992). As a result, many fish are often mandatorily released because they do not meet the criteria for harvest or are not the intended target species (i.e., bycatch). A large portion of fish are also released because of a growing conservation ethic among recreational anglers not interested in harvest (Policansky, 2002) or for other reasons (e.g., freezer is already full, preference for a different size or species, hassle of cleaning harvested fish). Here, management agencies and fisheries conservation organizations rely on voluntary guidelines (i.e., catch-and-release best practices) rather than legislation as a means to minimize angler impact on fish populations (Arlinghaus et al., 2007; Pelletier et al., 2007).

Although catch-and-release angling offers a more sustainable alternative to traditional harvest in most cases (Policansky, 2002), a proportion of released fish die as a result of being captured and handled (Wydoski, 1977), while others experience sublethal effects such as injury, physiological disturbance, behavioral alternations, and fitness impairment (Cooke et al., 2002). Depending on the gear used, the species of fish caught, the duration and general process of capture and handling (e.g., fight time, handling time, air exposure) and a range of environmental factors (e.g., water temperature, presence of predator), the mortality of released fish can range from less than 1% to >90% (Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005; Cooke and Suski, 2005; Cooke and Wilde, 2007). Given the high release rate in some recreational fisheries, impacts on physiology, behavior, and post-release survival have the potential to significantly affect fish populations (depending on characteristics of the fishery and population demographics of the fish population) and, subsequently, negatively impact the resource base of angling communities. In the last two decades,

however, a growing body of science has provided evidence suggesting that many angling impacts can be reduced by changes in individual angler behavior (e.g., angling and handling practices, gear choice; Brownscombe et al., 2017).

Individual angler behavior is often strongly influenced by personal beliefs, attitudes, and social norms within the angling community (Ajzen 1991; Fulton et al. 1996; Vaske and Donnelly 1999; Arlinghaus 2006; Stensland et al. 2013). These factors can vary widely across different segments of the angling population, particularly as angler specialization in terms of equipment and skills becomes more pronounced (Bryan, 1977; Fisher, 1997; Beardmore et al., 2013). Within the recreational angling community, there are two broad categories of gear type, conventional spinning gear and fly anglers. Fly fishing is often considered to be a more specialized form of recreational fishing, with anglers progressing towards this more nuanced form of casting and lure presentation with increasing experience and commitment to the sport. At times, this can result in fly anglers reporting a deeper connection to nature and conservation values (Snyder 2007; Taylor 2007). These differences in ethos across gear preferences can lead to differences in perceptions of a fishery and subsequent support for management regulations (Griffin et al., 2023).

In contemporary recreational fisheries, compliance with regulations presents a challenge as enforcement efforts are difficult to enforce due to high participation rates and diffuse effort over vast areas (Sullivan, 2002; Page and Radomski, 2006; Wilberg, 2009; Post et al., 2002). The prohibitive costs associated with enforcement efforts further complicate effective management (Post et al., 2002). Additionally, certain angler behaviors are inherently difficult to regulate (i.e., adoption of catch-and-release best practices). Consequently, shifting normative perceptions and beliefs through interpersonal communication (e.g., peer-to-peer sanctioning, outreach and education

programs) can play a powerful role in enhancing stewardship behavior within the recreational angling community (Balliet, 2010; Ostrom et al., 1992; Ostrom, 2014; Guckian et al., 2018; Bruskotter and Fulton, 2007). This underscores the importance of understanding current social norms, perceptions, and attitudes in the recreational fishery related to best practices, management regulations, perceived threats, and conservation strategies for successful fisheries management.

The evaluation of social norms, perceptions, and attitudes is of particular interest for the striped bass (*Morone saxatilis*) recreational fishery, one of the most popular and valuable recreational fisheries along the eastern seaboard of North America. Striped bass undertake seasonal migrations ranging from North Carolina in the fall and winter to Nova Scotia in the summer months (LeBlanc et al., 2020; Secor et al., 2020), providing recreational anglers with ample opportunities to target the species, catering to a wide range of budgets and skills. In 2016, the recreational striped bass fishery from North Carolina to Maine generated $13 billion USD of economic activity and contributed nearly $8 billion to the region's GDP (Southwick Associates, 2019). That same year in Massachusetts, 50% of recreational anglers fishing in saltwater specifically targeted striped bass, making over 20.8 million trips and contributing $1.6 billion to the GPD (Southwick Associates, 2019).

Habitat degradation and overfishing in the 1970s led to the collapse of striped bass stocks along the Atlantic coast of North America by the early 1980s (Richards, 1999; Uphoff, 2023). Although some rebuilding occurred because of subsequent management efforts, including a moratorium, reduced bag limits, quotas, and slot limits, the stock remains overfished (ASMFC, 2024). Though a commercial fishery exists, the recreational sector accounts for more than 80% of the harvest (NMFS, 2018). Moreover, because of regulations, the majority of striped bass caught by

recreational anglers are released back into the water (NMFS, 2018). In fact, because of growing concerns about the status of the striped bass stocks, the Atlantic States Marine Fisheries Commission (ASMFC) enacted emergency regulations in 2023 that reduced the harvestable slot limit across US Atlantic states to striped bass between 28 and 31 inches (71.12 – 78.84 cm; ASMFC, 2023), further increasing the number of striped bass to be mandatorily released. Releasing more striped bass, whether mandated or voluntary, could contribute to rebuilding stocks and ultimately to maintaining recreational fisheries (Policansky, 2002). However, the fate of fish can be impacted by angler behavior and potentially even anglers' knowledge and perceptions (Brownscombe et al., 2017; Chapman et al., 2018; Bower et al., 2024).

The goal of my study was to gain insights into social norms within the striped bass recreational fishery, along with angler perceptions of the fishery's state, catch-and-release practices, management regulations, and conservation efforts. Given that studies in other recreational fisheries revealed that gear specialization and angler values are correlated (Griffin et al., 2023), I hypothesized that there are differences in perceptions and attitudes between sectors of the striped bass recreational fishery that identify themselves based on the gear type they primarily use (fly fishing vs. conventional tackle). Using an online angler survey primarily consisting of closed-ended questions, I conducted a comprehensive examination of angler perceptions and attitudes regarding catch-and-release best practices, changes in fishing quality since the 1970s to the present, threats to the striped bass fishery, conservation needs, and existing management regulations, including the ASMFC emergency action.

3.3 Material and Methods

3.3.1 Sampling Frame and Distribution

Eligible participants for this survey were recreational anglers aged 18 years and older who had experience in marine striped bass angling along the Atlantic coast of North America, spanning from the Gulf of St. Lawrence in Canada to Georgia in the United States. The online survey launched on May 1st, 2023, and was open for responses until October 15th, 2023, coinciding with the striped bass angling season along the Atlantic seaboard. Survey distribution was carried out by a range of angler organizations (i.e., American Saltwater Guide Association), industry groups (i.e., Cheeky Fishing, Patagonia Fly Fishing), non-profits (i.e., International Gamefish Association, Keep Fish Wet, Stripers Forever), and fishing clubs (i.e., Cape Cod Salties, Cape Cod Trout Unlimited, Osterville Angler's Club, Cape Cod Flyrodders) who shared the survey via social media platforms (i.e., Instagram, Facebook) as well as through email and e-newsletters. We embraced a non-probabilistic approach given the ability of such an approach to reach a diffuse and specialized group of potential respondents (Howarth et al. 2024). As an incentive, participants were provided with the option to enter a raffle at the end of the survey to win a Patagonia Guidewater Backpack (retail value $299; Patagonia Inc., Ventura, California, US) The survey was administered through the Qualtrics online survey platform, and the methodology was approved by the University of Massachusetts Amherst Institutional Review Board (Protocol ID: 4398).

3.3.2 Survey Instrumentation

The survey was comprised of nine sections to collect data on 1) angler experience (e.g., years fishing, annual trip count, fishing location), 2) angling practices (e.g., gear preferences), 3) angling quality (e.g., decadal changes in fishing quality, perceived threats to the fishery), 4) agreement with regulations, 5) attitudes towards catch-and-release best practices and other conservation efforts, 6) media habits, 7) attitudes towards the ASMFC emergency action , 8) trust in science (not covered in this

manuscript), and 9) angler demographics (e.g., age, gender, guide employment, fishing focus (i.e., casual, active, advanced committed; see Appendix I for the complete questionnaire). All survey participants were presented with every section of the survey and asked to answer all questions provided, however, they had the option to skip questions. Display logics were included to hide questions that did not apply to respondents, and questions on agreement with fishing regulations varied based on respondents' fishing location. The questionnaire contained only closed-ended questions, with some providing an "other" option for respondents to give additional answers if their desired response was not listed.

3.3.3 Data Preparation and Analysis

Data preparation and analyses were performed using R (R Core Team, 2024). All responses were retained for subsequent data analysis; however, due to the limited sample size across provinces, no specific analyses were conducted on responses from Canada (n = 47). Responses obtained on a Likert scale were visualized using the *HH* package (Heiberger and Robbins, 2014).

3.3.3.1 Angler Characteristics and Demographic Information

To examine the distribution of responses across gender, age, fishing focus, annual fishing trips, guide employment, and preferred gear types (i.e., conventional vs. fly tackle, hook and lure types), I converted each category into percentages. I also assessed release rates based on gear preferences and utilized a Mann-Whitney U test to identify significant differences. Additionally, I converted responses regarding primary fishing locations and destinations into percentages and determined which states were most frequently reported as fishing location by respondents.

3.3.3.2 Catch-and-Release Best Practices

To assess angler knowledge and gauge participation in best practices aimed at mitigating potential catch-and-release effects, anglers were asked to rate the influence of several angling factors on the fate of released striped bass post-release (1= “Not at all” to 7= “A great deal”) and indicate their level of engagement in various best practices (1= “Never” to 7= “All the time”). Responses on the seven-point Likert scale were converted to numerical. Subsequent Mann-Whitney U tests were conducted to determine if the perceived influence of angling factors on post-release fate and engagement across best practices varied between conventional and fly anglers. To determine the factors that most influenced the degree of importance attributed to personal adoption of science-based best practices, I used an ordinal logistic regression with the following global model:

$$\tilde{Y}_{Importance\ of\ Best\ Practices} = b_1\,(Concern\ about\ the\ Fishery)_1 + b_2\,(Catch\ per\ Year)_2 + b_3\,(Satisfaction\ with\ the\ Fishing\ Quality)_3 + b_4\,(Gear\ Type)_4 + b_5\,(Age)_5 + b_6\,(Perception\ of\ Release\ Mortality\ as\ a\ Threat)_6 + b_7\,(Years\ of\ Experience)_7 + \varepsilon$$

Where $\tilde{Y}$ is the latent continuous variable of the ordered categorical variable Y, b is the contrast between thresholds of the ordered variable, and ε represents the remaining unexplained variation in the cumulative model (Bürkner and Vuorre, 2019). Candidate models were constructed using the *ordinal* package (Christensen, 2023), and the Akaike information criterion (AIC) was used to identify the best-performing model from the candidate set using *AICmodavg* (Mazerolle, 2023). Post hoc pairwise comparisons were generated for significant variables in the best-performing model using least-square means in the *emmeans* package (Lenth, 2024). Finally, the model fit was assessed with the Nagelkerke R^2 value (Nagelkerke, 1991) as well as the

Pulkstenis-Robinson and Hosmer Lemeshow test using the *generalhoslem* package (Jay, 2019; Fagerland and Hosmer, 2017).

3.3.3.3 Changes in Perceived Quality of Striped Bass Fishing

Detailed analyses were conducted to quantify observed changes in Atlantic striped bass fishing quality over time that could be tied to population health. Respondents were asked to rate their overall satisfaction with current fishing quality (1= "Extremely dissatisfied" to 7= "Extremely satisfied") as well as rate the fishing quality by each applicable decade from the 1970s to the present (1= "Extremely poor" to 7= "Extremely good"). After converting the five-point Likert scale into numerical data, Mann-Whitney U tests were used to identify differences in satisfaction with the current fishing quality as well as the perceived fishing quality across decades between conventional and fly anglers. To determine whether the mean striped bass fishing quality had changed from the 2000s, the decade with the reported best fishing quality, to the present, another Mann-Whitney U test was conducted on all responses. Kruskal-Wallis tests, with post-hoc Dunn's tests where appropriate, were used to determine whether anglers' perceptions of decadal fishing quality varied by experience, comparing those who began fishing in each decade to those with earlier fishing histories. Finally, an ordinal logistic regression was conducted to identify the factors driving general concern about the Atlantic striped bass recreational fishery using the following global model:

$$\tilde{Y}_{Concern\ about\ the\ Fishery} = b_1\,(Years\ of\ Experience)_1 + b_2\,(Gear\ Type)_2 + b_3\,(Satisfaction\ with\ the\ Fishing\ Quality)_3 + b_4\,(Catch\ per\ Year)_4 + b_5\,(Fishing\ Focus)_5 + b_6\,(Trips\ per\ Year)_6 + \varepsilon$$

3.3.3.4 Perceptions of Threats and Conservation Strategies for Striped Bass

When asked to rate the severity of threats to the striped bass recreational fishery (1= “Not at all” to 7= “Extremely”), respondents were allowed to select “other” and supply a threat if they felt that it was not listed. In most cases, these additional threats aligned with existing categories and were subsequently assigned to them. After conversion of categorical Likert-scale data into numerical values, Mann-Whitney U tests were conducted to identify if there were significant differences in how anglers using conventional gear versus fly fishing perceived threats to the fishery and if they differed in support of a range of management interventions. Further, respondents were asked to rate the level of responsibility associated with various agencies, institutions, and organizations for protecting and conserving the striped bass population. Additional Mann-Whitney U tests were then run to examine differences in perceptions of responsibility between conventional and fly anglers.

3.3.3.5 Agreement with Regulations and ASMFC Emergency Action

Agreement with regulations was evaluated for each state where respondents primarily fished or traveled to target striped bass. Again, responses were converted into numerical data and Mann-Whitney U tests were conducted to determine if conventional and fly anglers varied in support of state-specific regulations, including slot limit, bag limit, and gear restriction. Additionally, Mann-Whitney U tests were conducted to assess potential differences between conventional and fly anglers in their agreement with various statements concerning the foundation of Atlantic striped bass fishing regulations, as well as in their agreement with the ASMFC emergency action. To accommodate limited sample sizes in certain states, regional groupings were made. "New England" was comprised of Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut, the "Mid-Atlantic" was New York, New Jersey, Delaware, and Maryland, and the "South Atlantic" was Virginia, North Carolina, South Carolina,

and Georgia. These groupings allowed for the examination of agreement with the emergency action by region using a Chi-Squared Test of Independence. Additional descriptive plots for agreement with the ASMFC emergency action by individual state can be found in the supplementary material. Finally, to identify factors influencing agreement with the ASMFC emergency action, an ordinal logistic regression was run from the following global model:

$$\tilde{Y}_{Agreement\ with\ Emergency\ Action} = b_1\,(Age)_1 + b_2\,(Gear\ Type)_2 + b_3\,(Satisfaction\ with\ the\ Fishing\ Quality)_3 + b_4\,(Catch\ per\ Year)_4 + b_5\,(Concern\ about\ the\ Fishery)_5 + b_6\,(Trips\ per\ Year)_6 + b_7\,(Perception\ of\ Recreational\ Harvest\ as\ a\ Threat)_7 + \varepsilon$$

3.4 Results

3.4.1 Angler Characteristics and Demographic Information

The survey received 1651 responses, all of which were retained for data analysis. Respondents were predominantly men (n = 1127, 93.8%) between the ages of 25 and 64 (n = 907, 75.3%), identified as advanced anglers (n = 626, 52.4%), and reported taking more than 30 fishing trips per year (n = 614, 42.5%). Most respondents (n = 1091, 90.8%) were not employed as a fishing guide. Of all respondents, 42.6% (n = 630) primarily targeted striped bass using fly tackle, and 57.4% (n = 848) preferred conventional tackle using artificial soft bait with single hooks (n = 236, 27.8%), artificial hard bait with treble hooks (n = 227, 26.8%), natural bait (n = 199, 23.5%), and artificial hard bait with single hooks (n = 176, 20.8%). Over half of the respondents that provided information on release rate (n = 782, 51.6%) indicated releasing all of their caught striped bass that met the size limit regulations. The mean release rate of striped bass caught by fly anglers (92%) was significantly greater than

the mean release rate of anglers using conventional gear (82.6%; Mann-Whitney U test: $U = 172268$, $p < 0.001$).

Respondents fishing for striped bass in the United States primarily fished along the coast of Massachusetts (n = 661, 44.3%), Maine (n = 207, 13.9%), New Jersey (n = 159, 10.7%), and New York (n = 113, 7.6%) followed by Connecticut (n = 96, 6.4%), Rhode Island (n = 78, 5.2%), New Hampshire (n = 56, 3.8%), Maryland (n = 48, 3.2%), North Carolina (n = 24, 1.6%), Virginia (n = 21, 1.4%), Georgia (n = 13, 0.9%), Delaware (n = 8, 0.5%), and South Carolina (n = 8, 0.5%). Anglers fishing for striped bass in Canada primarily fished along the Atlantic coast of Nova Scotia or New Brunswick (n = 24, 51%), in the Gulf of Saint Lawrence (n = 17, 36.2%), and the coast of Quebec (n = 6, 12.8%). Respondents predominately traveled to Rhode Island (n=431, 37.4%), Massachusetts (n=356, 30.9%), Maine (n=282, 24.5%), New Hampshire (n=255, 22.1%), Connecticut (n=225, 19.5%), New York (n=184, 16%), and New Jersey (n=130, 11.3%) to fish for striped bass. Other travel destinations were Virginia (n=58, 5%), Maryland (n=50, 4.3%), North Carolina (n=50, 4.3%), Delaware (n=40; 3.5%), South Carolina (n=19, 1.7%), and Georgia (n=16, 1.4%). Overall, respondents most often targeted striped bass in Massachusetts (n=1017, 28.4%), Rhode Island (n=509, 14.2%), and Maine (n=489; 13.7%; Figure 3.1).

3.4.2 Catch-and-Release Best Practices

Both conventional and fly anglers perceived air exposure (Mann-Whitney U test: $U = 180482$, $p < 0.001$), hooking damage (Mann-Whitney U test: $U = 183460$, $p < 0.001$), physical injury during handling (Mann-Whitney U test: $U = 192472$, $p = 0.04$), and the duration of fight time (Mann-Whitney U test: $U = 191616$, $p < 0.01$) to have strong adverse effects on the fate of striped bass following release, with a greater proportion of fly anglers rating these factors as having a great deal of negative impact

(Figure 3.2). Similarly, slime loss (Mann-Whitney U test: $U = 167535$, $p < 0.001$), and water temperature (Mann-Whitney U test: $U = 180050$, $p < 0.001$), were generally perceived to have a less negative impact, yet fly anglers more often attributed a good amount to a great deal of influence to those factors compared to conventional anglers, who more often selected responses ranging from somewhat to not at all influential. Respondents regarded fish size as the least influential factor, with most of both angler groups deeming it only somewhat influential (Mann-Whitney U test: $U = 199582$, p-value > 0.05).

Both conventional and fly anglers reported high engagement in limiting handling time (Mann-Whitney U test: $U = 181092$, $p > 0.05$) and frequent use of circle or barbless hooks (Mann-Whitney U test: $U = 200040$, $p > 0.05$) when targeting striped bass (Figure 3.3). While conventional and fly anglers frequently reported to engage in practices such as holding fish horizontally (Mann-Whitney U test: $U = 175279$, $p = 0.024$), minimizing fight time (Mann-Whitney U test: $U = 175947$, $p < 0.01$), and wetting hands, towels, or the boat deck when handling fish (Mann-Whitney U test: $U = 135194$, $p < 0.001$), a greater proportion of fly anglers claimed to employ these practices all the time compared to conventional anglers. Further, a greater proportion of fly anglers than conventional anglers reported keeping striped bass submerged in the water frequently to all the time during handling (Mann-Whitney U test: $U = 140202$, $p < 0.001$). Additionally, fly anglers more often reported using knotless rubber nets (Mann-Whitney U test: $U = 151542$, $p < 0.001$) as well as avoiding fishing at high water temperatures (Mann-Whitney U test: $U = 131056$, $p < 0.001$), while anglers using conventional gear reported using dehooking tools and lip gripping devices (Mann-Whitney U test: $U = 209551$, p-value < 0.001) more frequently than fly anglers. Both groups reported low use of livewells (Mann-Whitney

U test: U = 252472, $p < 0.001$) or gloves (Mann-Whitney U test: U = 217370, $p < 0.001$), but a greater proportion of fly anglers reported never using these tools compared to anglers using conventional tackle.

The importance attributed to science-based catch-and-release best practices was best modeled by variation in gear preference, the perceived threat of release mortality to the fishery, and the level of concern about the fishery (Nagelkerke pseudo $R^2 = 0.17$, Pulkstenis-Robinson and Hosmer-Lemeshow tests $p > 0.05$) (Figure 3.4). Overall, fly anglers were more likely to consider science-based best practices very important compared to conventional anglers ($z = 3.43$, $p < 0.001$). Respondents who perceived release mortality as extremely ($z = -3.83$, $p < 0.01$), very ($z = 3.12$, $p = 0.03$), fairly ($z = -3.44$, $p = 0.01$), or somewhat ($z = 3.14$, $p = 0.03$) detrimental to the striped bass fishery were more likely to regard best practices as very important than those who perceived release mortality as not at all detrimental to the fishery. Further, respondents who were extremely ($z = -4.63$, $p < 0.001$) or very ($z = 3.78$, $p < 0.01$) concerned about the fishery were more likely to consider best practices as very important compared to those who were not at all concerned.

3.4.3 Changes in Perceived Quality of Striped Bass Fishing

Overall satisfaction with the fishing quality varied significantly based on gear preference, with 68.3% of anglers that used conventional gear expressed being somewhat to extremely satisfied, compared to lower levels among fly anglers (57.2%; Mann-Whitney U test: U = 265855, $p < 0.001$). Across decades, respondents perceived angling quality to be lowest in the 1980s, followed by the 1970s, and highest in the 2000s (Figure 3.5). Fishing quality was mostly rated as fair to very good in the 1990s to the present, although respondents reported a significant decline in angling quality from the 2000s to the 2020s (Mann-Whitney U test: U = 436696, p

< 0.001). Perceived decadal fishing quality differed significantly based on gear preference for all decades except for the period between 1980-1989 (Mann-Whitney U test: U = 17271, p > 0.05) and 2010-2019 (Mann-Whitney U test: U = 180949, p > 0.05). In the 1970s, a greater proportion of conventional anglers (22.4%) than fly anglers (11%) rated fishing quality as very good, while a greater proportion of fly (9.7%) than conventional anglers (6.2%) indicated extremely poor fishing quality (Mann-Whitney U test: U = 19041, p < 0.01). Further, more conventional (10%) than fly anglers (4%) considered fishing quality in the 1990s as poor, while more fly anglers (25.2%) than conventional anglers (18.8%) described fishing quality during this time period as very good (Mann-Whitney U test: U = 38798, p = 0.013). In the 2000s, a greater proportion of fly anglers (57.5%) rated fishing quality as good compared to conventional anglers (46.5%), while a greater proportion of conventional anglers (31.7%) than fly anglers (23.7%) considered it only fair (Mann-Whitney U test: U = 42774, p = 0.4). From 2020 to the present, fly anglers (29.2%) more frequently than conventional anglers (22.7%) described fishing quality as fair, while conventional anglers (12.3%) more often than fly anglers (5.6%) rated it as extremely good (Mann-Whitney U test: U = 249752, p < 0.001).

Although the majority of respondents considered decadal fishing quality worst during the 1980s, anglers who started fishing during that decade perceived fishing quality worse than those who had already fished in the 1970s (p < 0.001; Figure A.1). There was no significant difference in perceived fishing quality in the 1990s between anglers who started fishing in that decade or a previous decade (p > 0.05). Anglers who began fishing in the 1980s were significantly more likely to rate fishing quality in the 2000s as extremely good compared to those who started fishing in the 1970s (p < 0.001) and those who began in the 2000s (p < 0.001). Similarly, anglers who first

fished in the 1990s perceived fishing quality in the 2000s better than anglers who first fished in the 1970s ($p < 0.001$) or the 2000s ($p < 0.01$). There was no significant difference in perceived fishing quality in the 2010s between anglers with different levels of fishing experience ($p > 0.05$). Anglers who started fishing in the 2020s ($p < 0.01$) or the 2000s ($p < 0.01$) perceived fishing quality from the 2020s to the present better than those whose fishing experience dates back to the 1970s. The difference in perceived fishing quality from the 2020s to the present between anglers who first fished in the 2010s and anglers whose fishing experience dates back to the 1970s was not significant ($p = 0.06$). Further, anglers who first fished in the 1980s rated fishing quality in the 2020s to the present better than anglers who already fished in the 1970s ($p < 0.01$). Anglers who started fishing in the 1990s considered fishing quality in the 2020s worse than anglers who began fishing in the 1980s ($p = 0.02$), the 2000s ($p = 0.04$), and the 2020s ($p = 0.03$).

Concern about the current state of the striped bass fishery was best modeled by variance in gear preference, fishing focus, age, satisfaction with fishing quality, and fishing effort (i.e., days on the water) (Nagelkerke pseudo $R^2 = 0.21$, Pulkstenis-Robinson and Hosmer-Lemeshow tests $p > 0.05$; Figure 3.6). While concern about the current state of the fishery was generally high, respondents using fly gear were more concerned than those using conventional gear ($z = 4.49$, $p < 0.001$). Further, the likelihood of anglers feeling very concerned increased as satisfaction with the fishing quality decreased, and those who felt extremely dissatisfied were more likely to be very concerned compared to anglers who reported being neither satisfied nor dissatisfied ($z = -3.12$, $p = 0.03$), somewhat satisfied ($z = -3.44$, $p = 0.01$), very satisfied ($p < 0.01$), or extremely satisfied ($z = -4.99$, $p < 0.001$). Respondents identifying as advanced ($z = -2.76$, $p = 0.03$) or committed ($z = 3.55$, $p < 0.01$) anglers

were more likely to feel very concerned about the state of the fishery than anglers who fished casually. Lastly, anglers who went on more than 30 fishing trips per year expressed significantly greater concern compared to those who had not fished for striped bass in the 12 months prior to taking the survey ($z = 3.46$, $p = 0.02$). Although the likelihood of feeling very concerned about the Atlantic striped bass recreational fishery increased with age, post hoc pairwise comparisons revealed no significant influence.

3.4.4 Perceptions of Threats and Conservation Strategies for Striped Bass

Conventional and fly anglers most frequently perceived commercial harvest (Mann-Whitney U test: $U = 203144$, $p < 0.01$) and the loss/destruction of juvenile habitat (Mann-Whitney U test: $U = 188110$, $p < 0.001$) as most detrimental to the Atlantic striped bass fishery, although fly anglers more often perceived these factors as extremely negative (Figure 3.7). Similarly, a larger proportion of fly anglers felt that release mortality (Mann-Whitney U test: $U = 200780$, $p < 0.01$), general habitat loss/destruction (Mann-Whitney U test: $U = 182756$, $p < 0.001$), and decline in forage fish (Mann-Whitney U test: $U = 194505$, $p < 0.001$), are an extreme threat to the fishery compared to conventional anglers. There was consensus in the perceived level of threat posed by individual angler practices between the two groups, with respondents predominantly perceiving it as somewhat to extremely negatively affecting the fishery (Mann-Whitney U tests: $U = 215476$, $p > 0.05$). Anglers fishing with conventional gear generally exhibited less concern about bad water quality (Mann-Whitney U tests: $U = 189279$, $p < 0.001$), recreational harvest (Mann-Whitney U tests: $U = 165386$, $p < 0.001$), climate change (Mann-Whitney U tests: $U = 160486$, $p < 0.001$), recreational fishing regulations (Mann-Whitney U tests: $U = 190163$, $p < 0.001$), and depredation (Mann-Whitney U tests: $U = 207842$, $p = 0.042$) compared to

fly anglers. Other than the answer options listed, respondents most frequently (30.7%) indicated that poaching and lack of law enforcement negatively affected the fishery.

Despite differences in the degree of support (Mann-Whitney U test: $U = 171810$, $p < 0.01$), fly and conventional anglers most frequently indicated appropriate regulations for the commercial fishery to be an extremely important management intervention (Figure 3.8). Further, a greater proportion of fly anglers than conventional anglers indicated that enforcement of fishing regulations (Mann-Whitney U test: $U = 170331$, $p < 0.01$), appropriate fishing regulations for recreational fisheries (Mann-Whitney U test: $U = 165581$, $p < 0.001$), understanding striped bass populations through science (Mann-Whitney U test: $U = 146142$, $p < 0.001$), adoption of science-based catch-and-release best practices by recreational anglers (Mann-Whitney U test: $U = 155663$, $p < 0.001$), and fish habitat enhancement (Mann-Whitney U test: $U = 153532$, $p < 0.001$), are extremely important, although there was strong support for these management interventions among both groups. Support for measures such as understanding striped bass fishery performance through angling club competitions, angler apps, and angler diaries (Mann-Whitney U test: $U = 190906$, $p = 0.04$), and information on how to improve catch rates (Mann-Whitney U test: $U = 200106$, $p = 0.013$) was lowest for both angler groups, however a greater proportion of conventional anglers expressed that these are extremely important measures for improving the striped bass fishery. The only striped bass management intervention that groups did not differ on were improved access to fishing locations (Mann-Whitney U test: $U = 191106$, $p > 0.05$), which received a moderate degree of support from both groups.

Overall, both conventional and fly anglers identified individual anglers (Mann-Whitney U test: $U = 189590$, $p < 0.01$), guide associations (Mann-Whitney U

test: U = 166503, $p < 0.001$), the government (Mann-Whitney U test: U = 175744, $p < 0.001$), and scientists (Mann-Whitney U test: U = 176438, $p < 0.001$) as more responsible for the conservation and protection of the striped bass stock than the fishing tackle industry (Mann-Whitney U test: U = 158408, $p < 0.001$) and non-profit organizations (Mann-Whitney U test: U = 154502, $p < 0.001$), yet fly anglers more frequently assigned extreme responsibility to all entities listed (Figure 3.9).

3.4.5 Agreement with Regulations and ASMFC Emergency Action

Most respondents targeting striped bass in the New England states (Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut) and New York viewed the slot limit in effect before the emergency action (28 - 35”/71.1 – 88.9 cm) as either appropriate or too loose and the bag limit (1 fish) as appropriate. At the same time, they considered the gear restrictions (only inline circle hooks when angling with natural bait) as appropriate (Figure A.2-A.7). Conventional and fly anglers generally differed in their attitudes toward regulations, except for the bag limit (Mann-Whitney U test, U = 8940.5, p-value > 0.05) and gear restrictions in Connecticut (Mann-Whitney U test, U = 9426, p-value > 0.05), as well as the gear restrictions in New York (Mann-Whitney U test, U = 5986.5, p-value > 0.05). As for other regulations in the New England states and New York, a greater proportion of fly anglers considered the slot limit before the emergency action (Mann-Whitney U tests; Maine: U = 25416, $p < 0.001$; New Hampshire: U = 11268, $p < 0.001$; Massachusetts: U = 118406, $p < 0.001$; Rhode Island: U = 26484, $p < 0.01$; Connecticut: U = 9917.5, $p = 0.03$, New York: U = 6330.5, $p = 0.04$), and bag limit (Mann-Whitney U tests; Maine: U = 24535, $p < 0.01$; New Hampshire: U = 10484, $p < 0.01$; Massachusetts: U = 114908, $p < 0.001$; Rhode Island: U = 25673, $p = 0.01$, New York: U = 6234.5, $p = 0.05$) as too loose compared to conventional anglers. Conversely, a greater proportion of

conventional anglers considered the gear restrictions (Mann-Whitney U tests; Maine: $U = 25118$, $p < 0.001$; New Hampshire: $U = 10893$, $p < 0.001$; Massachusetts: $U = 120108$, $p < 0.001$; Rhode Island: $U = 25690$, $p < 0.01$) as somewhat or too strict compared to fly anglers. In New Jersey, conventional anglers predominantly perceived the slot limit in effect before the emergency action (28-38”) as either appropriate or too loose, while fly anglers almost unanimously said it was too loose (Mann Whitney U test: $U = 5538.5$, $p < 0.001$, Figure A.8). Similarly, while most respondents considered the bag limit (1 fish) appropriate, a larger proportion of fly anglers deemed it too loose compared to conventional anglers (Mann Whitney U test: $U = 5232.5$, $p < 0.01$). Most respondents considered the gear restrictions appropriate, yet a greater proportion of conventional anglers regarded them as somewhat strict or too strict, while a greater proportion of fly anglers perceived them as somewhat or too loose (Mann Whitney U test: $U = 5732$, $p < 0.001$). Due to the limited sample size, no statistical tests were conducted for Delaware, Maryland, Virginia, North Carolina, South Carolina, and Georgia; however, descriptive plots can be found in the supplementary material (Figure A.9-A.14).

Overall, respondents widely supported the ASMFC emergency action implemented in 2023, however, a greater proportion of fly anglers agreed compared to a greater proportion of anglers using conventional gear who expressed disagreement (Mann-Whitney U test, $U = 111809$, p-value < 0.001; Figure 3.10). There was no difference in agreement with the emergency action across different regions of the Atlantic coast (Chi-square test, $X\text{-squared} = 83494$, $df = 8$, p-value > 0.05). The best-performing ordinal logistic regression model showed that agreement with the ASMFC emergency action varied with gear preference, age, perception of recreational harvest as a threat to the fishery, and level of concern about the fishery (Nagelkerke pseudo

$R^2 = 0.23$, Pulkstenis-Robinson and Hosmer-Lemeshow tests $p > 0.05$; Figure 3.11). After post hoc pairwise comparisons, only perception of release mortality as a threat to the striped bass population and level of concern about the fishery significantly influenced agreement with the emergency action. Anglers who perceived recreational harvest as not at all threatening to the striped bass population were significantly more likely to disagree with the emergency action than those who perceived recreational harvest a little ($z = -3.12$, $p = 0.03$), somewhat ($z = 4.62$, $p < 0.001$), fairly ($z = -5.8$, p-value < 0.001), very ($z = 4.75$, p-value < 0.001) or extremely threatening ($z = -4.98$, p-value < 0.001). Further, the likelihood of agreement with the emergency action increased with the level of concern about the fishery, and respondents who were extremely concerned were significantly more likely to agree with the emergency action than those who were only somewhat ($z = 4.13$, $p < 0.001$), a little bit ($z = 3.16$, $p = 0.03$), not very much ($z = -5.55$, $p < 0.001$), or to not at all concerned ($z = -4.33$, $p < 0.001$).

Conventional and fly anglers differed in level of agreement with most statements concerning the basis of fishing regulations for striped bass (Figure 3.12). Overall, there was strong consensus among both groups that regulations should be informed by the latest available research, although fly anglers (62.8%) expressed strong agreement more frequently than conventional anglers (43.1%; Mann-Whitney U test, $U = 157330$, p-value < 0.001). Conversely, there was strong opposition among both groups to the notion that regulations are unnecessary, with fly anglers (83.5%) significantly more often than conventional anglers (73.1%) expressing strong disagreement (Mann-Whitney U test, $U = 228604$, p-value < 0.001). In comparison to conventional anglers (11.3%), a larger proportion of fly anglers (19%) disagreed with the statement that regulations should be guided by angler perceptions and experiences

(Mann-Whitney U test, U = 226266, p-value < 0.01). Further, a larger proportion of fly anglers (29.3%) than conventional anglers (20.9%) indicated that they somewhat agreed with the perspective that regulations should be founded on the judgment of guide associations (Mann-Whitney U test, U = 169673, p-value < 0.001) while a greater number of conventional (11.6%) than fly anglers (7.2%) strongly disagreed. Similarly, a larger proportion of fly (11.8%) than conventional anglers (4.4.%) agreed with the statement that regulations should be made by non-profit organizations, while a greater proportion of conventional anglers (18.8%) compared to fly anglers indicated disagreement (13.2%) (Mann-Whitney U test, U = 168879, p-value < 0.001). Regardless of gear preference, anglers shared similar perspectives on the role of state government in setting regulations, with the majority of angler responses ranging from strongly disagree to somewhat agree (Mann-Whitney U test, U = 202067, p-value > 0.05).

3.5 Discussion

Management regulations and guidelines for proper catch-and-release practices can be challenging to enforce, and decisions regarding compliance and the adoption of best practices are ultimately made at the level of the individual angler. Therefore, it is crucial to understand current behaviors, as well as the underlying social norms, attitudes, and perceptions within the recreational fishing community. This understanding can help shift social norms toward more responsible stewardship behaviors (REF), thereby enhancing the success of fisheries management. My online non-probabilistic survey revealed that anglers targeting striped bass have a varied understanding of the stressors affecting striped bass welfare post-release, although many reported regularly engaging in a range of catch-and-release best practices. Respondents noted a decline in the quality of Atlantic striped bass fishing since the

2000s, with the commercial fishery and the decline or loss of juvenile habitat perceived as the most severe threats. Respondents also expressed strong support for various conservation priorities, including management regulation. Despite general conservation-minded attitudes, the survey revealed heterogeneity across subgroups of the angling community (as has been documented in most recreational fishing surveys even when targeting a specific type of fish or in a rather defined geographic region; e.g., Arlinghaus et al., 2008; Nguyen et al,, 2012; Guay et al., 2021), with fly anglers typically demonstrating more conservation-oriented perspectives than those primarily using conventional gear. Collectively, these data provide additional reference points for the status and management of the striped bass fishery along the Atlantic coast of North America.

3.5.1 Catch-and-Release Best Practices

The reported release rate in this survey was high, with over half of respondents (51.6%) indicating they voluntarily release all striped bass they catch, even those of harvestable size. This finding underscores the importance of understanding current social norms surrounding catch-and-release best practices to promote proper angling and handling behavior in the fishery. Notably, release behavior varied among angler groups based on gear preferences, with fly anglers reporting higher release rates than those using conventional gear. This difference may stem from fly anglers' greater concern about the impact of recreational harvests on striped bass populations. Supporting this, Stensland et al. (2013) found that awareness of potential negative consequences can significantly influence angler behavior, and the belief that keeping fish may harm the fishery often leads to more frequent catch-and-release practices.

The degree of physical and physiological stress experienced by striped bass during catch-and-release angling directly influences their welfare and survival

following release (Graves et al., 2009; Griffin et al., 2024; Chapter 2). Thus, anglers' awareness of these factors is essential for informed decision-making regarding their angling practices. In my survey, most respondents deemed air exposure and hooking damage as the most harmful factors influencing the fate of released striped bass, while water temperature and fish size were perceived as least critical. Although data on catch-and-release impacts on striped bass is limited, existing research highlights hooking damage as a pivotal factor influencing the fate of released striped bass (Diodati and Richards, 1994; Dean et al., 2024; Griffin et al., 2024) and the primary cause of post-release mortality across recreational fisheries (Muoneke and Childress 1994; Bartholomew and Bohnsack 2005). The effects of angling-related air exposure have not been explored for striped bass; however, research on other recreationally targeted species has identified air exposure as a major factor influencing the fate of fish post-release (reviewed in Cook et al., 2015). In contrast to anglers' perceptions of water temperature as being among the least important factors influencing the fate of released striped bass, research shows that water temperature can have a significant influence on striped bass (Wilde et al. 2000; Millard et al., 2005; Griffin et al., 2024). Collectively, these findings highlight a gap between scientific knowledge and anglers' understanding of the effects of water temperature on striped bass survival. Consequently, there is a need for targeted educational efforts (Nguyen et al., 2017; Cooke et al., 2020) to raise awareness about how angler decisions and behavior can impact fish survival and what measures can be taken to mitigate these effects (i.e., avoid fishing in warm water; Jeanson et al. 2021).

While catch-and-release angling inevitably induces some level of stress in fish, anglers can mitigate their impact on fish intended for release by employing a variety of tools and techniques (Brownscombe et al., 2017). Anglers frequently reported

limiting handling time, holding fish horizontally, reducing fight time, wetting their hands, towels, or decks before handling, and using circle or barbless hooks. Some listed practices and tools are not commonly used in fly fishing, which may account for the lower engagement of fly anglers. For example, fly anglers were less likely to use dehooking tools and lip-gripping devices, as striped bass are typically caught with single J hooks, and fly anglers often fish from the shore, where fish can easily be landed by hand or with a net. Interestingly, despite anglers' strong awareness about the negative effects of air exposure on the survival of released striped bass, a substantial number—especially conventional anglers—still reported air exposing their catch at times. Fly anglers, who are often poised in the water when fishing, usually have less need to lift the fish out of the water. In contrast, conventional anglers, particularly those fishing from boats, often air-expose their catches when bringing fish on board for closer inspection, hook removal, or photos. Given that guidelines for catch-and-release often cannot be mandated, fostering a shift in social norms towards the adoption of best practices (i.e., limiting air exposure) can lead to long-term self-management among anglers (Cooke et al., 2013; Chapman et al. 2018).

Regardless of gear preference, respondents recognized the importance of catch-and-release best practices for striped bass. However, fly anglers often expressed greater awareness of the potential negative impacts of catch-and-release and more substantial support for adopting best practices than conventional anglers. This may be because fly anglers tend to be more deliberate in practicing catch-and-release and are more frequently targeted by conservation organizations and social media campaigns that promote sustainable angler behavior, such as best practices for catch-and-release (e.g., Patagonia Fly Fishing, Keep Fish Wet; Snyder, 2007; Danylchuk et al., 2018).

3.5.2 Changes in Perceived Quality of Striped Bass Fishing

Local ecological knowledge has been shown to closely parallel scientific understanding and effectively reflect the status of fisheries (Shephard et al., 2021; Griffin et al., 2023). Similarly, in this study, angler perceptions of striped bass fishing quality over the decades closely reflected documented trends in the species' population dynamics, thus emphasizing the potential value of angler surveys in informing fisheries management. Specifically, angler views on decadal fishing quality mirror the historical pattern of overfishing in the early 1970s, which led to a peak in striped bass landings followed by a stock collapse (Richards and Rago, 1999). In response, the ASMFC implemented a moratorium in the mid-to late-1980s, which successfully led to the stock's recovery in the 1990s (Richards and Rago, 1999) and the female spawning stock biomass exceeding its target in the early 2000s (ASMFC, 2022). However, consistent with anglers' reports of declining fishing quality, the spawning stock biomass sharply declined in the 2010s and has remained low since (ASMFC, 2022). Notably, anglers with fishing histories dating back to the 1970s generally rated fishing quality in recent decades, including the 2000s and the 2020s to the present, lower than anglers with shorter fishing histories. This suggests a loss of intergenerational knowledge transfer and possible "shifting baselines" phenomenon (Pauly, 1995), where more experienced anglers have witnessed a decline over time, while newer anglers might lack the reference points for previous conditions. This finding underscores the need for regular surveys within angling communities to capture local ecological knowledge before previous generations' perspectives are lost (Pereira and Hansen, 2003).

Overall satisfaction with fishing quality varied by gear preference, with anglers using conventional tackle being generally more satisfied than those who preferred fly gear. This difference may partly be due to conventional anglers reporting

higher annual catch rates than fly anglers in this study. Fish often aggregate in preferred habitats, and technological advancements, especially for boat anglers, enable more efficiency with locating fish to target (Dassow et al., 2020; Cooke et al., In Press). This can mask signs of overfishing or population decline, as catch rates may remain stable despite actual decreases in fish abundance—a phenomenon known as hyperstability (Hilborn et al., 1992). Due to their seasonal nearshore migrations and strong fidelity to specific spawning grounds (LeBlanc et al., 2020; Secor et al., 2020), striped bass can be reliably targeted by anglers across diverse environments and with various tackle types, which makes them particularly vulnerable to hyperstability. Furthermore, angler perceptions of good fishing quality may be skewed by the fishery's current reliance on the last robust year class of 2015 (ASMFC, 2023; Durell and Weedon**,** 2023). However, biological assessments reveal that this perception is misleading, as subsequent spawning events have shown limited success. The stock recorded a young-of-year (YOY) index below the long-term average for the fifth consecutive year in 2023 (Durell and Weedon, 2023), which hampers further recruitment to the stock.

Lastly, concern about the state of the fishery was generally high among anglers and increased as anglers became more committed to fishing. Research by Gray et al. (2015) and Shephard et al. (2023) indicates that more dedicated anglers develop a stronger connection to their environment and are more attuned to ecological issues and changes within the fishery. As a result, highly invested individuals often demonstrate a heightened sense of stewardship compared to less experienced anglers (Gray et al., 2015; Shephard et al., 2023). Moreover, as anglers become more specialized, fishing evolves into a central aspect of their identity and lifestyle, leading

to a greater sense of loss when resources decline and the fishery deteriorates (Ditton et al., 1992).

3.5.3 Perceptions of Threats and Conservation Strategies for Striped Bass

Striped bass currently face a range of impacts that adversely affect stock health, including loss of juvenile habitats, climate change, declining prey abundance, and release mortality (ASMFC, 2024; Dean et al., 2024; Dixon et al., 2024; Pan et al., 2023). In my survey, respondents identified the loss of juvenile habitat as a significant threat and expressed a relatively high level of self-reflection and responsibility. However, the majority of anglers believed that commercial harvest poses the greatest threat to striped bass populations. Contrary to this prevailing perception, recreational fishing accounts for a significantly larger portion of the striped bass harvest (over 80%) relative to the commercial sector (NMFS, 2018). These findings align with previous research indicating that recreational anglers commonly perceive themselves as less destructive to fish populations than the commercial fishery. In some cases, this has led angler lobbyists to downplay scientific findings regarding the impacts of recreational angling (Arlinghaus, 2006). As a result, anglers frequently attribute greater harm to fish stocks to factors such as commercial fisheries or seals while downplaying the effects of recreational harvest (Nussmann, 2005). The incorrect assumption of the commercial fishery as the primary threat to striped bass may diminish anglers' sense of responsibility to take action. To address this misperception and enhance anglers' perceived responsibility to adopt best practices, practitioners can implement targeted education campaigns that clearly communicate the relative impacts of both commercial and recreational fishing. Engaging anglers in discussions about their role in conservation and providing evidence-based information can foster a greater sense of accountability and encourage proactive stewardship behaviors.

Interestingly, respondents rated climate change, recreational fishing regulations, and depredation as the least severe threats to the fishery. However, research has shown that climate change-induced increases in water temperature can exacerbate other threats considered severe by anglers. For instance, elevated water temperatures decrease the amount of dissolved oxygen in the water, potentially increasing post-release mortality rates as fish struggle to meet oxygen requirements during and after the fight (Suski et al., 2006). Moreover, long-term warming could accelerate the loss of juvenile habitat and impact recruitment through direct mortality of eggs and larvae due to lethally high temperatures and indirectly via its influence on the timing of zooplankton blooms for first-feeding larvae (Shideler and Houde, 2014; Millette et al., 2020). Although presently considered a minor threat by survey respondents, another survey of shark depredation in U.S. recreational fisheries showed that striped bass were the most frequently depredated fish species in the northeast (Casselberry et al. 2022). Acknowledging the potential for heightened depredation events in the future is essential, particularly given that conservation efforts aimed at rebuilding predator populations, including sharks and seals, may enhance the likelihood of angler interactions over time. Lastly, aside from the items listed, nearly a third of respondents using the "other" field expressed non-compliance with fishing regulations as threatening the fishery. This is a phenomenon frequently observed in recreational fisheries as monitoring and enforcement efforts are challenging to enforce due to their high participation rates and diffuse effort over vast areas (Sullivan, 2002; Page and Radomski, 2006; Wilberg, 2009; Post et al., 2002). This further underscores the importance of exploring complementary pathways through grassroots initiatives aimed at shifting social norms that guide stewardship behaviors, even in the absence of compliance monitoring. Initiatives should

concentrate on changing beliefs by demonstrating how regulations support both individual goals and the collective well-being of the fishery (Cooke et al., 2013).

Unsurprisingly, given the perceived severity of commercial harvest and noncompliance as threats to the fishery, anglers expressed strongest support for the enforcement of fishing regulations and appropriate regulations for the commercial fishery as conservation strategies. These strategies were followed by support for appropriate regulations in the recreational fishery, continued research efforts for striped bass, adoption of science-based catch-and-release best practices, and fish habitat enhancement. With suitable habitats for striped bass in decline (Dixon et al., 2024), it is essential to heed anglers' call for continued science efforts and habitat enhancement, particularly in terms of restoration strategies in crucial spawning areas such as the Chesapeake Bay (Gauthier et al. 2013). Moreover, considering respondents' awareness of the potential adverse effects of catch-and-release practices on fish populations and their emphasis on individual anglers' responsibility for striped bass conservation, a grassroots movement for catch-and-release best practices and peer-to-peer influence could effectively complement management efforts and yield quicker results than formal regulatory approaches (Guckian et al. 2018).

3.5.4 Agreement with Regulations and ASMFC Emergency Action

As participation in the striped bass recreational fishery along the Atlantic coast of the United States (and Canada) continues to grow, effective management regulations are crucial for controlling stock exploitation and ensuring the fishery's sustainability (Radomski et al., 2001; Murphy et al., 2019). Understanding angler perspectives on these regulations enables policymakers and managers to anticipate potential conflicts arising from future regulatory changes and to make informed decisions that align with or challenge prevailing attitudes (Hunt et al., 2013). In my study, the majority of

respondents acknowledged the necessity of regulations and expressed a desire for these regulations to be grounded in scientific research. In states such as Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, and New Jersey, the majority of anglers considered the slot limit for striped bass to be either appropriate or too loose, while they viewed the one-fish bag limit and the gear regulation (i.e., only inline circle hooks when fishing with natural bait) as appropriate. Furthermore, respondents expressed strong support for the ASMFC emergency action implemented in May 2023, which standardized the slot limit across US Atlantic states to 28 to 31 inches (71.1 - 78.7 cm). Given the considerable number of anglers expressing themselves as amendable to more restrictive regulations, my results suggest that many participants in the recreational fishery may already demonstrate high levels of stewardship and practice self-regulatory actions such as voluntary catch-and-release and adoption of self-imposed gear restrictions.

Despite a general consensus on management regulations among anglers with different gear preference, fly anglers were generally more amendable towards more restrictive regulations. They commonly viewed the slot limit and bag limit as overly permissive and expressed stronger support for the ASMFC emergency action than conventional anglers. This difference may stem from the fact that fly anglers in this survey already engaged in catch-and-release more frequently than conventional anglers, who reported higher rates of harvesting fish. According to Fedler and Ditton (1986), low-consumptive anglers derive satisfaction and enjoyment from their fishing experiences primarily through interactions with nature, relaxation, and an escape from daily routines rather than through catching or harvesting fish. Consequently, these anglers demonstrate greater resilience to policy changes and are more open to accepting restrictive regulations (Fedler and Ditton, 1986). Finally, fly anglers'

stronger support for the mandated use of inline circle hooks when fishing with bait likely stems from the fact that this regulation primarily affects conventional anglers, while fly anglers who do not typically use bait are unaffected by these restrictions.

3.5.5 Differences between Angler Groups based on Gear Preference

The survey revealed a general consensus between conventional and fly anglers regarding their views on catch-and-release impacts and best practices, the quality of fisheries over the decades, threats to fish populations, their roles in striped bass conservation, and support for management interventions, including perspectives on regulations. However, a clear and consistent pattern emerged showing that fly anglers held more conservation-oriented social norms, perceptions, and attitudes compared to conventional anglers. Fly anglers generally exhibited a stronger inclination toward conservation, demonstrating greater engagement in catch-and-release, awareness of angling stressors, and adherence to best practices. A difference also became evident in their heightened concern about the fishery, perceived threats, and advocacy for conservation initiatives, including support for stricter management regulations grounded in current research.

The reasons for the contrast in perceptions and attitudes between the fly angler and conventional angler communities remain unclear, though differences may stem from the distinct ways these groups engage with the ecosystem. Fly anglers often spend extended periods wading in the water, which requires them to cultivate a deep understanding of fish behavior, habitat dynamics, and insect life cycles in order to successfully catch fish. This close interaction with their environment can foster a strong appreciation for ecological balance. Additionally, fly anglers may be more directly involved in conservation-related outreach, as they are often the focus of conservation organizations that promote an environmentally-conscious mindset

(Snyder 2007; Danylchuk et al. 2018). While these insights could provide valuable context, the specific factors driving the differing perspectives among angler groups remain unclear. As such, further research is needed to explore the underlying dynamics and preferences of fly and conventional anglers.

3.6 Limitations

While my survey received responses from anglers across all targeted provinces and states along the Atlantic coast of North America, it is noteworthy that over 70% of responses stemmed from anglers primarily fishing in New England, particularly Massachusetts. Although virtual snowball sampling schemes depend on participants sharing the survey within their networks to increase sample size, which can introduce sampling bias (Baltar and Brunet, 2012), this distribution is not surprising given that the majority of striped bass angling effort is concentrated in New England (Southwick Associates, 2019). Further, my findings may be subject to sampling bias, as responses could be skewed towards deeply involved (i.e., avidity bias) and conservation-minded anglers. This can likely be attributed to the highly specialized and conservation-oriented angler organizations (i.e., ASGA), fishing companies (i.e., Patagonia Fly Fishing, Cheeky Fishing), and non-profit organizations (i.e., IGFA, Keep Fish Wet, Stripers Forever) that were primarily responsible for aiding in the distribution of the survey link. However, given the extensive reach of these organizations within the angling community, collaborating with them for survey distribution was crucial to achieving an adequate sample size. Moreover, respondents were solicited through targeted social media posts and e-newsletters clearly outlining the survey's focus on striped bass anglers' perceptions and attitudes about fishing quality and threats to striped bass stocks. Although this may have contributed to a higher response rate among anglers who place stronger emphasis on striped bass conservation, the

monetary incentive offered for survey completion likely mitigated non-response bias. Non-probabalistic surveys are rather common in the recreational fishing sector as they are effective at reaching key informants in specialized fisheries (Howarth et al. 2024). Lastly, recall or memory bias (i.e., individuals forgetting or misattributing events to the wrong time period) may have affected the results, a phenomenon frequently acknowledged in angler surveys (Tarrant et al., 1993; Osborn and Matlock, 2010). However, considering that responses on decadal fishing quality largely mirrored the results of historical stock assessments (ASMFC, 2022), the influence of memory bias on my results is likely minimal.

3.7 Conclusion

In recreational fisheries, the responsibility for personal behavior and adherence to regulations, such as science-based best practices to reduce post-release mortality, ultimately lies with individual anglers. Therefore, harnessing the power of social norms to influence angler behavior presents a compelling and cost-effective strategy for enhancing stewardship and fostering long-term self-management through self-regulating systems (Cooke et al. 2013; Guckian et al. 2018). My survey highlighted several key issues that can guide targeted education and outreach programs aimed at shifting social norms toward voluntary conservation behaviors in the striped bass recreational fisheries. These initiatives should focus on educating anglers about the stressors associated with catch-and-release practices, promoting the adoption of catch-and-release best practices to minimize angler impact, and addressing misconceptions within the angling community regarding the relative impacts of both the commercial and recreational fishery on striped bass stocks. Ultimately, outreach initiatives informed by results of my study can foster greater stewardship behavior among anglers and establish a foundation for a more sustainable striped bass recreational

fishery that begins with the interaction between the angler and an individual fish (Cooke et al., In Press).

3.8 Figures

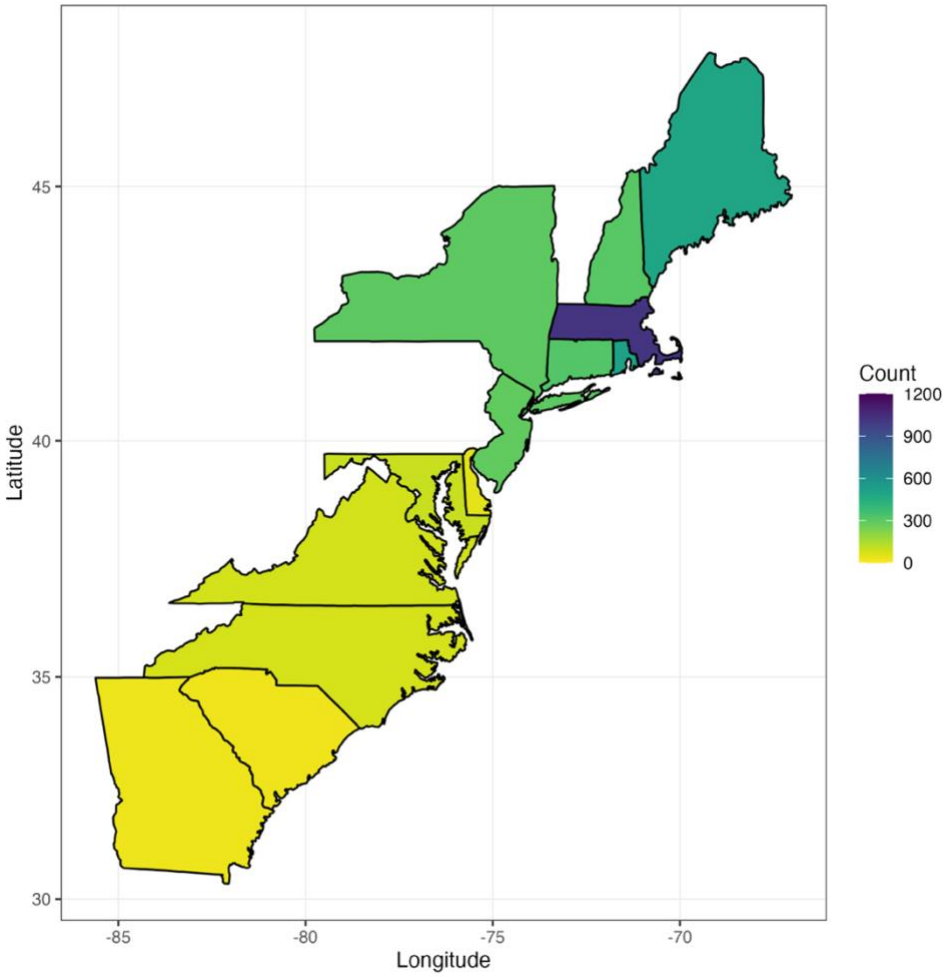

Figure 3.1. Frequency of reported fishing location by U.S. Atlantic state.

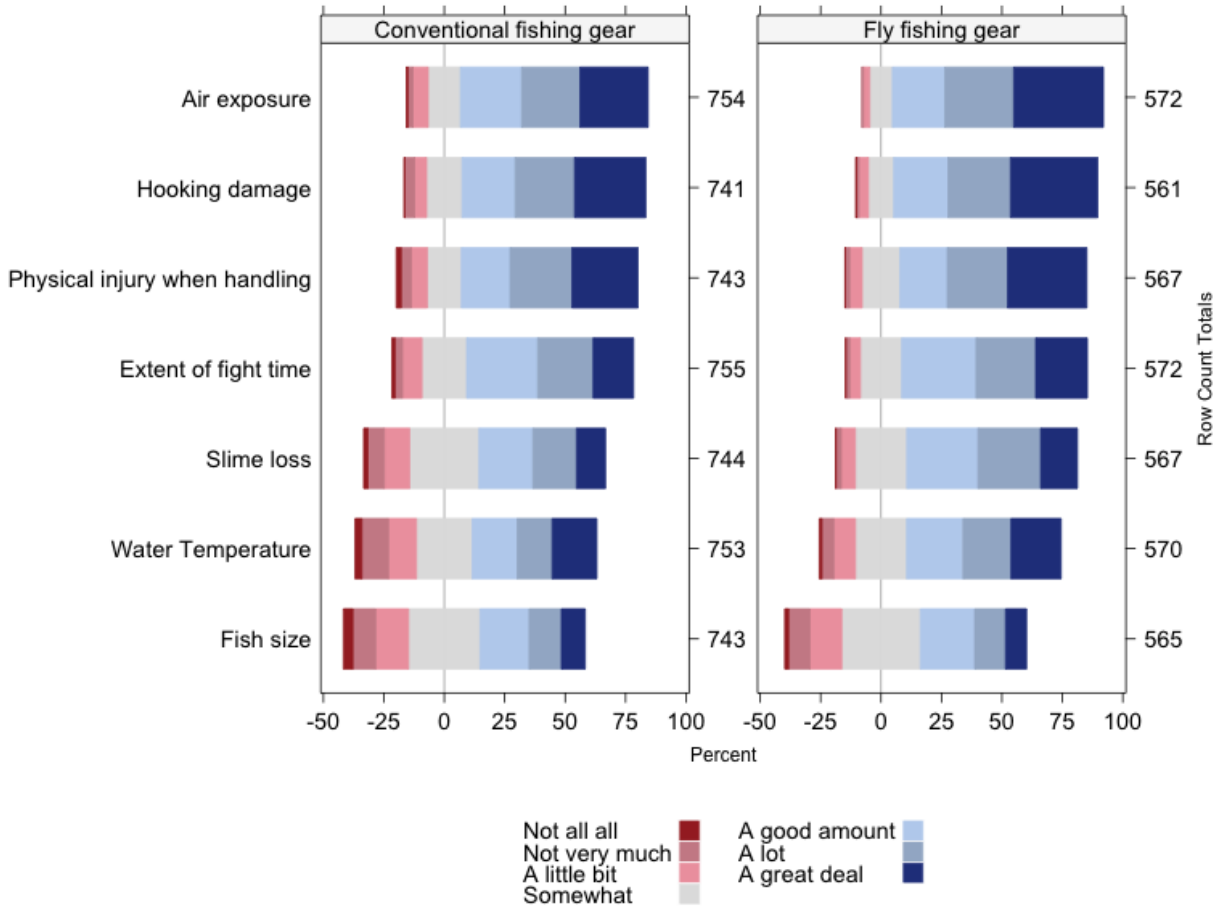

Figure 3.2. Perceived magnitude of influence of various angling factors on the fate of released striped bass rated on a seven-point Likert scale ranging from not at all to a great deal. Responses are presented separately for anglers using conventional gear and fly gear.

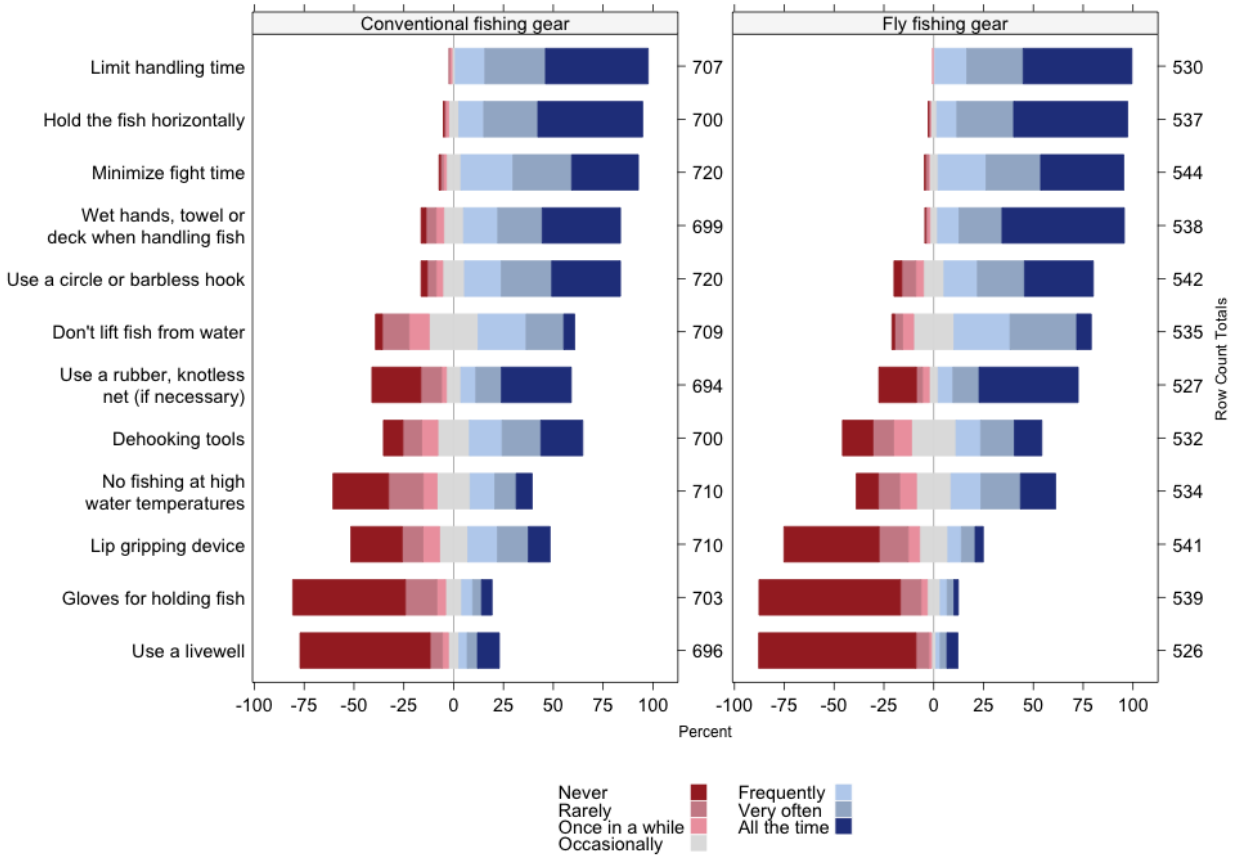

Figure 3.3. Level of engagement of anglers using conventional gear and fly gear in various catch-and-release best practices rated on a seven-point Likert scale ranging from never to all the time.

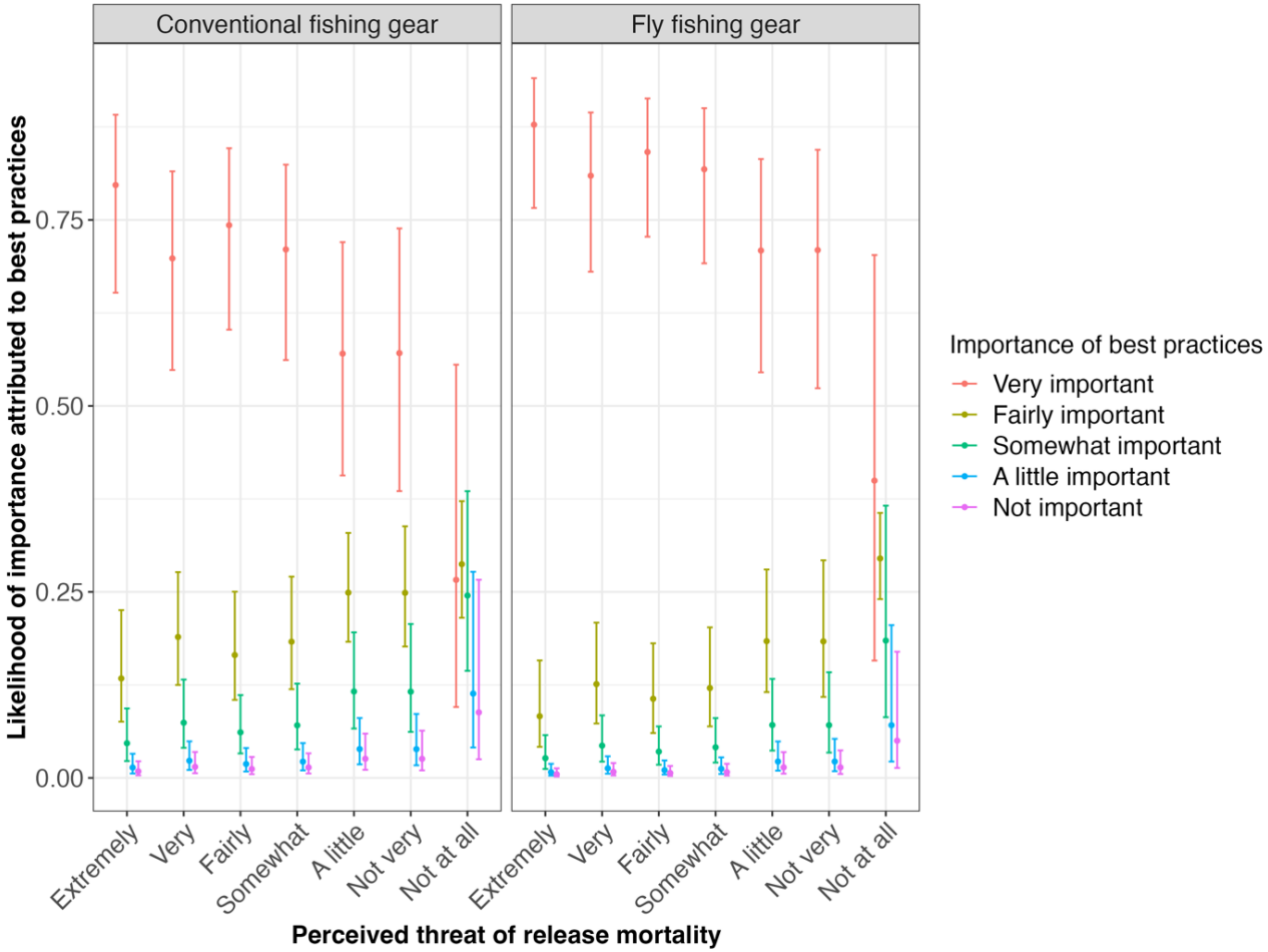

Figure 3.4. Predictive plots of the best-performing ordinal logistic regression model for importance attributed to science-based catch-and-release best practices for striped bass as a function of gear preference, perceived threat of release mortality to the fishery, and level of concern about the state of the fishery.

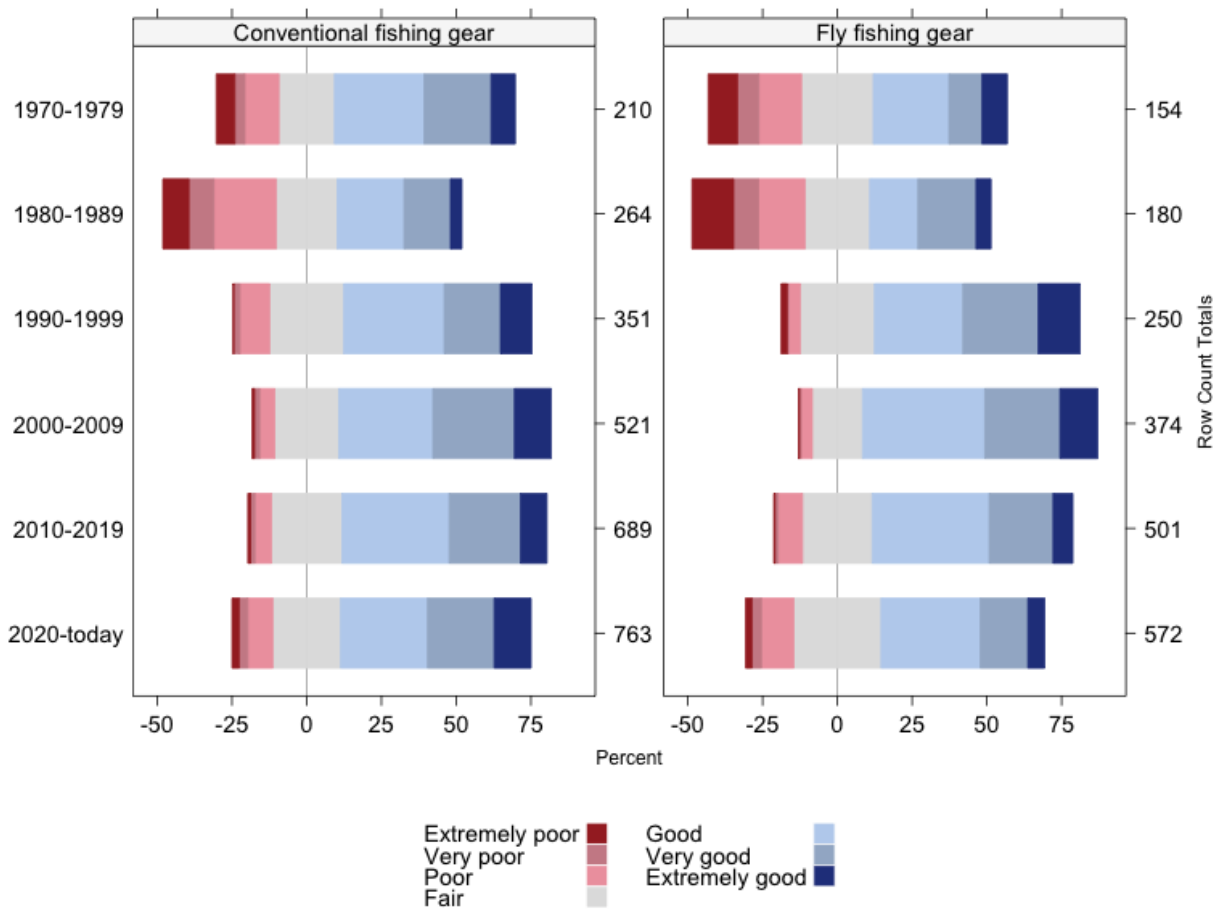

Figure 3.5. Perceived fishing quality of striped bass in the Atlantic across decades for anglers using conventional gear and fly gear. Row count totals are the total number of responses for each gear type in each decade.

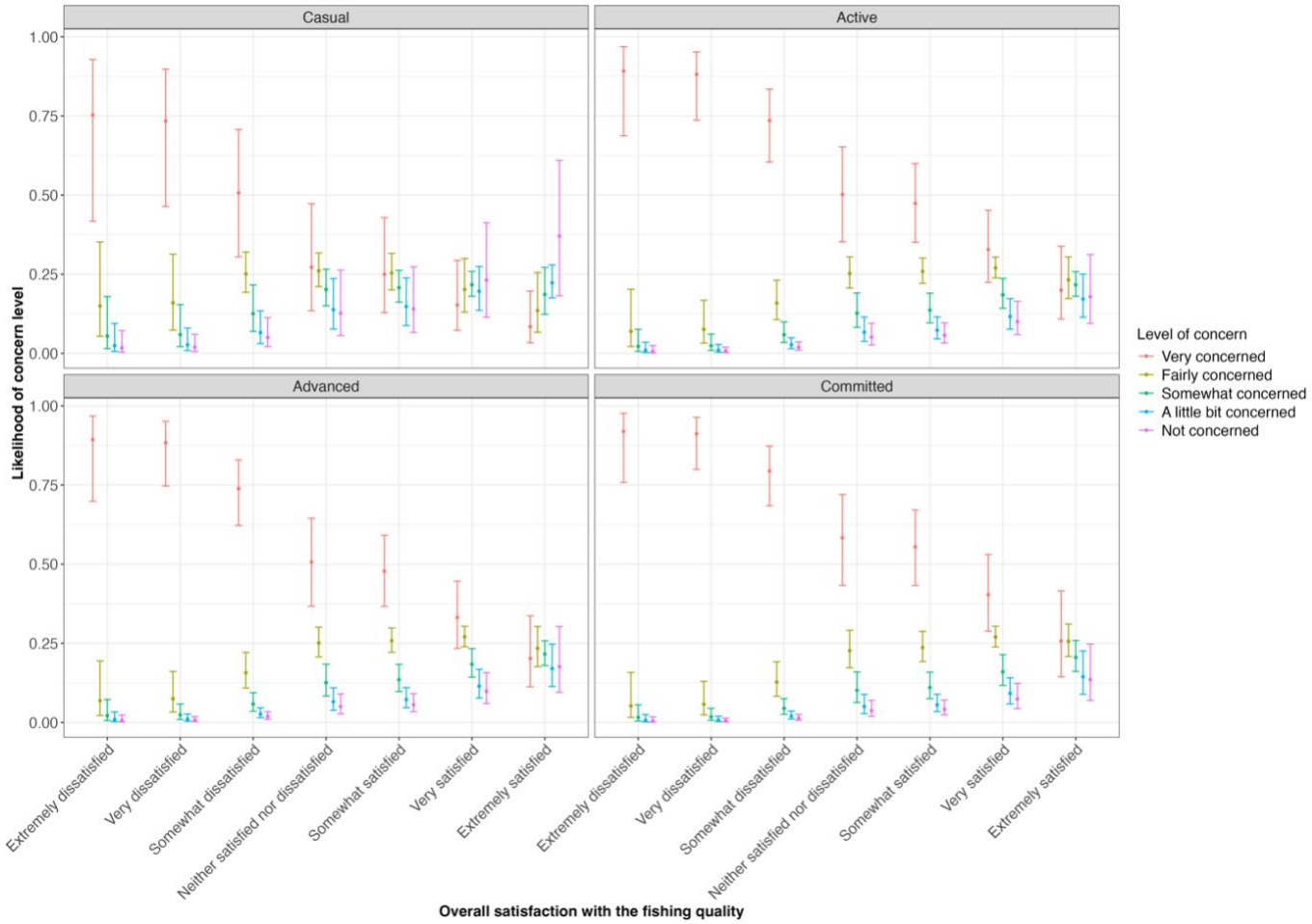

Figure 3.6. Predictive plots visualizing the results of the best-performing ordinal logistic regression model for concern about the striped bass fishery, which varied significantly with gear preference, fishing focus, age, satisfaction with the fishing quality, and catch rate.

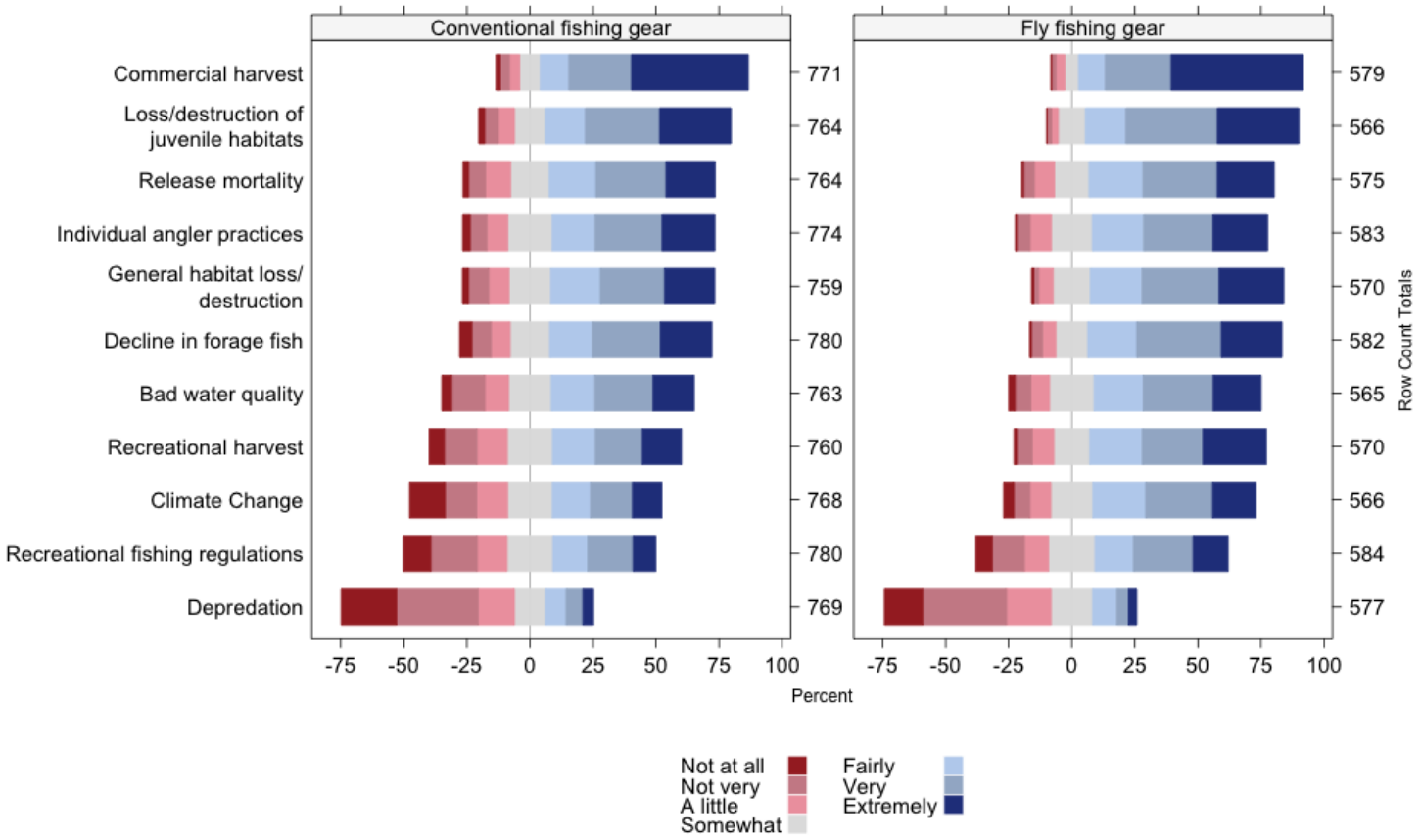

Figure 3.7. Perceived threats to striped bass stocks rated on a seven-point Likert scale ranging from not at all to extremely. Responses are presented separately for anglers using conventional gear and fly gear.

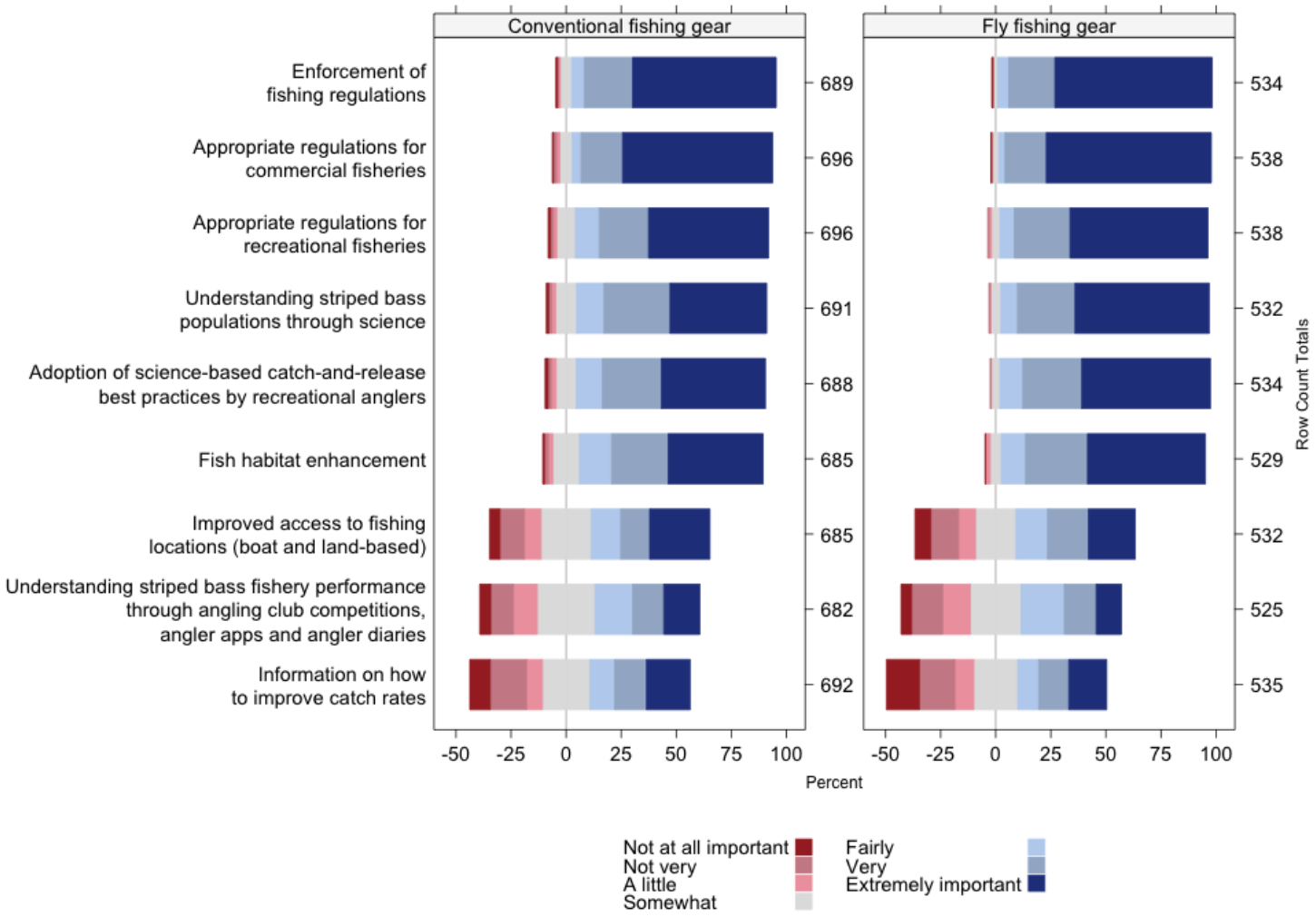

Figure 3.8. Angler support for a range of management interventions for Atlantic striped bass rated on a seven-point Likert scale ranging from not at all important to extremely important. Responses are presented separately for anglers using conventional gear and fly gear.

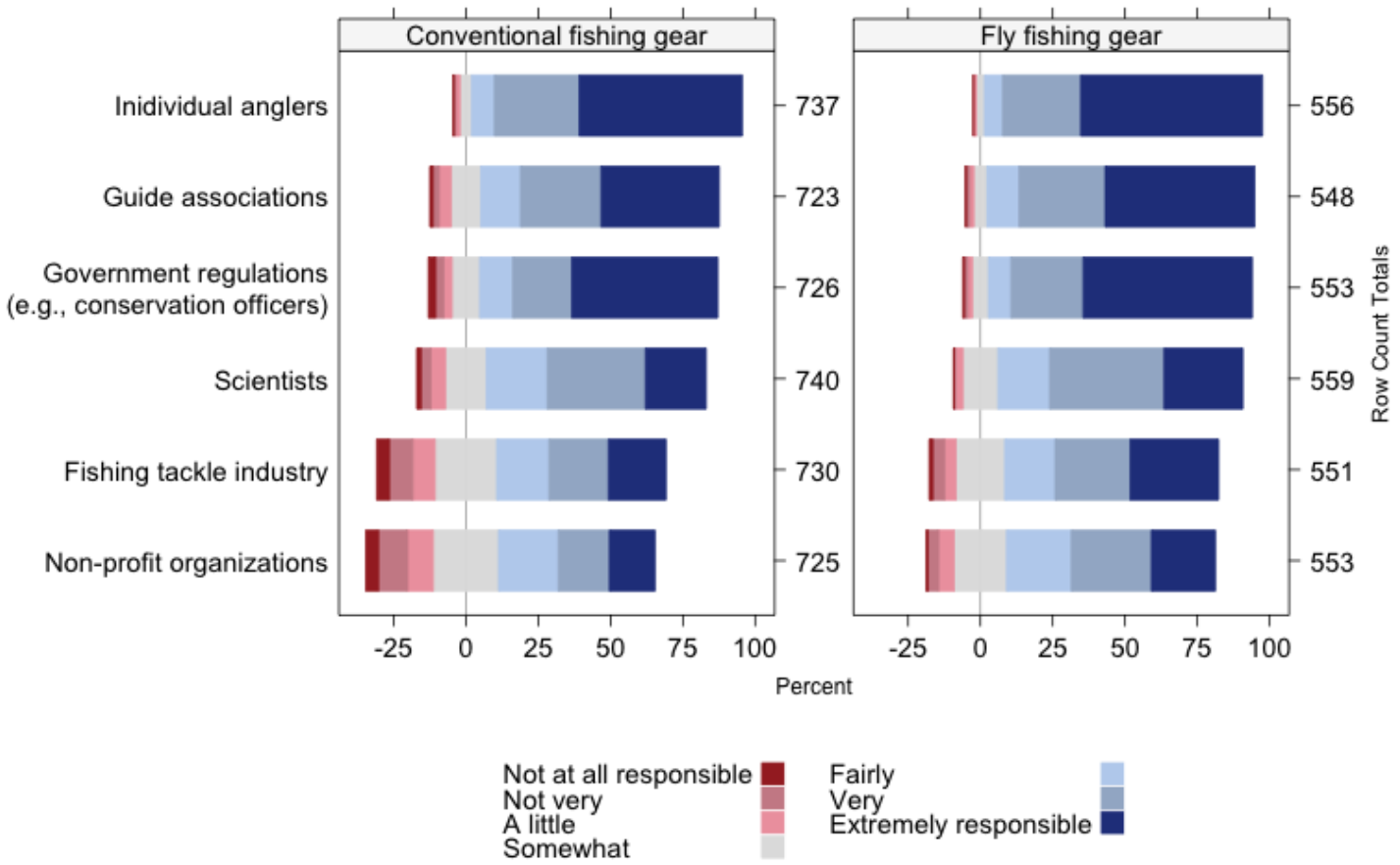

Figure 3.9. Perceived responsibility of fisheries stakeholders for the protection and conservation of Atlantic striped bass stock rated on a seven-point Likert scale ranging from not at all responsible to extremely responsible. Responses are presented separately for anglers using conventional gear and fly gear.

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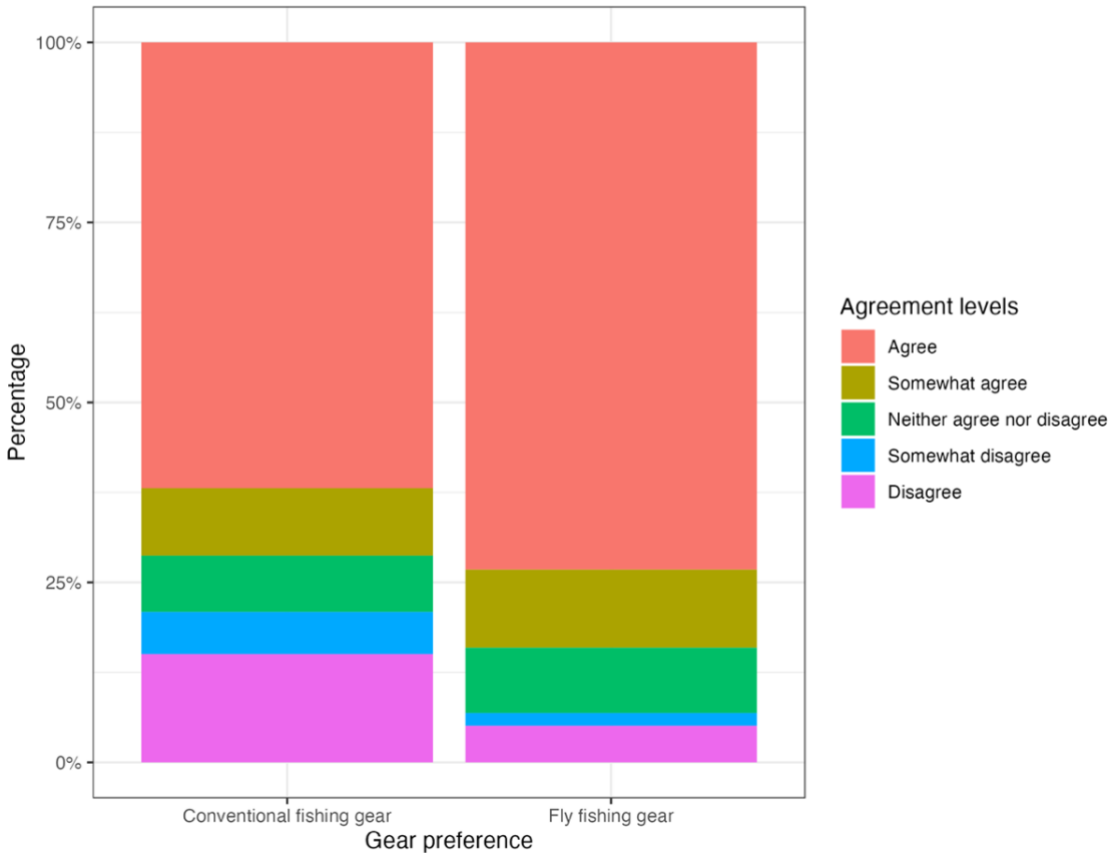


Figure 3.10. Frequency plots of angler agreement with the emergency action issued by the Atlantic States Marine Fisheries Commission rated on a five-point Likert scale ranging from agree to disagree. Responses are presented separately for anglers using conventional gear and fly gear.

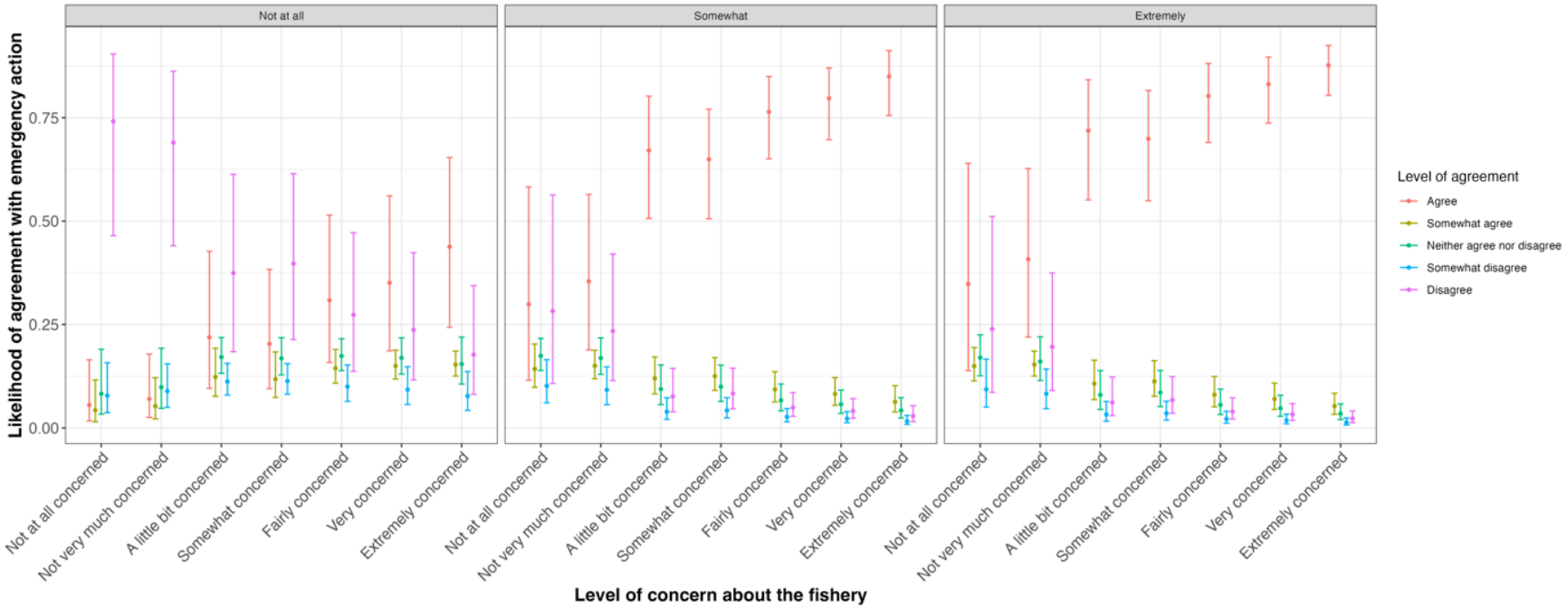


Figure 3.11. Predictive plots of the best-performing ordinal logistic regression model for agreement with regulations, which varied significantly based on gear preference, age, perception of recreational harvest as a threat to the fishery, and level of concern about the fishery.

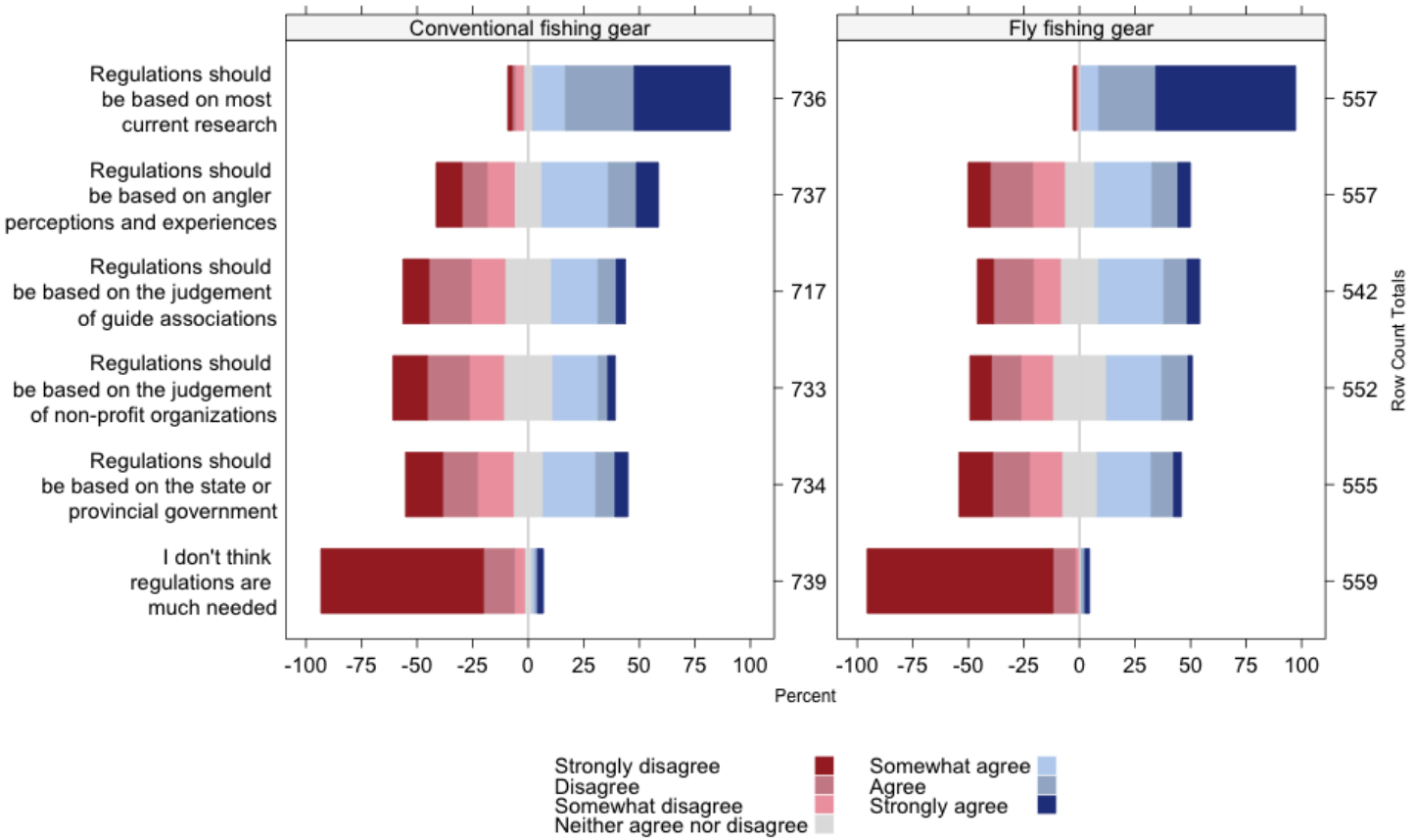


Figure 3.12. Angler agreement with statements concerning the foundation of management regulations rated on a seven-point Likert scale ranging from strongly agree to strongly disagree. Responses are presented separately for anglers using conventional gear and fly gear.

CHAPTER 4

SYNTHESIS & BROADER IMPLICATIONS

The overarching objective of my thesis was to use a multi-disciplinary approach to address critical knowledge gaps related to the striped bass recreational fishery along the Atlantic coast of North America. Given the diverse ways that striped bass are targeted in the recreational fishery, I conducted a field assessment to examine how striped bass respond to capture and handling, with a particular focus on the effects of air exposure - a factor that has not been specifically investigated for this species. To complement this, I also conducted an angler survey to identify discrepancies between scientific knowledge and angler perceptions and understanding of the fishery. Specifically, in Chapter 2, I assessed the physical and physiological condition of striped bass subjected to catch-and-release angling across gear types (conventional versus fly) and five air exposure treatments (0 s, 10 s, 30 s, 60 s, and 120 s) using reflex action mortality predictors (RAMP). Additionally, for a subset of fish, I assessed post-release activity and behavior using tri-axial accelerometer biologgers across three air exposure treatments (0s, 30s, and 120s). In Chapter 3, I distributed an angler survey through a broad network of fishing organizations, industry partners, and nonprofits to assess current social norms, perceptions, and attitudes in the striped bass recreational fishery related to catch-and-release best practices, threats to the fishery, and support for conservation strategies, including management regulations.

Findings from the field study covered in Chapter 2 revealed a significant impact of various angling stressors on the physiological condition of striped bass. Specifically, RAMP assessments showed that physiological impairment of striped bass was greater with longer fight and handling times, higher water temperatures, and larger body sizes. Moreover, striped bass caught on conventional gear exhibited

stronger physiological impairment compared to striped bass caught on fly gear. My study was also the first to specifically examine the influence of air exposure during catch-and-release on striped bass health. The results revealed a significant effect of air exposure on physiological condition, with decision tree analysis identifying both air exposure and total length as the primary factors influencing equilibrium in striped bass. Notably, 50% of striped bass lost their equilibrium after 120 s of air exposure, and generally poorer outcomes were predicted for striped bass larger than 65.41 cm. Further, the decision tree analysis revealed that hooking location has a significant impact on equilibrium of striped bass, with striped bass hooked in locations other than the jaw more often losing equilibrium compared to those hooked in the jaw. Particularly, striped bass caught on fly gear with single hook lures were more susceptible to deep hooking than those caught using conventional gear with either single or double hook lures. Conversely, striped bass caught with conventional gear and double hook lures exhibited higher rates of foul hooking and external tissue damage compared to those captured with either conventional or fly gear using single hooks.

Results from Chapter 2 also showed a significant influence of time following release on the post-release activity and behavior of striped bass. Although post-release activity levels for striped bass were initially low, activity increased consistently over time across all air exposure groups. However, striped bass that were not exposed to air showed quicker recovery, as indicated by higher post-release activity values, compared to those exposed to air for 30 or 120 seconds. Given that air exposure is a common aspect of catch-and-release angling events (i.e., taking pictures or removing hooks; Chhor et al., 2022) and has not been previously assessed, these findings are

particularly important for enhancing best practices for catch-and-release of striped bass.

Based on my research findings in Chapter 2, I was able to refine species-specific science-based best practices that anglers can use to mitigate the impact on striped bass intended for release: I recommend that anglers avoid using multiple-hook lures to reduce hooking injury through foul-hooking. Using fewer hooks can also reduce handling time and air exposure due to difficult hook removals, especially when using barbless hooks (Meka, 2004; Cooke and Suski, 2005). Moreover, employing heavier tackle and refraining from "playing the fish" can help reduce the adverse effects of prolonged fight time. To address the impacts of elevated water temperatures, anglers should avoid fishing on particularly hot days. While seasonal water closures can effectively shift angling to cooler seasons, I advocate for a grassroots approach that includes implementing weather forecast advisories to inform anglers about current water temperatures. Coupled with education and outreach programs, the adoption of science-based best practices can be facilitated, ultimately leading to more sustainable catch-and-release practices in the striped bass recreational fishery.

Expanding on my research findings in Chapter 2, continued research on striped bass catch-and-release is needed. Although striped bass appeared to be relatively resilient to the factors evaluated in Chapter 2, the study only assessed immediate physiological impairment and short-term mortality. Future research should focus on potential long-term mortality and sub-lethal effects resulting from angling stressors identified in my study. Additionally, my research focused on post-release activity for striped bass caught using conventional gear with double treble hooks. It is crucial to assess post-release activity, behavior, and mortality for other gear types,

such as fly fishing and single hooks. Lastly, given the high participation rates in the recreational fishery, future studies should investigate the cumulative effects of stress on striped bass resulting from repeated catch-and-release angling events.

The angler survey covered in Chapter 3 revealed high voluntary release rates among anglers and frequent engagement in catch-and-release best practices to mitigate impacts. Most anglers identified hooking injuries as a significant factor influencing the well-being of released fish, which aligns with research on catch-and-release of striped bass (Diodati and Richards, 1996). Interestingly, while many anglers recognized air exposure as a highly detrimental factor influencing the survival of striped bass post-release, a considerable number still reported exposing their catch to air. This gap between knowledge and behavior reveals a conflict between angler priorities and the welfare of the fish. Moreover, respondents rated water temperature and fish size as the least influential factors influencing fish following release. This perspective contradicts findings from the field assessment discussed in Chapter 2, which demonstrate that both water temperature and fish size significantly influence the physiological condition of striped bass. Collectively, the results from Chapters 2 and 3 highlight substantial gaps between the scientific understanding gained from the field study and the perceptions of anglers in the recreational fishery.

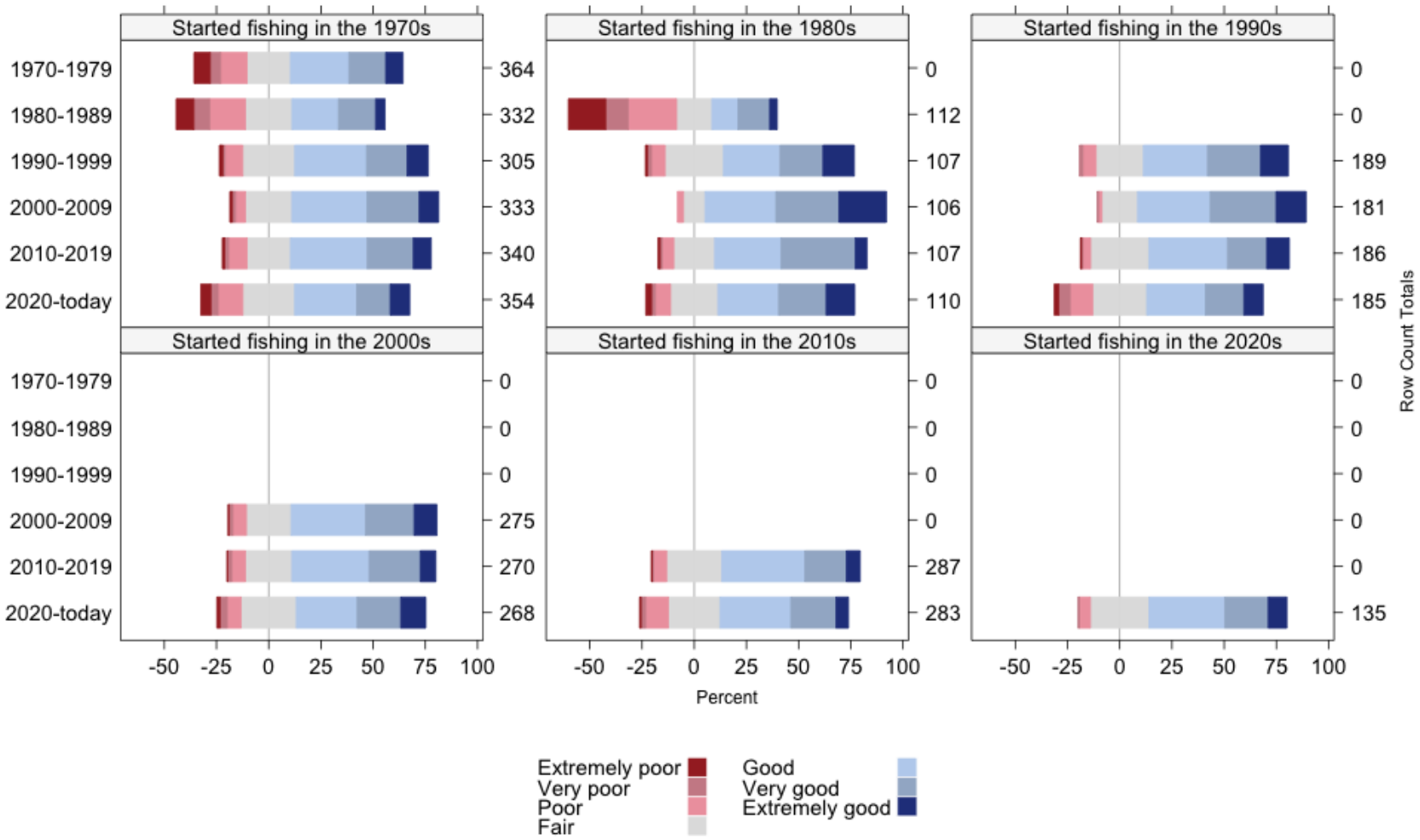
Results from Chapter 3 also reveal angler perceptions of threats to the fishery and a general concern about the state of the fishery. Anglers noticed a significant decline in fishing quality from the 2000s to the present. While respondents showed high levels of self-awareness, a majority attributed the most substantial threat to the striped bass population to the commercial fishery. However, scientific data shows that the recreational fishery accounts for a larger proportion of striped bass harvest. In fact, in recent years, recreational release mortality has exceeded the total commercial

harvest of striped bass by more than 400% (Dean et al., 2024). This misconception may be due to anglers not recognizing the cumulative effects of high participation in recreational fishing due to its widespread nature. As a result, they may attribute the decline in striped bass populations to other factors rather than their own potential impacts imposed by capture and handling methods. Besides commercial harvest, a high number of anglers identified the loss and destruction of habitat to be a threat to striped bass populations, which is consistent with recent habitat research (Dixon et al., 2024). Lastly, the social science survey indicated that respondents recognize the importance of implementing catch-and-release best practices for striped bass, while also highlighting the need for continued research efforts and habitat enhancement. Lastly, they expressed strong support for the enforcement and implementation of management regulations in both the commercial and recreational fishery, as well as for the emergency action implemented in 2023.

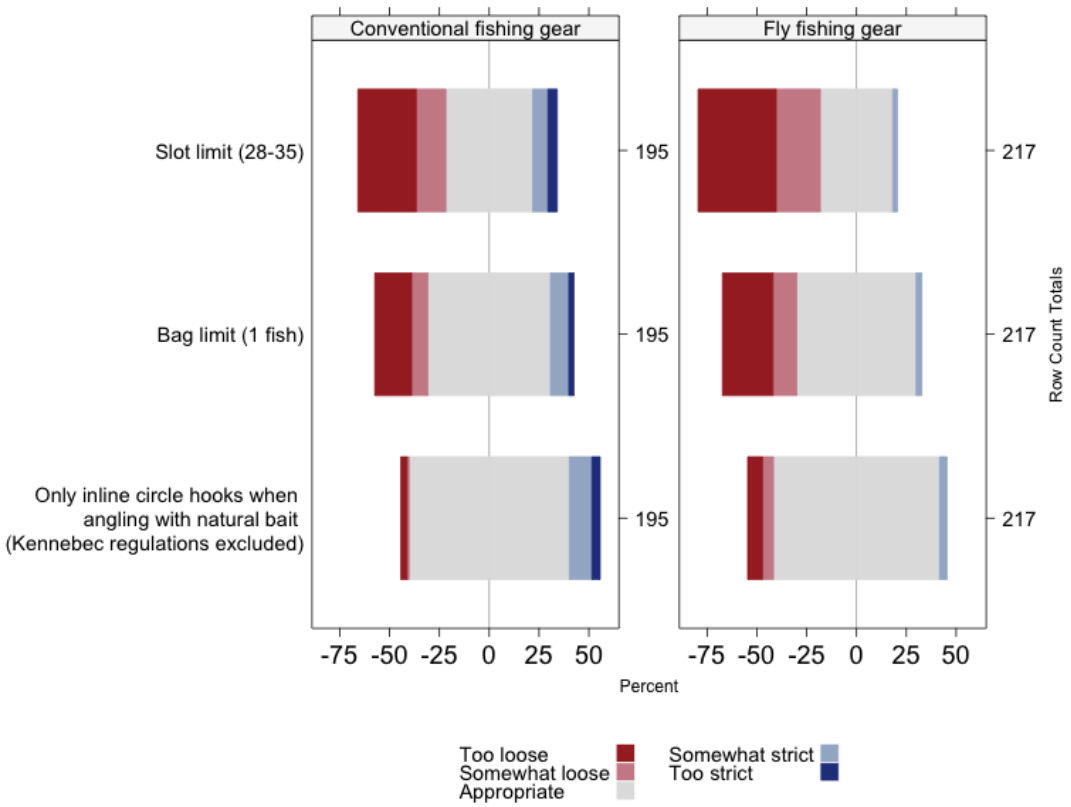
Generally, the survey results indicate strong conservation-minded attitudes and perceptions among anglers in the striped bass recreational fishery, however, fly anglers demonstrated a greater commitment to conservation behavior than conventional anglers. This difference may stem from varying social norms within these subgroups, influenced by their distinct fishing styles. Fly anglers often cultivate a deeper connection to nature through practices such as fly imitation and wading, which may enhance their understanding of natural processes. Finally, fly anglers are frequently targeted by conservation organizations that actively promote sustainable fishing practices. The survey can serve as a foundation for more targeted inquiries, such as in-person interviews, to gain deeper insights into the differences in social norms and values between subgroups, such as conventional and fly anglers. Additionally, given the strong support expressed throughout the survey for

management regulations and conservation efforts, future surveys could explore support for specific hypothetical regulatory scenarios and conservation efforts.

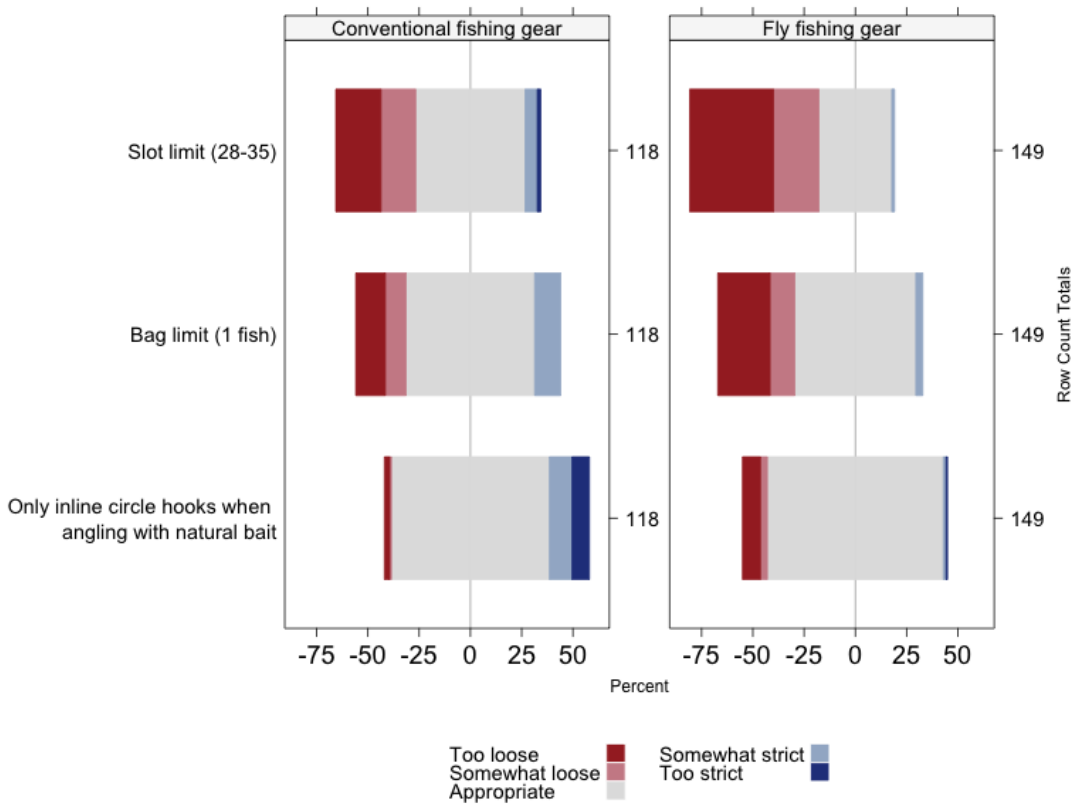
This multi-disciplinary project has addressed critical knowledge gaps regarding striped bass responses to catch-and-release practices and helped hone species-specific science-based best practices that help anglers minimize their impact while also illuminating perceptions, social norms, and behaviors within the recreational fishery across different angler subgroups. Collectively, the results from both studies can inform management decisions by integrating ecological knowledge with social dynamics, ultimately fostering greater acceptance of management strategies. Moreover, the insights from Chapters 2 and 3 can guide targeted education and outreach programs designed to effectively communicate science-based best practices to anglers, thereby closing the identified knowledge-action gaps between scientific information and practical application. To address the identified discrepancies between angler knowledge and behavior, these initiatives could promote a shift in social norms toward more conservation-minded practices (i.e., leaving fish submerged in the water). Additionally, outreach programs should emphasize the significant role that recreational anglers play in the fishery, highlighting their collective impact and dispelling misconceptions about threats to striped bass populations, particularly regarding the commercial fishery. Ultimately, shifts in social norms resulting from these outreach efforts may prove more effective than monitoring initiatives, as they can lead to long-term self-management even in the absence of oversight. Finally, future surveys could assess the effectiveness of educational campaigns on angler behaviors and attitudes toward conservation practices.



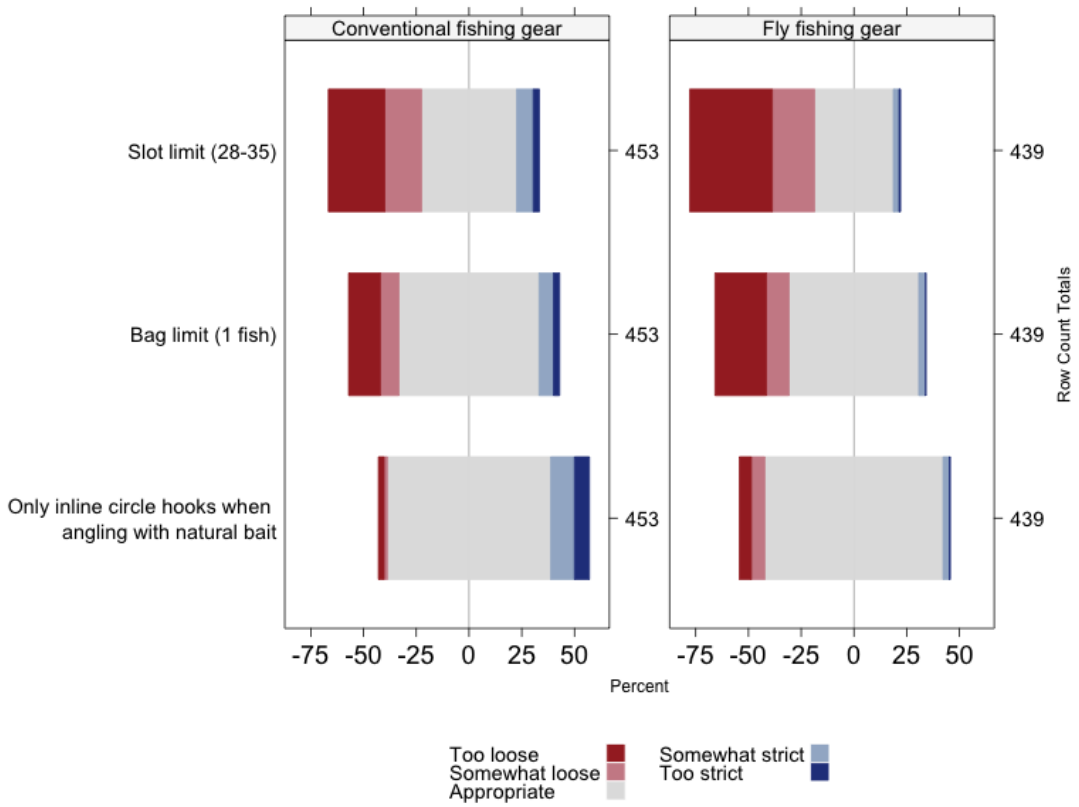
Appendix Figure A.1. Perceived striped bass fishing quality in the Atlantic across decades divided by angler experience. Angling quality is rated on a seven-point Likert scale ranging from extremely poor to extremely good.



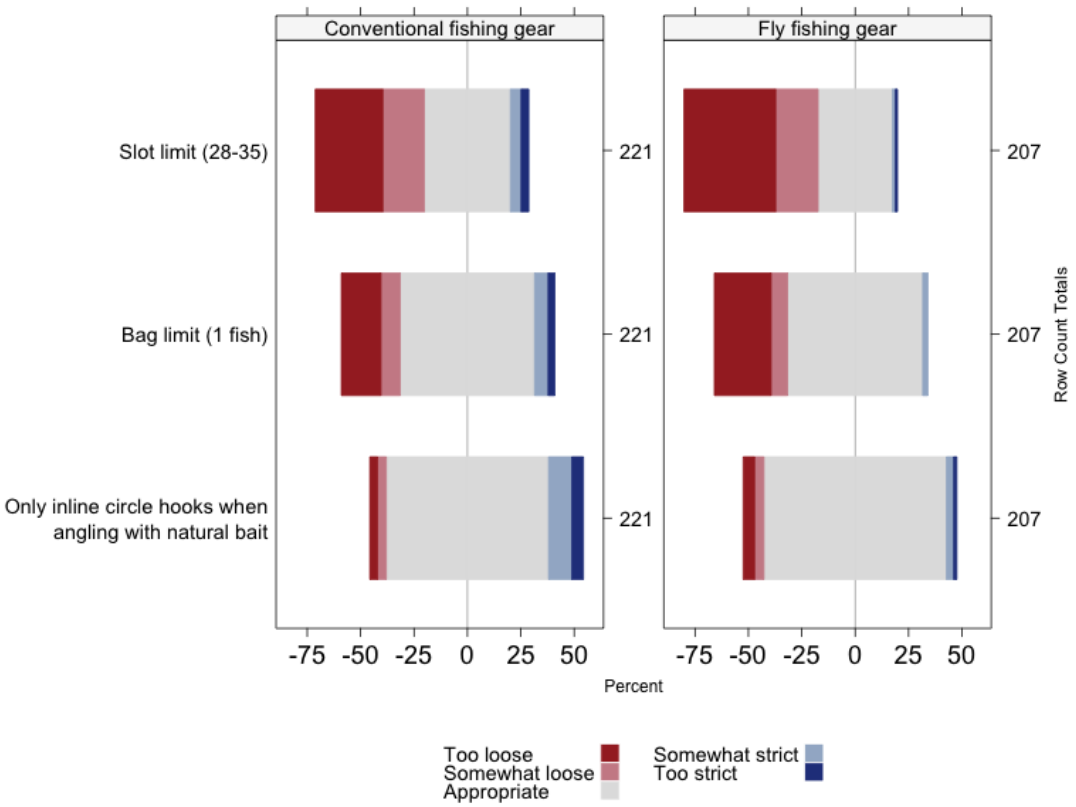
Appendix Figure A.2. Angler agreement with fishing regulations in Maine in place prior to the ASMFC emergency measure, rated on a five-point Likert scale from too loose to too strict. Responses are presented separately for anglers using conventional gear and fly gear.



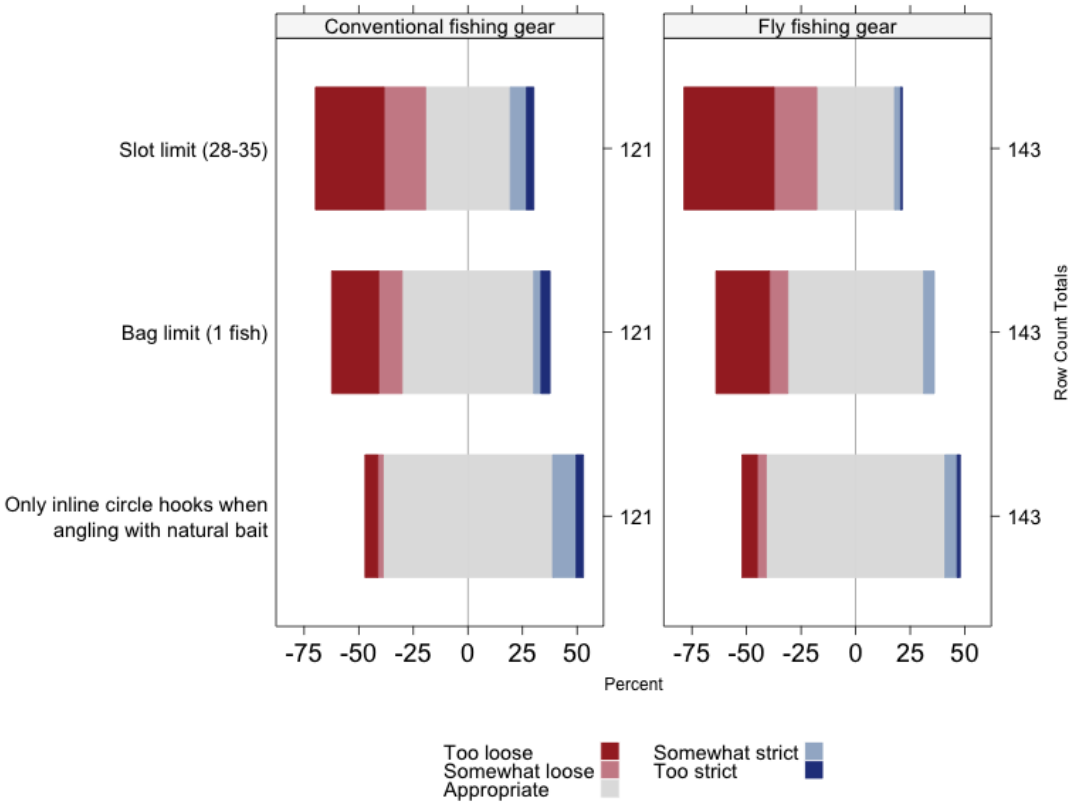
Appendix Figure A.3. Angler agreement with fishing regulations in New Hampshire in place prior to the ASMFC emergency measure, rated on a five-point Likert scale from too loose to too strict. Responses are presented separately for anglers using conventional gear and fly gear.



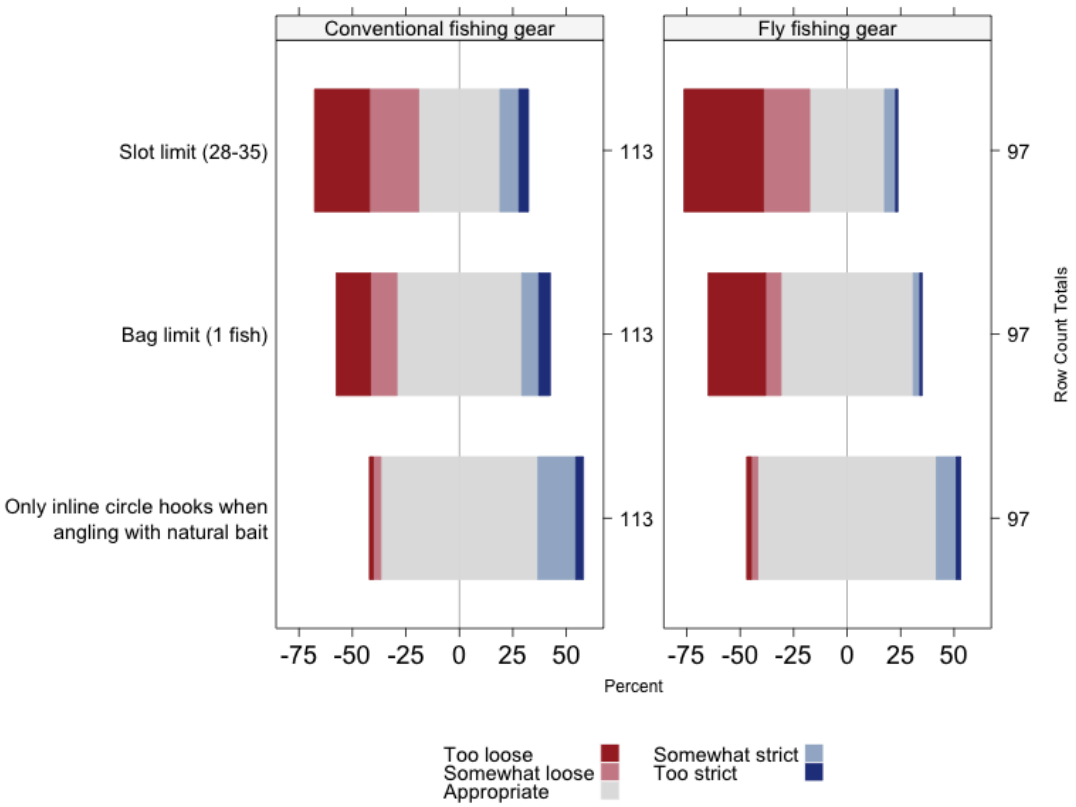
Appendix Figure A.4. Angler agreement with fishing regulations in Massachusetts in place prior to the ASMFC emergency measure, rated on a five-point Likert scale from too loose to too strict. Responses are presented separately for anglers using conventional gear and fly gear.



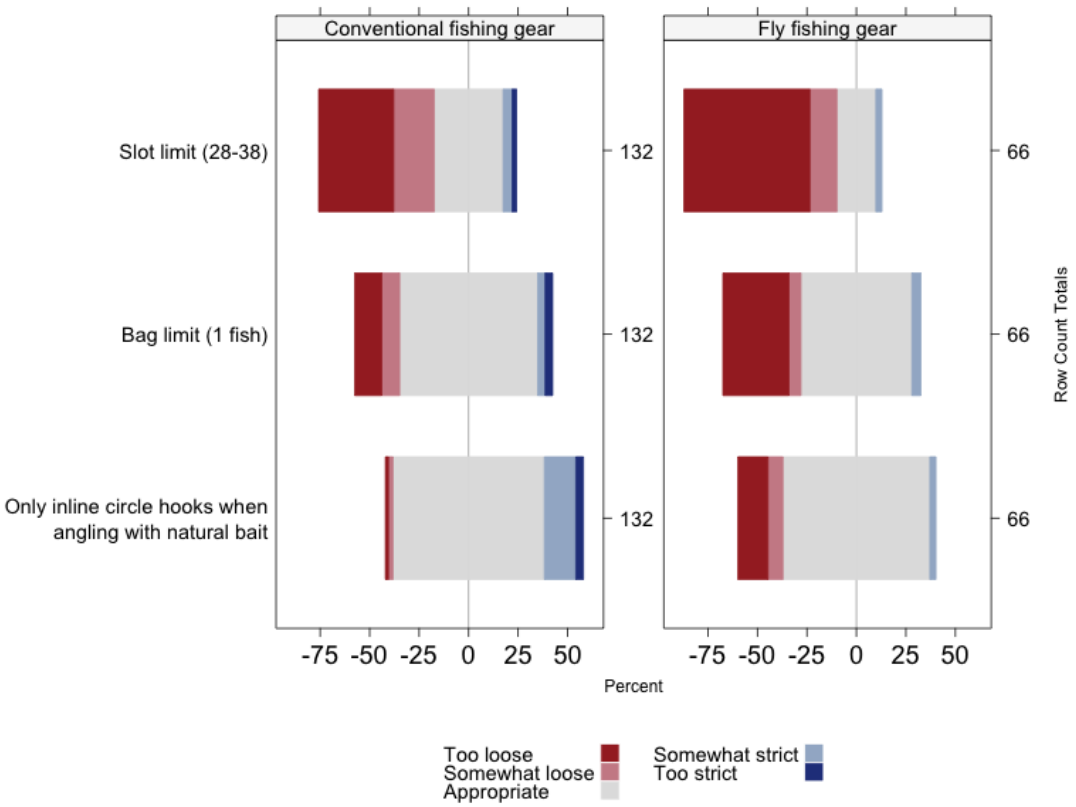
Appendix Figure A.5. Angler agreement with fishing regulations in Rhode Island in place prior to the ASMFC emergency measure, rated on a five-point Likert scale from too loose to too strict. Responses are presented separately for anglers using conventional gear and fly gear.



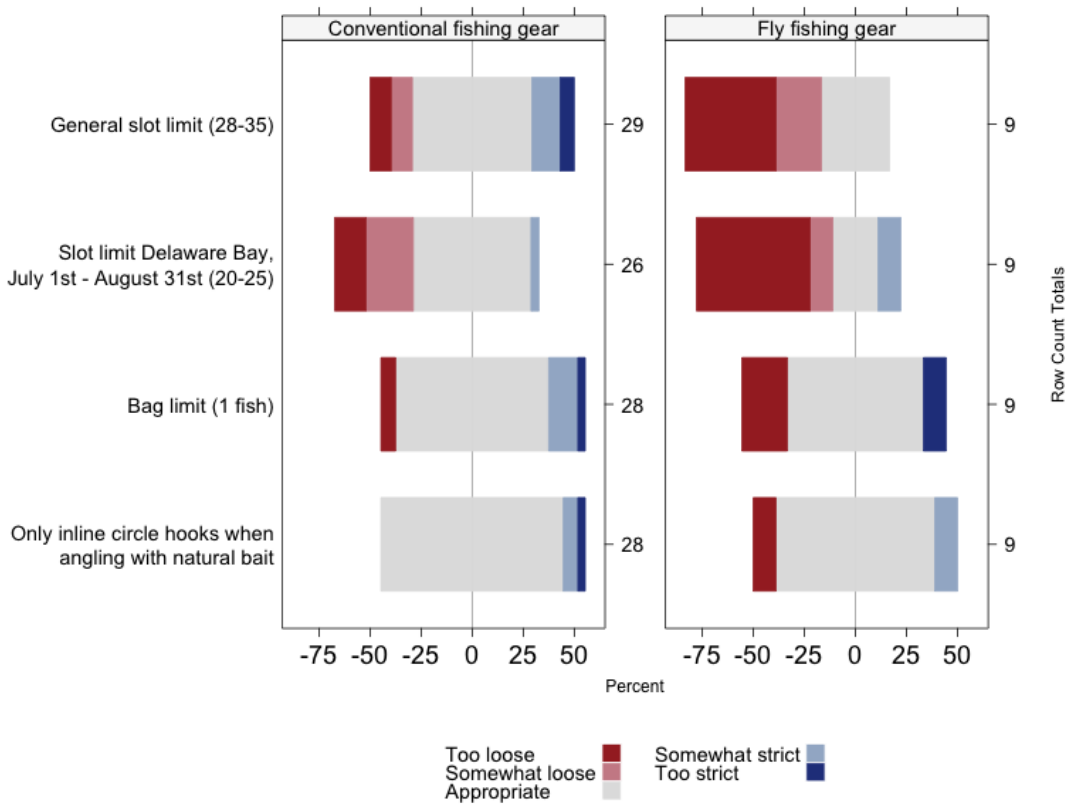
Appendix Figure A.6. Angler agreement with fishing regulations in Connecticut in place prior to the ASMFC emergency measure, rated on a five-point Likert scale from too loose to too strict. Responses are presented separately for anglers using conventional gear and fly gear.



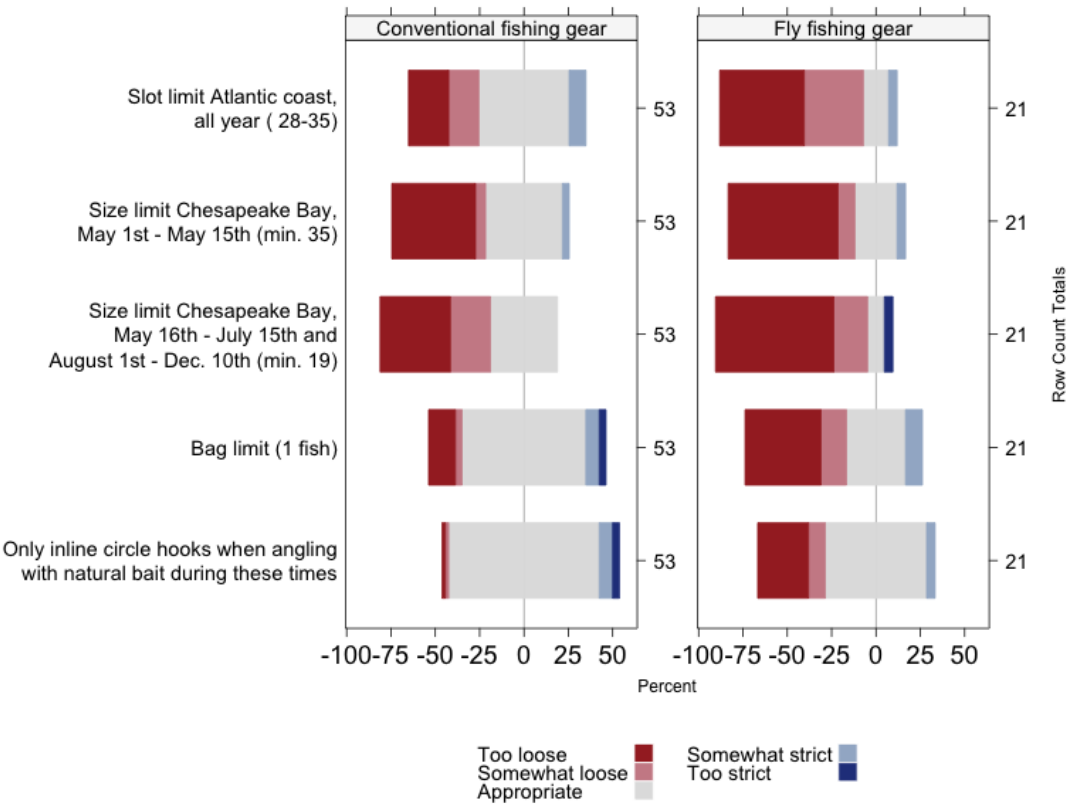
Appendix Figure A.7. Angler agreement with fishing regulations in New York in place prior to the ASMFC emergency measure, rated on a five-point Likert scale from too loose to too strict. Responses are presented separately for anglers using conventional gear and fly gear.



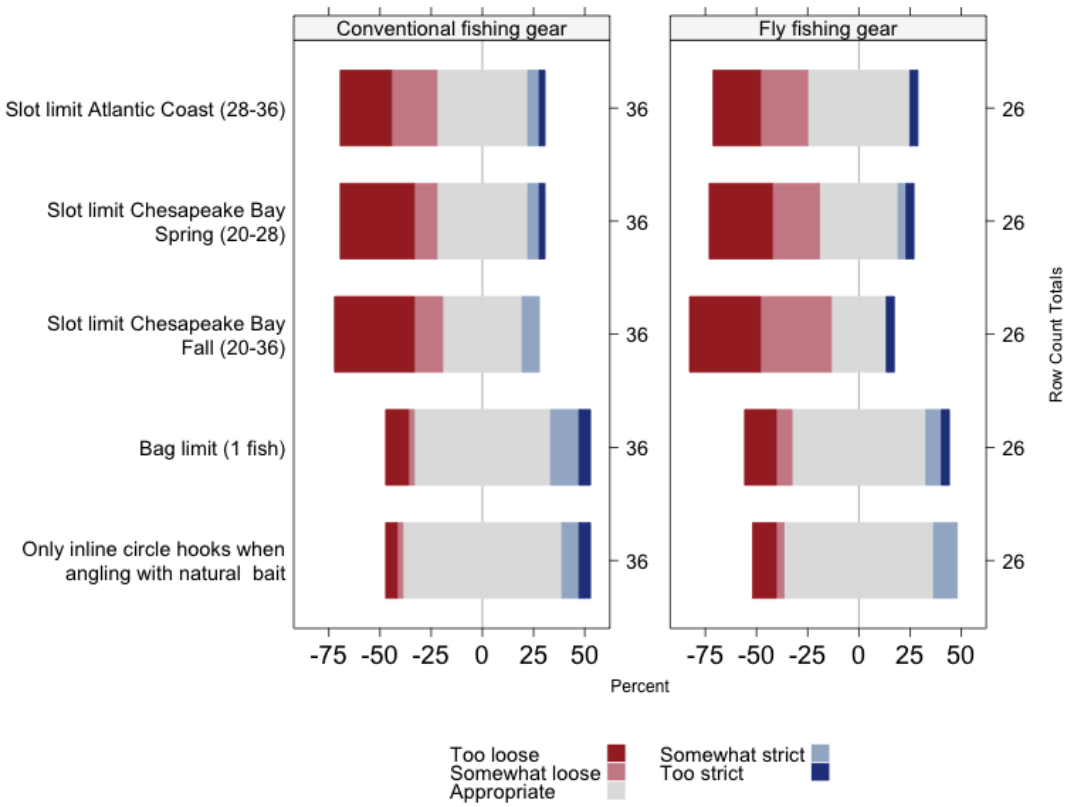
Appendix Figure A.8. Angler agreement with fishing regulations in New Jersey in place prior to the ASMFC emergency measure, rated on a five-point Likert scale from too loose to too strict. Responses are presented separately for anglers using conventional gear and fly gear.



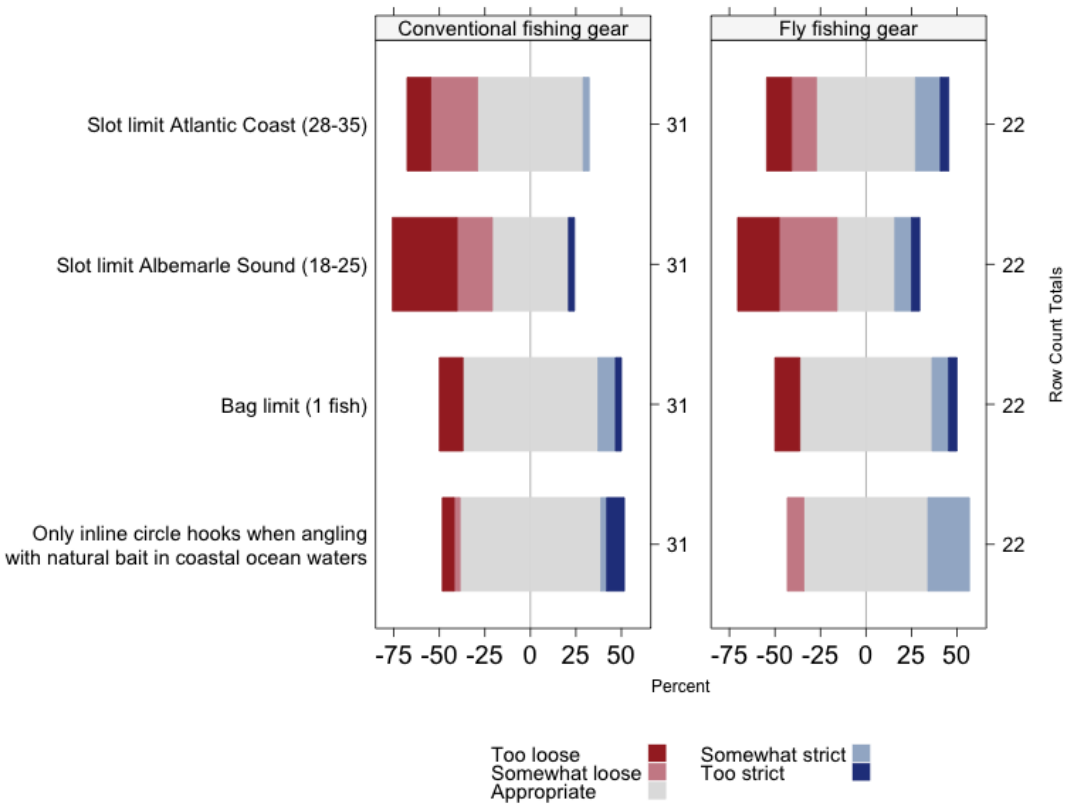
Appendix Figure A.9. Angler agreement with fishing regulations in Delaware in place prior to the ASMFC emergency measure, rated on a five-point Likert scale from too loose to too strict. Responses are presented separately for anglers using conventional gear and fly gear.



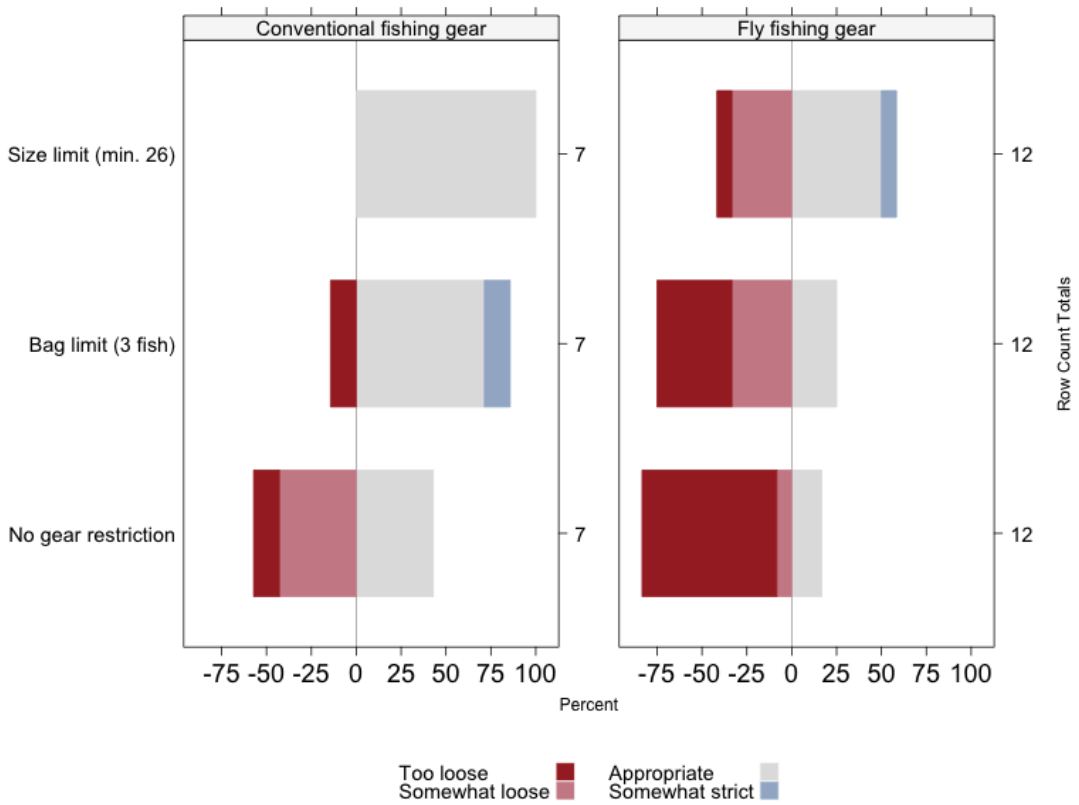
Appendix Figure A.10. Angler agreement with fishing regulations in Maryland in place prior to the ASMFC emergency measure, rated on a five-point Likert scale from too loose to too strict. Responses are presented separately for anglers using conventional gear and fly gear.



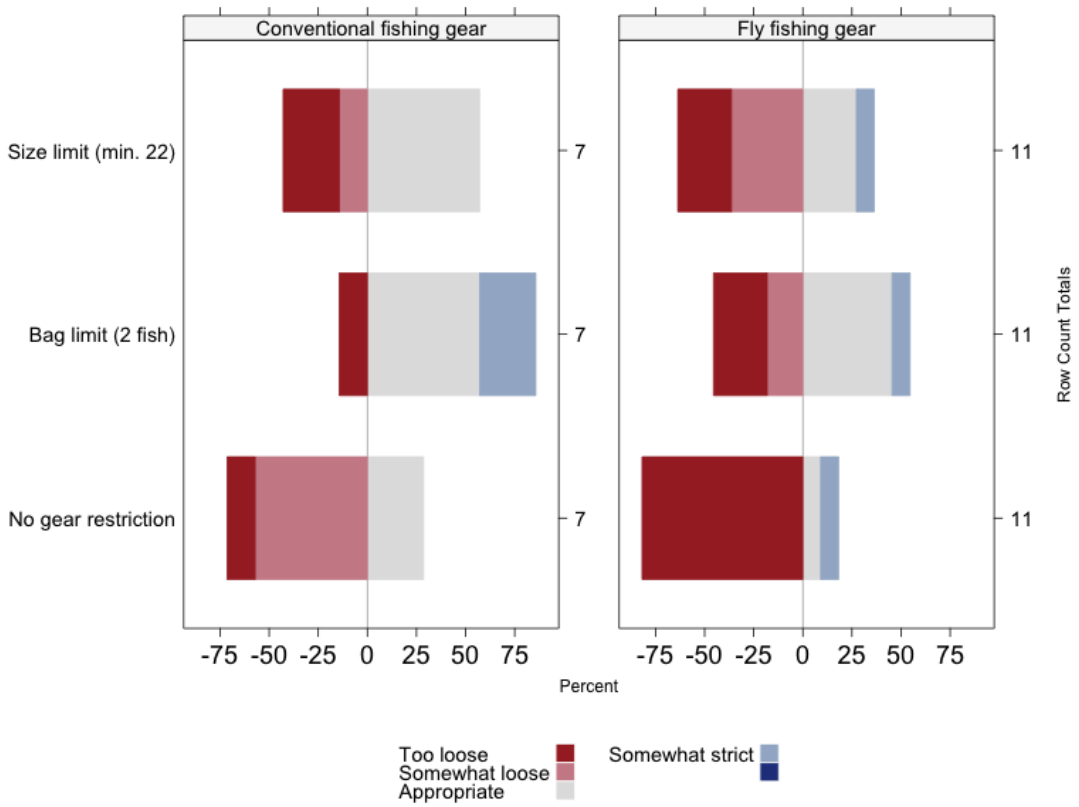
Appendix Figure A.11. Angler agreement with fishing regulations in Virginia in place prior to the ASMFC emergency measure, rated on a five-point Likert scale from too loose to too strict. Responses are presented separately for anglers using conventional gear and fly gear.



Appendix Figure A.12. Angler agreement with fishing regulations in North Carolina in place prior to the ASMFC emergency measure, rated on a five-point Likert scale from too loose to too strict. Responses are presented separately for anglers using conventional gear and fly gear.



Appendix Figure A.13. Angler agreement with fishing regulations in South Carolina in place prior to the ASMFC emergency measure, rated on a five-point Likert scale from too loose to too strict. Responses are presented separately for anglers using conventional gear and fly gear.



Appendix Figure A.14. Angler agreement with fishing regulations in Georgia in place prior to the ASMFC emergency measure, rated on a five-point Likert scale from too loose to too strict. Responses are presented separately for anglers using conventional gear and fly gear.

LITERATURE CITED

Aas, Ø., C. E. Thailing, and R.B. Ditton. 2002. Controversy over catch-and-release recreational fishing in Europe. In: Pitcher, T., Hollingworth, C. (Eds.), Recreational Fisheries: Ecological, Economic and Social Evaluation. Blackwell Science, Oxford 95–106.

Adams, A.J., 2017. Guidelines for evaluating the suitability of catch and release fisheries: lessons learned from Caribbean flats fisheries. Fisheries Research 186:672 –680.

Arlinghaus, R., M. Bork, and E. Fladung. 2008 Understanding the heterogeneity of recreational anglers across an urban–rural gradient in a metropolitan area (Berlin, Germany), with implications for fisheries management. Fisheries Research 92:53–62.

Arlinghaus, R. 2006. Overcoming human obstacles to conservation of recreational fishery resources, with emphasis on central Europe. Environmental Conservation 33: 46-59.

Arlinghaus, R., R. Tillner, and M. Bork. 2015. Explaining participation rates in recreational fishing across industrialised countries. Fisheries Management and Ecology 22:45–55.

Arlinghaus, R., S.J. Cooke, J. Lyman, D. Policansky, A. Schwab, C. Suski, S.G. Sutton, and E.B. Thorstad. 2007. Understanding the complexity of catch-and-release recreational fishing: An integrative synthesis of global knowledge from historical, ethical, social, and biological perspectives. Reviews in Fisheries Science 15:75-167.

Atlantic States Marine Fisheries Commission. 2023. ASMFC Atlantic striped bass board to support stock rebuilding through emergency action and Addendum II initiation. Arlington, VA.

Atlantic States Marine Fisheries Commission. 2024. Atlantic striped bass stock assessment update finds resource remains overfished with a less than 50% chance of rebuilding by 2029. Annapolis, MD.

Atlantic States Marine Fisheries Commission. 2022. Atlantic striped bass stock assessment update. Prepared by the ASMFC striped bass stock assessment subcommittee and technical committee. Accepted for management use by the Atlantic striped bass management board, November 2022.

Atlantic States Marine Fisheries Commission. 2024. River herring benchmark stock assessment finds populations remain depleted at a coastwide level though some rivers show signs of improvement. Arlington, VA.

Ajzen, I. 1991. The theory of planned behavior. Organizational Behavior and Human Decision Processes 50:179-211.

Balliet, D. 2010. Communication and cooperation in social dilemmas: a meta-analytic review. The Journal of Conflict Resolution 54:39-57.

Baltar, F., and I. Brunet. 2012. Social research 2.0: virtual snowball sampling method using Facebook. Internet Research 22:57–74.

Bartholomew, A., and J.A. Bohnsack. 2005. A review of catch-and-release angling mortality with implications for no-take reserves. Reviews in Fish Biology and Fisheries 15:129-154.

Bates, D., M. Machler, B. Bolker, and S. Walker. 2015. Fitting Linear Mixed-Effects Models Using lme4. J. Stat. Softw. 67:1–48.

Beardmore, B., W. Haider, L.M. Hunt, and R. Arlinghaus. 2013. Evaluating the ability of specialization indicators to explain fishing preferences. Leisure Sciences, 35:273–292.

Beitinger, T.L. 1990. Behavioral reactions for the assesment of stress in fishes. Journal of Great Lakes Research 16:495–528.

Bettoli, P. W., and R.S. Osborne. 1998. Hooking mortality and behavior of striped bass following catch and release angling. North American Journal of Fisheries Management 1:609–615.

Bower, S.D., A. Jeanson, J.A. Robichaud, M.L. Piczak, N. Young, A. Clarke, A.J. Danylchuk, and S.J. Cooke. 2024. Predicting differences in angler beliefs, threat perceptions, and actions in British Columbia's rainbow trout and steelhead fisheries. Environmental Challenges 15:100868.

Breiman, L., J H. Friedman, R.A. Olshen, and C.J. Stone. 1984. Classification and regression trees. Routledge.

Brownscombe, J.W., A.J. Danylchuk, J.M. Chapman, L.F.G. Gutowsky, and S J. Cooke. 2017. Best practices for catch-and-release recreational fisheries – angling tools and tactics. Fisheries Research 186:693–705.

Brownscombe, J.W., J.D. Thiem, C. Hatry, F. Cull, C.R. Haak, A.J. Danylchuk, and S.J. Cooke. 2013. Recovery bags reduce post-release impairments in locomotory activity and behavior of bonefish (Albula spp.) following exposure to angling-related stressors. Journal of Experimental Marine Biology and Ecology. 440:207 –215.

Brownscombe, J.W., L. Nowell, E. Samson, A.J. Danylchuk, and S.J. Cooke. 2014. Fishing related stressors inhibit refuge-seeking behavior in released subadult great barracuda. Transactions of the American Fisheries Society 143:613–617.

Brownscombe, J.W., L.P. Griffin, T. Gagne, C.R. Haak, S.J. Cooke, and A.J. Danylchuk. 2015. Physiological stress and reflex impairment of recreationally angled bonefish in Puerto Rico. Environmental Biology of Fishes 98:2287 – 2295.

Brownscombe, J.W., R.J. Lennox, A.J. Danylchuk, and S.J. Cooke. 2018. Estimating fish swimming metrics and metabolic rates with accelerometers: the influence of sampling frequency. Journal of Fish Biology 93:207–214.

Bruskotter, J.T. and D.C. Fulton. 2007. The influence of anglers value orientations on fisheries stewardship norms. In aquatic stewardship education in theory and practice, edited by B. A. Knuth and W. F. Siemer. Bethesda, MA: American Fisheries Society 157-168.

Bryan, H. 1977. Leisure value systems and recreational specialization: The case of trout fishermen. Journal of Leisure Research 9:174-187.

Bürkner, P.-C., and M. Vuorre. 2019. Ordinal regression models in psychology: a tutorial, Advances in Methods and Practices in Psychological Science 2:77–101.

Carr-Harris, A., and S. Steinback. 2020. Expected economic and biological impacts of recreational Atlantic Striped Bass fishing policy. Frontiers in Marine Science 6: 814.

Casselberry, G.A., E M. Markowitz, K. Alves, J. Dello Russo, G.B. Skomal, and A.J. Danylchuk. 2022. When fishing bites: Understanding angler responses to shark depredation. Fisheries Research 246:106174.

Chapman, D.A., T.O. Gagne, K.L. Ovitz, L.P. Griffin, A.J. Danylchuk, and E.M. Markowitz. 2018. Modeling intentions to sanction among anglers in a catch-and-release recreational fishery for golden dorado (*Salminus brasiliensis*) in Salta, Argentina. Human Dimensions of Wildlife 23:391-398.

Chhor, A.D., D.M. Glassman, J.W. Brownscombe, A.T. Trahan, A.J. Danylchuk, and S.J. Cooke. 2022. Short-term behavioral impacts of air-exposure in three species of recreationally angled freshwater fish. Fisheries Research 253:106342.

Christensen, R. H. B. 2023. Regression models for ordinal data. R package ordinal version 2023.12–4.1.

Coggins, L. G., M.J. Catalano, M.S. Allen, W.E. Pine, W. E., and C.J. Walters. 2007. Effects of cryptic mortality and the hidden costs of using length limits in fishery management. Fish and Fisheries 8:196–210.

Coleman, F.C., W.F. Figueira, J.S. Ueland, and L.B. Crowder. 2004. The impact of United States recreational fisheries on marine fish populations. Science 305:1958–1960.

Cook, K.V., R.J. Lennox, S.G. Hinch, and S.J. Cooke. 2015. Fish out of water: how much air is too much?. Fisheries, 40: 452-461.

Cooke, S.J., B.C. Neely, C.T. Hasler, J.D. Schooley, J.W. Brownscombe, L. LaRochelle, A.J. Danylchuk, T.L. Hunt, and J.D. Norman. In Press. Emerging live sonar technologies in freshwater recreational fisheries: issues and opportunities. Fisheries. 00:000-000.

Cooke, S.J., C.D. Suski, B.L. Barthel, K.G. Ostrand, B.L. Tufts, and D.P. Philipp. 2003a. Injury and mortality induced by four hook types on bluegill and pumpkinseed. North Amercian Journal of Fisheries Management 23:883–893.

Cooke, S.J., C.D. Suski, M.J. Siepker, and K.G. Ostrand. 2003b. Injury rates, hooking efficiency and mortality potential of largemouth bass (*Micropterus salmoides*) captured on circle hooks and octopus hooks. Fisheries Research 61:135 –144.

Cooke, S.J., and C.D. Suski. 2005. Do we need species-specific guidelines for catch-and-release recreational angling to effectively conserve diverse fishery resources? Biodiversity and Conservation 14:1195–1209.

Cooke, S.J., C.D. Suski, R. Arlinghaus, and A.J. Danylchuk. 2013. Voluntary institutions and behaviours as alternatives to formal regulations in recreational fisheries management. Fish and Fisheries 14: 439–457.

Cooke, S.J., and D.P. Philipp. 2004. Behavior and mortality of caught-and-released bonefish (*Albula spp.)* in Bahamian waters with implications for a sustainable recreational fishery. Biological Conservation 118, 599–607.

Cooke, S.J., and G.R. Wilde. 2007. “The fate of fish released by recreational anglers,” in By-catch Reduction in the World’s Fisheries (Springer) 181–234.

Cooke, S J., and H.L. Schramm. 2007. Catch-and-release science and its application to conservation and management of recreational fisheries. Fisheries Management and Ecology 14:73–79.

Cooke, S.J., and I.G. Cowx. 2006. Contrasting recreational and commercial fishing: searching for common issues to promote unified conservation of fisheries resources and aquatic environments. Biological Conservation 128:93–108.

Cooke, S.J., and I.G. Cowx. 2004. The role of recreational fishing in global fish crises. BioScience 54:857–859.

Cooke, S.J., J.F. Schreer, K.M. Dunmall, and D.P. Philipp. 2002. Strategies for quantifying sub-lethal effects of marine catch-and-release angling: insights from novel freshwater applications. in American Fisheries Society Symposium 121–134.

Cooke, S.J., S. Clark Danylchuk, S.R. Tracey, R. Arlinghaus, R.J. Lennox, J.W. Brownscombe, A. Weir, S.G. Hinch, D.A. Patterson, M.L. Guckian, and A.J Danylchuk. In Press. Individual outcomes matter in the context of responsible and sustainable catch-and-release practices in recreational fisheries and their management. Fisheries. 00:000-000.

Cooke, S.J., V.M. Nguyen, D. Anastakis, S. D. Scott, M.R. Turetsky, A. Amirfazli, A. Hearn, and C.E. Milton. 2020. Diverse perspectives on interdisciplinarity from Members of the College of The Royal Society of Canada. FACETS 5:138–165.

Coutant, C.C. 1985. Striped bass, temperature and dissolved oxygen: A speculative hypothesis for environmental risk. Transactions of the American Fisheries Society 114:31-61.

Danylchuk, A.J., S. Clark Danylchuk, A. Kosiarski, S.J. Cooke, and B. Huskey. 2018. Keepemwet Fishing—An emerging social brand for disseminating best practices for catch-and-release in recreational fisheries. Fisheries Research 205:52-56.

Danylchuk, A.J., A. Adams, S.J. Cooke, and C.D. Suski. 2008. An evaluation of the injury and short-term survival of bonefish (*Albula spp.)* as influenced by a mechanical lip-gripping device used by recreational anglers. Fisheries Research 93:248-252.

Danylchuk, A.J., S.E. Danylchuk, S.J. Cooke, T.L. Goldberg, J.B. Koppelman,and D.P. Philipp. 2007. Post-release mortality of bonefish, *Albula vulpes*, exposed to different handling practices during catch-and-release angling in Eleuthera, The Bahamas. Fisheries Management and Ecology 14:149–154.

Dassow, C.J., A.J. Ross, O.P. Jensen, G.G. Sass, B.T. van Poorten, C.T. Solomon, and S.E. Jones. 2020. Experimental demonstration of catch hyperstability from habitat aggregation, not effort sorting, in a recreational fishery. Canadian Journal of Fisheries and Aquatic Sciences 77:762–769.

Davie, P.S., and R.K. Kopf. 2006. Physiology, behaviour and welfare of fish during recreational fishing and after release. New Zealand Veterinary Journal 54:161–172.

Davis, M. W. 2010. Fish stress and mortality can be predicted using reflex impairment. Fish and Fisheries 11:1–11.

Dean, M.J., W.S. Hoffman, B I. Gahagan, G.A. Nelson, and M.P. Armstrong. 2024. Evaluating the conservation benefit of circle hooks for the Atlantic Striped Bass recreational fishery. Marine and Coastal Fisheries e10308.

De'Ath, G., and K.E. Fabricius. 2000. Classification and regression trees: A powerful yet simple technique for ecological data analysis. Ecology 81:3178–3192.

Diodati, P.J., and R.A. Richards. 1996. Mortality of striped bass hooked and released in salt water. Transactions of the American Fisheries Society 125:300–307.

Ditton, R.B., D.K. Loomis, and S. Choi. 1992. Recreation specialization: Reconceptualization from a social worlds perspective. Journal of Leisure Research 24:35–51.

Dixon, R.L., M.C. Fabrizio, T.D. Tuckey, and A.J. Bever. 2024. Spatiotemporal Variation in habitat suitability within a major producing area for age-0 Atlantic striped bass, *Morone saxatilis*. Estuaries and Coasts 47:2473–2492.

Dowle, M., A. Srinivasan, J. Gorecki, M. Chirico, P. Stetsenko, T. Short, S. Lianoglou, E. Antonyan, M. Bonsch, and H. Parsonage. 2024. Package ‘data. table.’ Extension of ‘data. frame.

Durell, E. Q., and C. Weedon. 2023. Striped bass seine survey juvenile index web page. https://dnr.maryland.gov/fisheries/pages/striped-bass/juvenile-index.aspx. Maryland Department of Natural Resources, Fishing and Boating Services.

Fagerland, M.W., and D.W. Hosmer. 2016. Tests for goodness of fit in ordinal logistic regression models. Journal of Statistical Computation and Simulation 86: 3398–3418.

Fedler, A.J., and R.B. Ditton. 1986. A framework for understanding the consumptive orientation of recreational fisherman. Environmental Management 10:221–227.

Fedler, A.J., and R.B. Ditton. 1994. Understanding angler motivations in fisheries management. Fisheries 19:6–13.

Ferguson, R.A., and B.L., Tufts. 1992. Physiological effects of brief air exposure in exhaustively exercised Rainbow Trout (Oncorhynchus mykiss): Implications for catch and release fisheries. Canadian Journal of Fisheries and Aquatic Sciences 49:1157–1162.

Fisher, M. R. 1997. Segmentation of the angler population by catch preference, participation, and experience: A management-oriented application of recreation specialization. Journal of Fisheries Management 17:1-10.

Food and Agriculture Organization. 2012. FAO technical guidelines for responsible fisheries. No. 13. Recreational Fisheries. Rome.

Fulton, D.C., M.J. Manfredo, and J. Lipscomb. 1996. Wildlife value orientations: a conceptual and measurement approach. Human Dimensions of Wildlife 1:24–47.

Gagne, T. O., K.L. Ovitz, L.P. Griffin, J.W. Brownscombe, S.J. Cooke, and A.J. Danylchuk. 2017. Evaluating the consequences of catch-and-release recreational angling on golden dorado (*Salminus brasiliensis*) in Salta, Argentina. Fisheries research 186:625-633.

Gale, M.K., S.G. Hinch, and M.R. Donaldson. 2013. The role of temperature in the capture and release of fish. Fish and Fisheries 14: 1–33.

Gauthier, D.T., C. Audemard, J.E.L. Carlsson, T.L. Darden, M.R. Denson, K.S. Reece, and J. Carlsson. 2013. Genetic population structure of US Atlantic coastal striped bass (*Morone saxatilis*). Journal of Heredity 104:510-520.

Gleiss, A.C., R.P. Wilson, and E.L.C. Shepard. 2011. Making overall dynamic body acceleration work: on the theory of acceleration as a proxy for energy expenditure. Methods in Ecology and Evolution 2:23 –33.

Granek, E.F., E.M.P. Madin, M.A. Brown, W. Figueira, D.S. Cameron, Z. Hogan, G. Kristianson, P. de Villiers, J.E. Williams, J. Post, S. Zahn, and R. Arlinghaus. 2008. Engaging recreational fishers in management and conservation: Global case studies. Conservation Biology 22:1125–1134.

Graves, J.E., A.Z. Horodysky, and R.J. Latour. 2009. Use of pop-up satellite archival tag technology to study postrelease survival of and habitat use by estuarine and coastal fishes: an application to striped bass (*Morone saxatilis*). Fishery Bulletin 107:373.

Gray, S., J. Hilsberg, A. McFall, and R. Arlinghaus. 2015. The structure and function of angler mental models about fish population ecology: The influence of specialization and target species. Journal of Outdoor Recreation and Tourism 12:1-13.

Griffin, L.P., G. Fordham, G. Curd, C. Narty, P.-A. Adam, J.W. Brownscombe, S.J. Cooke, and A.J. Danylchuk. 2022. Short-term response of giant trevally (*Caranx ignobilis*) to capture and handling in a catch-and-release fly fishing recreational fishery, Republic of Seychelles, Western Indian Ocean. Fisheries Research 252:106337.

Griffin, L.P., H.M. Hollema, J. Kneebone, S.D. McCormick, G.B. Skomal, and A.J. Danylchuk. 2024. Physical injury, physiological stress, and behavior impairment of striped bass (*Morone saxatilis*) after catch-and-release by spin and fly angling. Fisheries Management and Ecology e12703.

Griffin, L.P., G.A. Casselberry, E.M. Markowitz, J.W. Brownscombe, A.J. Adams, B. Horn, S.J. Cooke, and A.J, Danylchuk. 2023. Angler and guide perceptions provide insights into the status and threats of the Atlantic tarpon (*Megalops atlanticus*) fishery. Marine Policy 151:105569.

Guay, J.D., J.L. Brooks, J.M. Chapman, H. Medd, S.J. Cooke and V.M. Nguyen. 2021. Survey-derived angler characteristics and perspectives in the shore-based shark fishery in Florida. Marine and Coastal Fisheries. 13:693-711.

Guckian, M.L., A.J. Danylchuk, S.J. Cooke, and E M. Markowitz. 2018. Peer pressure on the riverbank: Assessing catch-and-release anglers' willingness to sanction others' (bad) behavior. Journal of Environmental Management 219:252-259.

Gustaveson, A.W., R.S. Wydoski, and G.A. Wedemeyer. 1991. Physiological response of largemouth bass to angling stress. Transactions of the American Fisheries Society 120:629–636.

Harrell, R.M. 1988. Catch and release mortality of striped bass caught with artificial lures and baits. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 41:70–75.

Heiberger, R., and N. Robbins. 2014. Design of diverging stacked bar charts for Likert scales and other applications. Journal of Statistical Software 57:1–32.

Hilborn, R., and C.J. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Springer Science & Business Media.

Holder, P.E., L.P. Griffin, A.J. Adams, A.J. Danylchuk, S.J. Cooke, and J.W. Brownscombe. 2020. Stress, predators, and survival: Exploring permit (*Trachinotus falcatus*) catch-and-release fishing mortality in the Florida Keys. Journal of Experimental Marine Biology and Ecology 524:151289.

Hothorn, T., F. Bretz, P. Westfall, R.M. Heiberger, A. Schuetzenmeister, and S. Scheibe. 2024, Package 'multcomp.' Simultaneous inference in general parametric models. Project for Statistical Computing, Vienna, Austria.

Howarth, A., S.J, Cooke, V.M. Nguyen, and L.M. Hunt. 2024. Non-probabilistic surveys and sampling in the human dimensions of fisheries. Reviews in Fish Biology and Fisheries 34:597-622.

Hughes, R. M. 2015. Recreational fisheries in the USA: economics, management strategies, and ecological threats. Fisheries Science 81:1–9.

Hunt, L.M., S.G. Sutton, and R. Arlinghaus. 2013. Illustrating the critical role of human dimensions research for understanding and managing recreational fisheries within a social-ecological system framework. Fisheries Management and Ecology 20:111–124

Hysmith, B.T., J.H. Moczygemba, and G.R. Wilde. 1994. Hooking mortality of striped bass in Lake Texoma, Texas-Oklahoma. in Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 413–420.

Ihde, T.F., M.J. Wilberg, D.A. Loewensteiner, D.H. Secor., and T.J. Miller. 2011. The increasing importance of marine recreational fishing in the US: challenges for management. Fisheries Research 108:268–276.

Jay, M. 2019. generalhoslem: Goodness of fit tests for logistic regression models. R package version 1.3.4.

Jeanson, A.L., A.J. Lynch, J.D. Thiem, W.M. Potts, T. Haapasalo, A.J. Danylchuk, T.D. Beard Jr., R. Arlinghaus, L. Hunt, N. Young, and S.J. Cooke. 2021. A bright spot analysis of inland recreational fisheries in the face of climate change: learning about adaptation from small successes. Reviews in Fish Biology and Fisheries 31:181-200.

Kassambara, A. 2023. Package 'rstatix.' Pipe-friendly framework for basic statistical tests.

Kieffer, J. D. 2000. Limits to exhaustive exercise in fish. Comparative Biochemistry and Physiology Part A: Molecular and Integrative Physiology 126:161–179.

Kuhn, M., and R. Quinlan, R. 2021. C50: C5.0 decision trees and rule- based models. R package version 0.1.5.

Kuhn, M. 2021. caret: Classification and regression training. R package version 6.0–90.

Lantz, B. 2019. Machine learning with R: Expert techniques for predictive modeling. Packt Publishing.

LaRochelle, L., A.D. Chhor, J.W. Brownscombe, A.J. Zolderdo, A.J. Danylchuk, and S.J. Cooke. 2021. Ice-fishing handling practices and their effects on the short-term post-release behaviour of Largemouth bass. Fisheries Research 243:106084.

LeBlanc, N M., B.I. Gahagan, S.N. Andrews, T.S. Avery, G.N. Puncher, B.J. Reading, and C.F. Buhariwalla. 2020. Genomic population structure of striped bass (*Morone saxatilis*) from the Gulf of St. Lawrence to Cape Fear River. Evolutionary Applications 13:1468–1486.

Lennox, R.J., J.W. Brownscombe, S.J. Cooke, and A.J. Danylchuk. 2018. Post-release behaviour and survival of recreationally-angled arapaima (*Arapaima cf. arapaima*) assessed with accelerometer biologgers. Fisheries Research 207:197 –203.

Lennox, R.J., M.R. Donaldson, G.D. Raby, K.V. Cook, L. LaRochelle, J.C. Madden, S.J. Cooke, D.A. Patterson, and S.G. Hinch. 2024. Using vitality indicators to predict survival of aquatic animals released from fisheries. Conservation Physiology 12:coae034.

Lenth, R. V. 2024. emmeans: Estimated marginal means, aka least-squares means. R package version 1.10.6.

Lucy, J., and A.L. Studholme. 2002. Catch and release in marine recreational fisheries: Proceedings of the Symposium, National Symposium on Catch and Release in Marine Recreational Fisheries, Held at Virginia Beach, Virginia, USA, 5-8 December 1999. American Fisheries Society.

Lukacovic, R., and J.H. Uphoff. 2002. Hook location, fish size, and season as factors influencing catch- and-release mortality of striped bass caught with bait in Chesapeake Bay. in American Fisheries Society Symposium 97–100.

Lynch, A.J., H.S. Embke, E.A. Nyboer, L.E. Wood, A. Thorpe, S.C. Phang, D.F. Viana, C.D. Golden, M. Milardi, R. Arlinghaus, C. Baigun, T.D. Beard Jr, S.J. Cooke, I.G. Cowx, J.D. Koehn, R. Lyach, W. Potts, A.M. Robertson, J. Schmidhuber, and O.L.F. Weyl. 2024. Inland recreational fisheries contribute nutritional benefits and economic value but are vulnerable to climate change. Nature Food 5:433-443.

Lüdecke, D., 2024. sjPlot: Data visualization for statistics in social science. R. Package Version 2.8.17.

Martin, L., B. Negrete Jr., and A.J. Esbaugh. 2023. The effects of size on exhaustive exercise and recovery in a marine sportfish, the red drum (*Sciaenops ocellatus*). Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology 266:110844.

Massachusetts Division of Marine Fisheries. 2002. Massachusetts Striped Bass Monitoring Report for 2019. Technical Report TR-75.

Mazerolle, M.J. 2023. AICcmodavg: Model selection and multimodel inference based on (Q)AIC(c). R package version 2.3–3.

Meka, L. 2004. The influence of hook type, anglere, and fish size on injuryr and the duration of capture in an Alaskan catch-and-release rainbow trout fishery. North American Journal of Fisheries Management 24:1309-1321.

Meka, J., and S.D. McCormick. 2005. Physiological response of wild rainbow trout to angling: impact of angling duration, fish size, body condition, and temperature. Fisheries Research 72:311-322.

McLean, M.F., M.K. Litvak, E.M. Stoddard, S.J. Cooke, D.A. Patterson, S.G. Hinch, D.W. Welch, and G.T. Crossin. 2020. Linking environmental factors with reflex action mortality predictors, physiological stress, and post-release movement behaviour to evaluate the response of white sturgeon (*Acipenser transmontanus* Richardson, 1836) to catch-and-release angling. Comparative Biochemistry and Physiology. Part A: Molecular and Integrative Physiology 240:110618.

Millette, N C., J.J. Pierson, and E.W. North. 2020. Water temperature during winter may control striped bass recruitment during spring by affecting the development time of copepod nauplii. Journal of Marine Science 77: 300–314.

Millard, M.J., J.W. Mohler, A. Kahnle, and A. Cosman. 2005. Mortality associated with catch-and-release angling of striped bass in the Hudson River. North American Journal of Fisheries Management 25:1533-1541.

Muoneke, M.I., and W M. Childress. 1994. Hooking mortality: A review for recreational fisheries. Reviews in Fisheries Science 2:123–156.

Murphy, R., S. Scyphers, S. Gray, and J. H. Grabowski. 2019. Angler attitudes explain disparate behavioral reactions to fishery regulations. Fisheries 44:475-487.

Nagelkerke, N. J.1991. A note on a general definition of the coefficient of determination. Biometrika 78:691–692.

National Marine Fisheries Service. 2018. Fisheries of the United States, 2017 in U.S. Department of Commerce, NOAA Current Fishery Statistics No. 2017.

Nelson, K.L. 1998. Catch-and-release mortality of striped bass in the Roanoke River, North Carolina. North American Journal of Fisheries Management 18:25–30.

Nguyen, V.M., M. Rudd, S.J. Cooke, and S.G. Hinch. 2012. Differences in information use and preferences among recreational salmon anglers: implications for management initiatives to promote responsible fishing. Human Dimensions of Wildlife. 17:248-256.

Nguyen, V.M., N. Young, and S.J. Cooke. 2017. A roadmap for knowledge exchange and mobilization research in conservation and natural resource management. Conservation Biology 31:789–798.

Northeast Fisheries Science Center. 2019. Marine recreational information program data. Available at: www.fisheries.noaa.gov/recreational-fishing-data/recreational-fishing-data-and-statistics-queries.

Nussmann, M. 2005. The recreational fisher's perspective. Science 307:1560c-1561c.

Olden, J.D., L.T. Lawler, and N. LeRoy Poff. 2008. Machine learning methods without tears: A primer for ecologists. The Quarterly Review of Biology 83:171–193.

Osborn, M.F., and G.C. Matlock. 2010. Recall bias in a sportfishing mail survey. North American Journal of Fisheries Management 30:665–670.

Ostrom, E. 2014. Collective action and the evolution of social norms. Journal of Natural Resources Policy Research 6:245-252.

Ostrom, E., J. Walker, and R. Gardner. 1992. Covenants with and without a sword: self-governance is possible. The American Political Science Review 86:404-417.

Page, K.S., and P. Radomski. 2006. Compliance with sport fishery regulations in Minnesota as related to regulation awareness. Fisheries 31:166–178.

Pan, X., S. Arsenault, K. Rokosz, and Y. Chen. 2024. Spatial variability of striped bass spawning responses to climate change. Global Ecology and Conservation 42:e02405.

Pauly, D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. Trends in Ecology and Evolution 10:430.

Pelletier, C., K.C. Hanson, and S.J. Cooke. 2007. Do catch-and-release guidelines from state and provincial fisheries agencies in North America conform to scientifically based best practices? Environmental Management 39:760–773.

Pereira, D.L., and M.J. Hansen. 2003. A perspective on challenges to recreational fisheries management: summary of the symposium on active management of recreational fisheries, North American Journal of Fisheries Management 23:1276–1282.

Policansky, D. 2002. Catch-and-release recreational fishing: a historical perspective. recreational fisheries: Ecological, Economic and Social Evaluation 6:74–94.

Post, J.R., M. Sullivan, S. Cox, N.P. Lester, C.J. Walters, E.A. Parkinson, A.J. Paul, L. Jackson, and B.J. Shuter. 2002. Canada's recreational fisheries: the invisible collapse? Fisheries 27:6–17.

Quinlan, J. 1992. C4.5 programs for machine learning. Morgan Kaufmann Publishers.

Quinn, S., 1996. Trends in regulatory and voluntary catch-and-release fishing. In: multidimensional approaches to reservoir fisheries management. American Fisheries Society Symposium 152–162.

Raby, G.D., J.R. Packer, A.J. Danylchuk, and S.J. Cooke. 2014. The understudied and underappreciated role of predation in the mortality of fish released from fishing gears. Fish and Fisheries 15:489–505.

Raby, G.D., M.R. Donaldson, S.G. Hinch, D.A. Patterson, A.G. Lotto, D. Robichaud, K.K. English, W.G. Willmore, A.P. Farrell, and M.W. Davis. 2012. Validation of reflex indicators for measuring vitality and predicting the delayed mortality of wild coho salmon bycatch released from fishing gears. Journal of Applied Ecology 49:90 –98.

Raby, G. D., S.G. Hinch, D.A. Patterson, J.A. Hills, L.A. Thompson, and S.J. Cooke. 2015. Mechanisms to explain purse seine bycatch mortality of coho salmon. Ecological Applications 25:1757–1775.

Radomski, P.J., G.C. Grant, P.C. Jacobsen, and M.F. Cook. 2001. Visions for recreational fishing regulation. Fisheries Magazine 26:7-18.

R Core Team, R: A language and environment for statistical computing. R foundation for statistical computing, R foundation for statistical computing, Vienna, 2024. (https://www.r-project.org)

Richards, P.A., and P.J. Rago. 1999. A case history of effective fishery management: Chesapeake Bay striped bass. North American Journal of Fisheries Management 19:356-375.

Schramm, H.L., and J.G. Davis. 2006. Survival of largemouth bass from populations infected with largemouth bass virus and subject- ed to simulated tournament conditions. North American Journal of Fisheries Management 26:826–832.

Schreck, C.B., B.L. Olla, and M.W. Davis. 1997. Behavioral responses to stress. Fish Stress and Health in Aquaculture 62:145–170.

Schroeder, D.M., and M.S. Love. 2002. Recreational fishing and marine fish populations in California. California Cooperative Oceanic Fisheries Investigations Report, 182–190.

Secor, D.H., M.H.P. O'Brien, B.I. Gahagan, J.C. Watterson, J.C., and D.A. Fox. 2020. Differential migration in Chesapeake Bay striped bass. PLOS One 15:e0233103.

Shepard, E.L.C., R.P. Wilson, L.G. Halsey, F. Quintana, A. Gomez Laich, A.C. Gleiss, N. Liebsch, A.E. Myers, and B. Norman. 2008. Derivation of body motion via appropriate smoothing of acceleration data. Aquatic Biology 4:235–241.

Shephard, S., C.J. List, and R. Arlinghaus. 2023. Reviving the unique potential of recreational fishers as environmental stewards of aquatic ecosystems. Fish and Fisheries 24:339–351.

Shephard, S., D. Ryan, P. O'Reilly, and W. Roche. 2021. Using local ecological knowledge to inform semi-quantitative fishery surveillance indicators: an example in marine recreational angling, Journal of Marine Sciences 78:3805–3816.

Shideler, A.C., and E.D. Houde. 2014. Spatio-temporal variability in larval-stage feeding and nutritional sources as factors influencing striped bass (*Morone saxatilis*) recruitment success. Estuaries and Coasts 37:561-575.

Snyder, S. 2007. New streams of religion: Fly fishing as a lived religion of nature. Journal of the American Academy of Religion 75:896–922.

Southwick Associates. 2019. The economic contributions of recreational and commercial striped bass fishing. Fernandina Beach, FL.

Spinu, M.V. 2024. Package 'lubridate.' Make Dealing with Dates a Little Easier.

Steinback, S.R., B. Gentner, and J. Castle. 2004. The economic importance of marine angler expenditures in the United States. US Department of Commerce, National Oceanic and Atmospheric Administration.

Stensland, S., Aas, Ø., and M. Mehmetoglu. 2013. The influence of norms and consequences on voluntary catch and release angling behavior. Human Dimensions of Wildlife 18:373-385.

Sullivan, M. G. 2002. Illegal angling harvest of walleyes protected by length limits in Alberta. North American Journal of Fisheries Management 22:1053–1063.

Suski, C.D., S.S. Killen, J.D. Kieffer, and B.L. Tufts. 2006.The influence of environmental temperature and oxygen concentration on the recovery of largemouth bass from exercise: implications for live–release angling tournaments. Fish Biology 68:120-136.

Suski, C.D., S.S. Killen, S.J. Cooke, J.D. Kieffer, D.P. Philipp, and B.L. Tufts. 2004. Physiological significance of the weigh-in during live-release angling tournaments for largemouth bass. Transactions of the American Fisheries Society 133:1291–1303.

Tarrant, M.A., M.J. Manfredo, P.B. Bayley, and R. Hess. 1993. Effects of recall bias and nonresponse bias on self-report estimates of angling participation. North American Journal of Fisheries Management 13:217–222.

Taylor, B. 2007. Focus introduction: Aquatic nature religion. Journal of the American Academy of Religion 75:863–874.

Teffer A.K., S.G. Hinch, K.M. Miller, D.A. Patterson, A.P. Farrell, S.J. Cooke, A.L. Bass, P. Szekeres, and F. Juanes. 2017. Capture severity, infectious disease processes and sex influence post- release mortality of sockeye salmon bycatch. Conservation Physiology 5:cox017.

Thompson, J.A., S.G. Hughes, E.B. May, and R.M. Harrell. 2002. Effects of catch and release on physiological responses and acute mortality of striped bass. in American Fisheries Society Symposium139–143.

Twardek, W.M., R.J. Lennox, M.J. Lawrence, J.M. Logan, P. Szekeres, A.J. Danylchuk, and S.J. Cooke. 2018. The post-release survival of walleye following ice angling on Lake Nipissing. North American Journal of Fisheries Management 38:159–169.

Uphoff, J.H. 2023. Perspective comes with time: What do long-term egg and juvenile indices say about Chesapeake Bay Striped Bass productivity? Marine and Coastal Fisheries 15:e10248.

Vaske, J.J., and M.P. Donnelly. 1999. A value-attitude- behavior model predicting wildland preservation voting intentions. Society and Natural Resources 12:523–537.

Wang Y., M.P. Wilkie, G.J.F. Heigenhauser, and C.M. Wood. 1994. The analysis of metabolites in rainbow trout white muscle: a comparison of different sampling and processing methods. Journal of Fish Biology 45:855–873.

Warnes, G.R., B. Bolker, T. Lumley, and R.C. Johnson. 2018. gmodels: Various R programming tools for model fitting. R package version 2.18.1.

Wickham, H., R. Francois, L. Henry, and K. Müller. 2020. dplyr: A Grammar of Data Manipulation. R package version 0.8.4.

Wilberg, M. J. 2009. Estimation of recreational bag limit non-compliance using contact creel survey data. Fisheries Research 99:239-243.

Wilde, G.R., M.I. Muoneke, P.W. Bettoli, K.L. Nelson, and B.T. Hysmith. 2000. Bait and temperature effects on striped bass hooking mortality in freshwater. North American Journal of Fisheries Management 20:810–815.

Wood, C. M. 1991. Acid–base and ion balance, metabolism, and their interactions, after exhaustive exercise in fish. Journal of Experimental Biology 160:285–308.

Wydoski, R. S. 1977. Relation of hooking mortality and sublethal hooking stress to quality fishery management. Catch-and-release fishing as a management tool. Humboldt State University, Arcata, California, 43-87.

Zeileis, A., G. Grothendieck, J.A. Ryan, J.M. Ulrich, and F. Andrews. 2023. Package 'zoo.'. R. Package Version 1–8.12.

Zuur, A.F., E.N. Ieno, and C S. Elphick. 2010. A protocol for data exploration to avoid common statistical problems. Methods in Ecology and Evolution 1:3 – 14.