California Department of Fish and Wildlife Evaluation of Regulation Change Petition 2022–12: Proposed 20–30–inch Harvest Slot Limit for Striped Bass (*Morone saxatilis*)

Petition submitted August 1, 2022 by Nor–Cal Guides and Sportsmen's Association (NCGASA)

Report prepared by:
Erin Ferguson[1]
Colby Hause[1]
Jonathan Nelson[1]
Dylan Stompe[2]
Ken Oda[2]
Lanette Richardson[1]

California Department of Fish and Wildlife
[1]Fisheries Branch and [2]Marine Region
1010 Riverside Parkway
West Sacramento, 95605

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Striped Bass Fishery Background

Native to the East and Gulf Coasts of North America, Striped Bass (*Morone saxatilis*) were introduced to Pacific waters in 1879 when 132 individuals were planted in San Francisco Bay (Scofield 1930). After one additional fish transfer in 1882 (Smith 1895), a commercial fishery was established in the San Francisco Bay area by the late 1880s (Hart 1973). To protect the increasingly popular sport fishery, the commercial Striped Bass fishery closed in 1935. Prior to 1956, fishing regulations generally included a 12–inch minimum length limit (MLL) and a five fish daily bag limit. From 1956–1981 the MLL increased to 16 inches with a daily bag limit reduction to three fish (Stevens and Kohlhorst 2001). In response to declines in legal–size Striped Bass in the 1970's (Kohlhorst 1999) and at the request of anglers, the California legislature established a short–lived Striped Bass Management program in 1981, which included stocking Striped Bass in California rivers using private and state–run hatcheries. In the same year, Striped Bass regulations were further restricted to an 18–inch MLL and a daily bag limit of two fish, (14 CCR 5.75; 14 CCR 27.85) which remain in effect today.

The Striped Bass Management Plan was terminated in 2004 due to observed increases in the Striped Bass population and growing concern over the impact of Striped Bass predation on native fish species (SB 692, 2003). In 2020, the Fish and Game Commission unanimously adopted an amendment to the Striped Bass policy that eliminated a numeric target for population size and replaced it with a broader commitment to sustain Striped Bass populations in support of a robust and self-sustaining recreational fishery (FGC 2020).

Summary of Proposed Regulation Change Petition

The Nor–Cal Guides and Sportsmen's Association (NCGASA) submitted a regulation change proposal to the Fish and Game Commission on August 1, 2022 (Tracking number [TN] 2022–12). The proposed regulation change would impose a slot limit within anadromous and marine waters whereby only Striped Bass from 20 to 30 inches would be available for harvest in the sport fishery, with no proposed change to the bag limit. Currently, any Striped Bass 18 inches or greater may be harvested within anadromous and marine waters with a daily bag limit of two fish. The NCGASA–proposed Striped Bass regulation change did not consider or propose any changes to the current bag limit, season, or geographic range.

<u>The NCGASA stated need for the proposed shift from 18 to 20–inch minimum harvest length:</u>

"This will allow more opportunity (at least one more year) for females to spawn after initial maturity (which is around 18 inches). It would also protect any unripe

Striped Bass (male or female) that fall between 18 to 20 inches from harvest." (M. Smith, personal communication, November 1, 2022).

The NCGASA stated need for the proposed 30–inch maximum harvest length:

"This will allow protection to the most fecund female spawners and contributes to increased spawning success of the population." (M. Smith, personal communication, November 1, 2022).

Communication between NCGASA and the California Department of Fish and Wildlife (Department)

Since petition TN 2022-12 was submitted, the Department has met with NCGASA and their scientific advisors multiple times. The meetings and email correspondences helped to clarify desired short- and long-term Striped Bass fishery outcomes and share available data so that the Department could fairly and accurately evaluate the contents of the petition on its face, as well as the intent of the petitioner. Through those discussions the Department also tracked these additional comments from the petitioner.

Additional comments from NCGASA:

- *"The Striped Bass population is in desperate trouble at each life stage. The population is collapsing and is no longer viable," (Page 2, TN 2022–12).*
- *"Current regulations allow for the removal of female Striped Bass before they reach sexual maturity as well as removal of the largest females from the system," (Page 3, TN 2022–12).*
- *"20 inches may not be ideal for protecting reproductive females (that would be 24 or 26 inches) but it is an initial starting point that balances at least one more year toward maturity and maintains recreational angler opportunity. We are open to adjusting the lower slot upwards in a phased approach as populations sizes gradually increase."* (M. Smith, personal communication, November 1, 2022).
- *"20–30 inches was what the majority of the Striped Bass fishing organizations and angling community contacted by NCGASA from Monterey to Yuba City were in agreement to for socio economics and food for fishing families."* (J. Stone, personal communication, November 1, 2022).

Evaluation Summary

The Department received and evaluated a regulation change petition (TN 2022–12), whereby if implemented, would impose a Harvest Slot Limit (HSL) of 20–30 inches on Striped Bass in marine and anadromous waters. The Department evaluated if the Striped Bass population warrants further protection through changes to current angling regulations, and if the proposed HSL would produce the biological and fisheries improvements desired by the petitioners.

Within Striped Bass native ranges, Atlantic states have adopted various combinations of regulatory practices to meet their management goals (Figure 15, ASMFC 2022). Examples include various harvest slot ranges, split slot limits, seasonal and geographic regulations, changes to bag limits, gear restrictions, and others. The petition only requested a specific HSL and did not include alternative HSL options or other considerations such as changes to season, bag limit, or geographic range; therefore the Department's evaluation is focused on the proposed 20–30–inch HSL and does not include evaluation of these other factors. The Department gathered available data from inland and marine creel surveys, juvenile and adult abundance surveys, and a Striped Bass Angler Preference Questionnaire. Additionally, modeled population and fishery responses under the current 18–inch MLL regulation were compared to the proposed 20–30–inch HSL and an alternative 18–30–inch HSL that maintains the current 18–inch MLL.

The Department could support a regulation change for Striped Bass, including a HSL, if it were determined that the population warranted further regulatory protections or that regulatory protections would improve the angler experience.

Harvest slot limits can provide effective population and fisheries benefits such as increased productivity, population growth, reduced overfishing, and trophy fisheries. Harvest slot limits are best determined using species–specific biological metrics, population dynamics, consideration of environmental influences, impacts to fisheries participants, and management goals and objectives.

Relative to the current MLL, a HSL is estimated to decrease the risk of recruitment overfishing, defined as exploitation at a rate beyond stock replacement (Goodyear 1990, Mace and Sissenwine 1993) (Figure 13a). Therefore, implementation of an HSL may result in increased Striped Bass population growth if carrying capacity is not constrained. Population model simulations resulted in a 53% probability of recruitment overfishing (i.e., probability of a spawner potential ratio [SPR] < 0.35; Figure 13a) under the current 18–inch MLL, suggesting that the current regulation may not be adequate for long–term population sustainability and growth. Under an 18–30–inch and 20–30–inch HSL, model simulations resulted in a decreased risk of recruitment overfishing by 14% and 19%, respectively (Figure 13a), indicating that a harvest slot may improve recruitment success.

Population model simulations resulted in a higher proportion of fecundity contribution from older (age 10+) females under HSLs compared to the current MLL (Figure 13b), which may have positive implications on recruitment for Striped Bass. However, there was *no difference* in this metric between the 18–30–inch HSL and the 20–30–inch HSL. Thus, it is unlikely that raising the lower limit from 18 to 20-inch (while maintaining the 30–inch upper limit) will have substantial impacts on reproductive output.

Relative to the current MLL, the evaluated 18–30 inch and 20–30–inch HSL regulations resulted in similar improvements to catch and trophy–sized catch (Figure13e-f), but harvest was substantially lower under the 20–30–inch slot (21%; Figure 13d). Population model simulations resulted in 13% lower harvest under the proposed 20–30–inch HSL compared to the 18–30–inch HSL.

Prioritizing harvest numbers above other fishery objectives (e.g., increased catch, size of catch, fishing opportunities, angler satisfaction, etc.) is best supported by the current 18–inch MLL or implementing a wide harvest slot that encompasses the majority of sizes that are vulnerable to catch modeled for the recreational fishery. If the management objective is to enhance recreational fishing opportunities in the form of catch numbers, HSLs better achieve this goal compared to the current MLL. Possibly the most realized benefit of HSLs in terms of catch comes in the form of catch size, as HSLs produced substantially higher numbers of trophy–sized catch compared to the current MLL (Figure 13f). Thus, HSLs can provide multiple benefits to the angler experience, including higher catch rates and improved quality of catch (as defined by fish size). If the fishery objective is to be more protective and increase spawning opportunity, then the HSL needs to be set to minimize harvest of the most abundant spawning size classes, which will inherently decrease harvest opportunity.

As stated above, the focus of this evaluation was to determine if (1) the population warrants further protection through changes to current angling regulations and (2) to assess if the proposed HSL would produce the biological and fisheries improvements desired by the petitioners. While the Department is in support of an HSL for the Striped Bass fishery as a concept, available monitoring data suggest that the adult population is relatively stable and further protections to the population in the form of regulatory changes may not be warranted at this time; however, regulatory changes in the form of a slot limit could enhance recreational fishing opportunities in both catch numbers and catch size.

Declines in recruitment to age–0 in the Delta (Figure 8) suggests some level of reduced spawning and/or recruitment success, though recent abundance

estimates (2011–2016) imply relative stability in the adult (> 18 inches TL) population.

Recent abundance estimates calculated using the combined inland and marine harvest estimated from the Central Valley Angler Survey (CVAS) and the California Recreational Fisheries Survey (CRFS) creel surveys, as well as harvest rate from tag returns, resulted in an average of 1,157,275 legal–sized (> 18–inches TL) Striped Bass estimated from 2011–2016. Relative measures of angler catch/harvest of adult Striped Bass collected in the CVAS also suggest stability in the adult (> 18 inches) population. Angler effort targeting Striped Bass has not significantly changed during 1991–2016, however, angler catch-per-unit-effort (CPUE) has increased significantly over the same period (Figure 2). Data collected from Commercial Passenger Fishing Vessels (CPFV) during 1995–2020 also indicate that CPUE has significantly increased over time (Figure 3). The average size of Striped Bass harvested by anglers has not changed significantly over time (Figure 5). However, length data on fish released was not historically recorded, and thus it is possible that the size of fish released in the fishery has changed over time.

Despite evidence of stability in the adult population, the Department is not opposed to implementing a HSL to benefit the angling experience. However, our evaluation has concluded that a 20–30–inch HSL, as proposed by petitioners, may not be adequate in meeting the petitioner's stated fishery and population objectives.

The Department does not support increasing the MLL from 18 to 20 inches because it would likely not produce the biological or fisheries responses described in the petition.

One of the stated desires of the petitioners is to protect the earliest spawners. The Department has determined that increasing the current MLL from 18 to 20 inches fails to provide sufficient protections to sexually mature female Striped Bass and would not provide the fisheries response sought. The potential for increased population fecundity contributed by mature females between 18 and 20 inches is negligible based on the percentage of female maturity in that size and age range. Females are roughly 3 years old at 18–20 inches. Literature on the fecundity and maturity of Striped Bass on the West Coast suggests that most females mature between ages 4 and 5 when they are around 22–24 inches, and nearly all females are mature by age 6 when they are approximately 27 inches (Collins 1982, Raney 1989, Scofield 1930). In Atlantic stocks, recent studies have found less than 10% of individuals mature at age 3 (Brown et al. 2024), and stock assessments for Atlantic Striped Bass use a sexual maturity of 0% for age–3 females in population models (2014 ASMFC; 2022 ASMFC).

To incorporate natural variation in age–at–maturation in our population model of West Coast Striped Bass, we set the mean length at maturation for females at 22.8 inches with a 95% probability between ~ 20–26 inches (Appendix A2f). There was no difference in the proportion of fecundity contributed by older females when comparing the model simulations between the proposed 20–30–inch HSL inch to the alternative 18–30–inch HSL (Fig. 13b). In other words, increasing the lower limit from 18 to 20 inches does not translate into an increase in egg contribution by older fish. This is important for population persistence considering energy investment into individual offspring changes with female size, such that larger fish produce offspring that are greater in size and number compared to smaller fish (Lim et al. 2014). This can have implications on recruitment success, as larger offspring are less vulnerable to size–dependent mortality and therefore typically experience higher survival rates (Conover and Schultz 1997). Furthermore, the difference in the probability of recruitment overfishing (probability of SPR < 0.35) under an 18–30–inch HSL vs 20–30–inch HSL was relatively small (5%; Figure 13a), suggesting that recruitment gains under each lower limit are similar.

It is estimated that harvest would decrease by 21% under a 20–30–inch HSL compared to the current 18-inch MLL (Fig. 13d). This may have an outsized impact on disadvantaged communities that utilize Striped Bass for sustenance. Additionally, increasing the MLL to 20 inches is not supported by the angling public contacted through an electronic questionnaire distributed by CDFW (n = 18,751). The Striped Bass Angler Preference Questionnaire indicated that 71% supported the current 18–inch MLL. Data from inland and marine creel surveys indicate that Striped Bass CPUE, size of the catch, and harvest have been stable for decades, and both fisheries have seen an increase in the number of released Striped Bass.

Furthermore, increasing the MLL from 18 to 20 inches will likely minimize potential population benefits due to an increase in discard mortality. Discard mortality (i.e., release mortality) can be high (Table A4), especially during unfavorable environmental conditions such as elevated water temperatures, which are common as climate change increases the severity and frequency of drought conditions in California. Discard mortality rates for California Striped Bass fisheries are not currently monitored; however, the Department's Central Valley Angler Survey qualitatively observes an increase in moribund Striped Bass during late–spring through summer when water temperatures are elevated. Mortality rates of discarded Striped Bass are well documented in Atlantic Coast recreational fisheries (see Appendix A2b).

CDFW is supportive of an upper HSL to support a trophy fishery but has not determined if 30 inches is the most appropriate size.

The upper 30–inch HSL proposed by the petitioner was not determined based on biological evidence or supporting scientific data, but instead informed by angler preference in the Striped Bass fishing organizations and angling communities contacted by petitioners. The narrow focus of the current evaluation precluded additional analysis of what the most biologically appropriate HSL, or combination of regulatory strategies (as observed in the East Coast regulations), would be best to meet the goals of both the Department and the petitioners.

While it would be prudent to compare additional HSLs, the Department could support an upper HSL of 30 inches (as proposed by petitioners) to create opportunity for a trophy fishery. Results from the Striped Bass Angler Preference Questionnaire indicate that 63% of respondents were supportive of a catch–and–release trophy Striped Bass fishery. 'Trophy' size was also defined as ≥ 30 inches by most respondents in that survey). Based on the creel surveys, a 30–inch upper HSL would likely not have substantial impacts on harvest patterns. Creel data indicate that reported harvest of fish > 30 inches is low and many anglers informally report to creel clerks that they currently release larger fish for various reasons. Based on model results, implementing an upper slot limit of 30 inches with the current 18–inch MLL only decreased estimated harvest by approximately 8% (Figure 13d).

In concept, an upper HSL of 30 inches could be more protective of the female spawning biomass and may contribute to increased recruitment. Model simulations resulted in an 8.1% increase in the proportion of fecundity contributed by older fish under both evaluated HSLs (20-30 and 18–30 inch) compared to the current 18–inch MLL (Fig. 12b). However, a number of factors could minimize the expected recruitment response resulting from a 30-inch HSL. Anglers harvest a very low proportion of > 30–inch fish (< 6%; Figure 6 and Figure 7), and the Department lacks the data necessary to determine if this observation is driven by (1) anglers choosing to release larger fish, (2) low abundance of > 30–inch fish in the population, (3) larger fish being less vulnerable to catch in the fishery (see Appendix section A2c), or (4) a combination of these factors.

Additionally, decreasing the upper slot limit (< 30 inches) may be necessary to be more protective of the greatest proportion of the female spawning biomass. Regardless, for significant spawning and recruitment gains to be realized, the benefit would likely come at the cost of harvest opportunity. With these considerations in mind, additional analysis would be necessary to determine if 30 inches is the most efficient upper HSL in terms of maximizing stock conservation gains while minimizing impacts to the fishery (i.e., loss of catch or harvest opportunity).

Implementation of a harvest slot may necessitate removal of spearfishing as a method of take for Striped Bass.

It is common to allow spearfishing for fish species with MLLs based on the assumption that anglers can visually estimate if a fish is larger than the minimum size. It becomes extremely difficult, if not impossible, for an angler to accurately visually estimate the size of a fish that has a minimum and maximum size limit. In addition, the lethal nature of a speargun would make it impossible to release a fish in good condition if outside the harvest slot. This can result in illegal harvest if retained and put the angler at risk; or the angler releases a moribund fish that can no longer contribute to future spawning and catch, which is counter to the purpose of the HSL. Additionally, the release of a moribund fish is considered wanton waste of fish by definition in regulation. California currently does not allow spearfishing take for any species with a harvest slot limit, however, a few regions on the East Coast allow take by spear where Striped Bass have slot limits (Figure 15).

Based on available data in California, there is insufficient evidence to support that Striped Bass predation is a primary contributor to declining salmonid and smelt populations.

Observations of salmonids in Striped Bass stomachs vary by life stage and season, but overall remains relatively low (Stevens 1966; Michel et al. 2018; Stompe et al. 2020; Peterson et al. 2020; Brandl et al. 2021). An extensive review of literature pertaining to Striped Bass predation in the Sacramento– San Joaquin River Delta suggests that sub–adult size classes are more likely to encounter and consume native fish due to their longer Delta and freshwater residency and more optimal predator–to–prey ratio (PPR) (see Appendix 3).

While older (larger) Striped Bass consume more prey on an individual basis, total consumption is often greater for sub–adults compared to adults due to a higher abundance of younger (smaller) fish (Loboschefsky et al. 2012). It is likely that smaller sub–adult Striped Bass (ages 1 and 2) that are present year–round and have a wide geographic distribution in the Delta and Central Valley rivers have more opportunity to contact native fish species. A shift in MLL from 18 to 20 inches may contribute to an increase or shift in predation habits for Striped Bass between 18 and 20 inches.

The majority of larger Striped Bass (> 21 inches, Dorazio et al. 1994) are more migratory, spend less time in the freshwater environment, and are less likely to target smaller sized prey due to PPR. There may also be a contingent of large Striped Bass that are freshwater residents, posing some constant, yet unquantified, level of predation pressure. Establishing an upper HSL at 30 inches will not likely have a noticeable impact on predation of juvenile salmonids and smelt due to (1) PPR, (2) high variation in the size of prey consumed, and (3) little evidence of prey specialization.

Department Recommendation

The Department does not recommend a 20–30–inch HSL as proposed in the petition. The Department recommends maintaining the current 18–inch MLL regulation and is supportive of establishing an upper HSL. Modeling suggests a 30-inch upper limit could result in decreased risk of recruitment overfishing (and thus stock conservation benefits) and increased catch and trophy fishing opportunity, but it cannot confirm if 30 inches is the most appropriate size due to the narrow scope of the current analysis. While there is public support for maintaining the 18–inch MLL (71% or respondents) and establishing a catch–and–release trophy fishery (64% of respondents), the highest percentage of respondents supported no change in harvest regulations (54% of respondents) in the Striped Bass Angler Preference Questionnaire. Creel data suggest that the Striped Bass fishery in California is currently stable, and the current regulations are not contributing to perceived population declines; however, modeling results suggest that the current 18-inch MLL on its own may not be adequate for long-term population stability and growth.

The Department will continue to support harvest opportunity for anglers as long as the available data reflect trends that are in line with the guidance laid out in the Fish and Game Commission Striped Bass Policy. In the absence of additional funding, monitoring, and staffing that would be necessary to conduct a more comprehensive, multifaceted approach to determine the most effective angling regulation, the Department believes there could be some benefit to the Striped Bass fishery by implementing a HSL and could support a HSL of 18-30 inches.

Scientific Evaluation of Striped Bass Fishery

Evaluation of the health and performance of a fishery includes understanding angler usage and participation, appropriate regulatory tools to control the impact of recreational angling on fish stocks, biological fisheries metrics, and how these factors relate to management objectives and realized fisheries responses. In order for regulatory tools, such as daily bag and size limits, to be effective, responses in angler effort must be reliably estimated relative to regulatory adjustment or management objectives. However, predicting angler effort responses to regulatory adjustment is difficult because responses depend on many factors, including the structure of prevailing and proposed regulations and the drivers of angler behavior (Carr–Harris and Steinback 2020). While quantitatively accounting for angler effort responses in fishery outcomes was beyond the scope of this evaluation, data on angler preference and sentiment regarding the current fishery and alternative regulations were considered alongside biological fisheries metrics.

Female spawning stock biomass is a metric of stock performance that is often relied on in fisheries management. Understanding the biological consequences of alternative harvest size restrictions such as minimum length limits, harvest bag limits, harvest slots (minimum and maximum length limits), and protected harvest slots is important in preventing recruitment overfishing, a condition in which the spawning stock is depleted to a level at which future recruitment declines strongly (Allen et al. 2013). In practice, harvest slot policies have been proposed as alternatives to minimum length regulations in some recreational fisheries because they are more likely to preserve natural age structures, positively affect spawning and recruitment potential, increase total harvest and trophy catch numbers, and reduce risk of population decline (Arlinghaus et al., 2010; Koehn and Todd, 2012; Ayllón et al., 2019). The Department must evaluate if the Striped Bass population is at risk of recruitment overfishing under current regulations, as well as weigh stock conservation outcomes against fishery objectives under alternative length–based harvest scenarios.

The Department’s scientific evaluation of the Striped Bass fishery contains a summary of the Department’s public outreach efforts in the form of results from the Striped Bass Angler Preference Questionnaire, proceedings from a town hall meeting, Striped Bass angling regulations from their native range of the Eastern

United States, and assessments of available Department data sets (inland and marine creel surveys and juvenile and adult abundance monitoring). Additionally, the Department has leveraged current and historic data, literature, and life history modeling tools to inform an age and size–structured population model to evaluate potential fishery tradeoffs resulting from changes in harvest regulations. Lastly, considerations for how changing the current Striped Bass fishing regulations may impact native species is reviewed. All of this information was used to inform the Department's assessment of the necessity, effectiveness, and feasibility of implementing a 20–30–inch slot limit in the Striped Bass fishery.

Public Input

Understanding angler usage and participation is key to evaluating the health and performance of a fishery, as failing to consider angler effort responses can result in regulations that are insufficient in meeting intended objectives. (Carr–Harris and Steinback 2020). In response to the NCGASA proposal, the Department developed a Striped Bass Angler Preference Questionnaire and hosted a public Town Hall to gather information from the Striped Bass angling community on their thoughts about the overall fishery and determine if there was a general desire for changes to the Striped Bass fishery.

Striped Bass Angler Preference Questionnaire

The questionnaire was sent out electronically to ~1 million angling license holders and was available in 7[1] languages. Prior to distribution, the questionnaire was reviewed by Fisheries Branch managers, the Human Dimensions Unit (who reviewed content for bias, leading language, etc.), and final approval was given by the Office of Communication and Outreach Branch (OCEO). There were 26,410 responses to the questionnaire, of which 18,751 indicated they do fish for Striped Bass and 7,659 did not. Briefly, results show that ~71% of Striped Bass anglers (11,981 out of 16,875) support the current minimum size for retention at 18 inches. When offered options for changing the minimum size limit, 54% of responses (8,975 out of 16,621) did not support increasing the minimum size from 18 inches while ~28% (4,653 out of 16,621) supported either lowering the minimum or no minimum at all (Table 1). However, 64% of responses (10,750 out

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[1] The initial Striped Bass Angler Preference Questionnaire (APQ) was only distributed in English due to the timing aligned with the change of the State of California fiscal year (July 1) and the need for renewal of the translation services contract. Upon contract renewal, the survey was redistributed (through email and social media posts) in Spanish, Tagalog, Vietnamese, Russian, Simplified Chinese, and Traditional Chinese.

of 16,797) supported a catch–and–release fishery for trophy sized Striped Bass even if it would require setting a maximum size limit (in effect a slot limit) on Striped Bass that could be harvested (Table 2). The definition of a trophy Striped Bass varied widely between responses, with 30, 36, and >40 inches reported most frequently (Figure 1). Complete results can be found in Appendix 1.

Table 1. Results from Question 4 in the 2022 Striped Bass Angler Preference Questionnaire. Results reflect responses to the question: Would you like to see the minimum size limit for harvest of Striped Bass:

No change (%)	No minimum size (%)	Lower than 18 inches (%)	Higher than 18 inches (%)	Number of Responses
54	8	20	18	16,621

Table 2. Results from Question 6 in the 2022 Striped Bass Angler Preference Questionnaire. Results reflect responses to the question: Would you support a catch and release fishery for trophy sized Striped Bass? This would require setting a maximum size/slot limit on Striped Bass.

Yes (%)	No (%)	Number of Responses
64	36	16,797

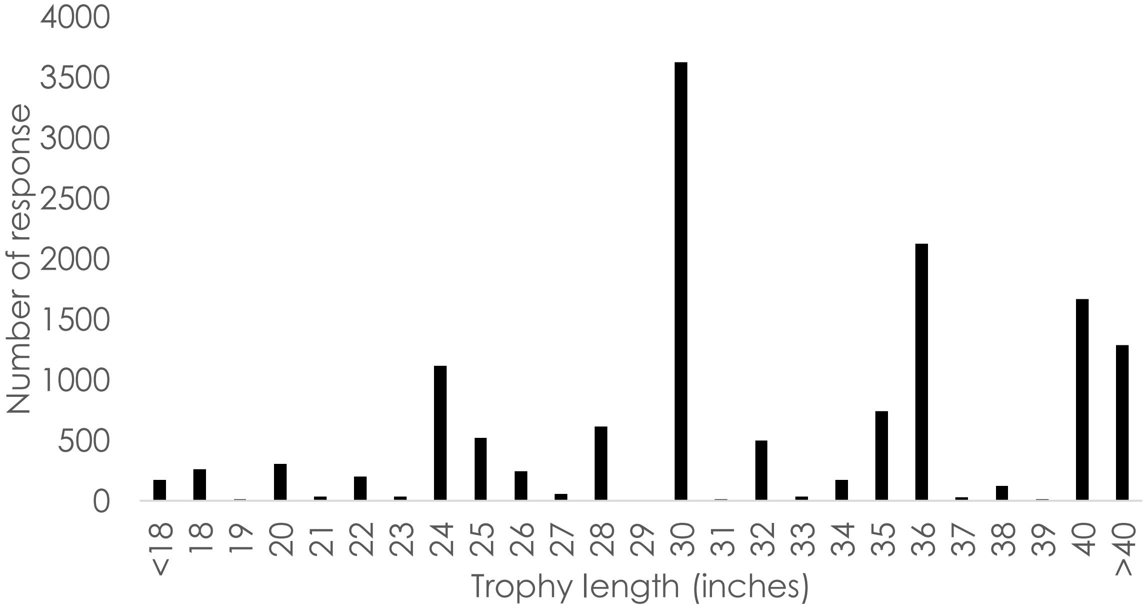


Figure 1. Figure A2 *in* **Appendix 1**, 2022 Striped Bass Angler Preference Questionnaire Results Summary. Fill–in–the blank responses to what size Striped Bass anglers considered a trophy. Data source: 2022 Striped Bass Angler Preference Questionnaire.

Joint Town Hall Meeting

The Department hosted a joint public town hall meeting with the NCGASA on August 24, 2022. The meeting platform was hybrid with the option to attend in–person at the Fisheries Branch headquarters in West Sacramento or virtually via Zoom. The purpose of the meeting was to discuss the regulation change petition brought forth by the NCGASA, the Department's evaluation of the petition to date, and allow public questions and comments to the NCGASA and the Department.

The meeting was well attended with approximately 50 members of the public in attendance and 100 more attending virtually. Forty–five public comments were made at the meeting with 40 commenters supporting the proposed slot limit (20–30 inches TL), two commenters opposing the proposed slot limit, and three commenters who were neutral on the issue.

CDFW Monitoring Studies

Angler Derived Fishery Data: Creel Surveys

There is limited monitoring data for Striped Bass in California, restricting the Department's ability to accurately estimate population and size class abundance. The Department's primary sources of recreational angling data are collected by our Inland (Central Valley Angler Survey) and Marine (California Recreational Fisheries Survey) creel programs. From these programs, fishery metrics such as effort, catch, harvest, and size of the catch can be estimated; however, the size ranges observed in the fishery may not be reflective of the size class distribution or abundance in the population.

CPUE as a relative measure of abundance, for the purpose of monitoring trends in the Striped Bass fishery, can be used when absolute population estimates do not exist (Hilborn and Walters 1992, Quinn and Deriso 1999). However, these measures are best used in conjunction with population estimates to better understand CPUE trends in a broader context (Ward et al. 2013). Hyperstability is the "illusion of plenty", where CPUE is not linearly related to fish density. This often occurs when fisheries target aggregations of fish. Catch rates can remain stable, while abundance of the population declines (Erisman et al. 2011). Hyperstability has been documented in many commercial fisheries and a few recreational fisheries (Shuter et al. 1998, Rose and Kulka 1999, Erisman et al. 2011), and is often attributed to fish aggregations and changes in gear efficiency in commercial fisheries. However, the mechanisms driving hyperstability in recreational fisheries can be attributed to improved fishing techniques (technology, gear, and bait) and information sharing (social media, etc.).

Department creel surveys try to account for sampling factors that could contribute to hyperstability through their study designs. Sampling occurs over a large geographic area, year–round, and applies other randomly selected factors (start times, launch locations/ports, sample day, etc.). Building random stratification into the study design captures variability in angler effort (spatially and temporally), fish distribution and/or seasonality, and the range of angler experience (catchability).

Based on The Department's Central Valley Angler Survey (CVAS) data, angler effort (total angler hours) targeting Striped Bass has not significantly changed during 1991–2016, however angler CPUE has increased significantly over the same period (Figure 2). Similarly, data collected from Commercial Passenger Fishing Vessels (CPFV) during 1995–2020 also indicate that Striped Bass CPUE has significantly increased over time (Figure 3), providing evidence that fishery performance is improving in both fresh and marine waters.

While CPUE from angler–based surveys have remained relatively stable or even increased over time (potential hyperstability), recruitment to age–0 has precipitously declined in the Delta (see Juvenile and Adult Monitoring section below). However, recruitment to age 3 (size of entry to the fishery) has been shown to be strongly density dependent (Figure 4, Kimmerer et al. 2000). This may buffer changes in fishable sized Striped Bass from the decline in recruitment of age–0 fish.

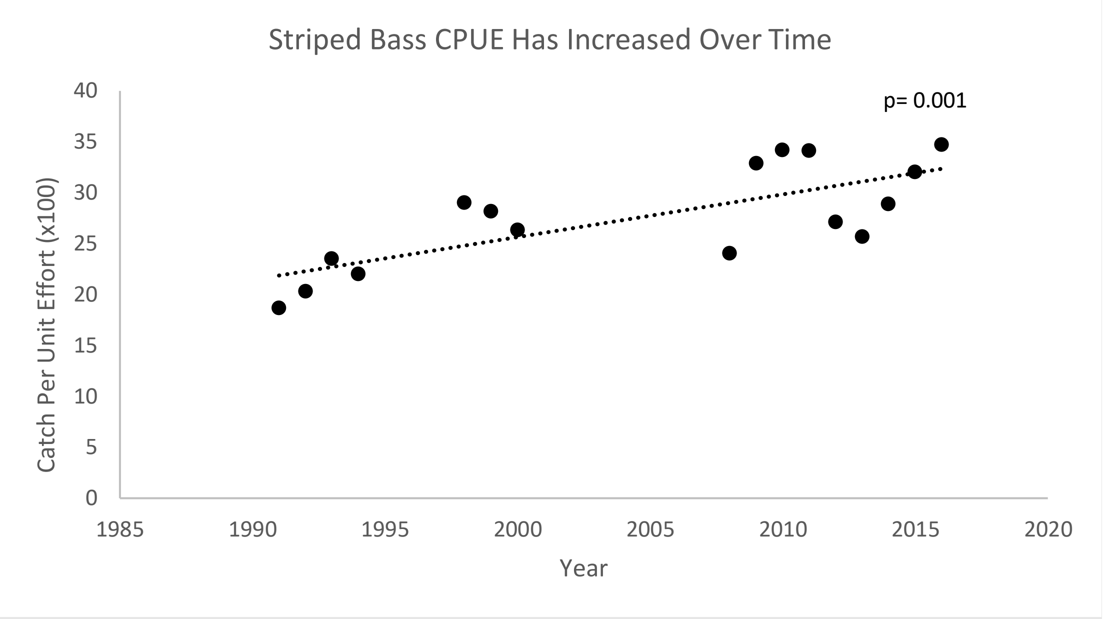


Figure 2. Average catch of Striped Bass per angler hour. Striped Bass CPUE has significantly increased over time (p = 0.001). Data source: CVAS data.

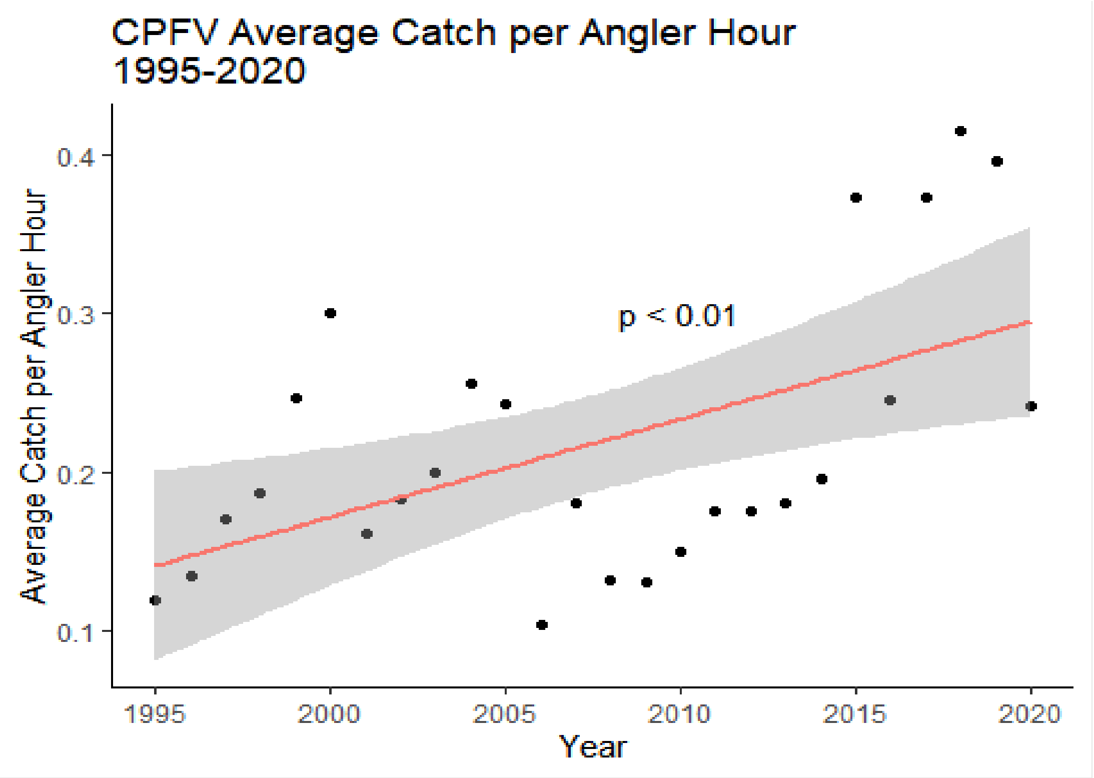


Figure 3. Average catch of Striped Bass per angler hour. Data source: CPFV Logs.

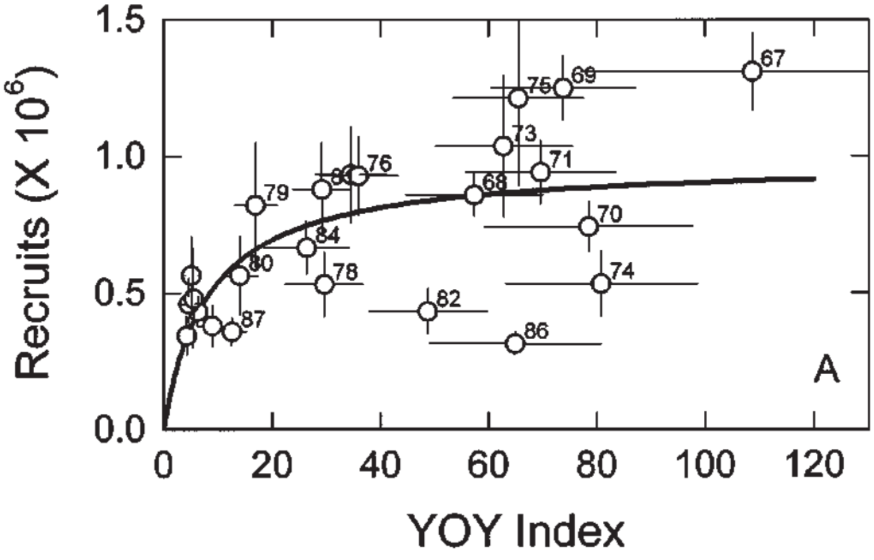


Figure 4. From Kimmerer et al. 2000 Fig 5(A). Young–of–the–year (YOY) index was estimated from a combination of Summer Townet Survey, Fall Midwater Trawl Survey and the San Francisco Bay Study. Recruits refers to abundance estimates of age–3 fish in the Adult Striped Bass Study.

Catch-per-unit-effort is one metric which is often used to evaluate fisheries stability. A declining CPUE may be an indication of overexploitation by recreational anglers. While an increasing CPUE may result from improvements in fishing technology (lures, fish finders, etc.) that increase anglers' ability to locate and catch fish, and/or may be an indication of an increasing Striped Bass population, particularly of sub–adults that are sub–legal size (<18 inches) for harvest in the fishery. Evidence of the latter comes from the significant increase in numbers of Striped Bass reported as released in both the inland and ocean/bay fisheries. Anglers typically report releasing Striped Bass because they are 1) practicing catch–and–release fishing, 2) the fish is larger than they find desirable, and most commonly 3) because the fish is smaller than what they can either legally keep or want to keep. However, angler catch data alone cannot be used to assess the status and trends of the Striped Bass population; fishery–independent population studies and assessments are also needed to address these questions.

Another metric that can be evaluated for fisheries performance is fish size. An indication that a fishery may be in decline is a significant decrease in the size of fish harvested. The average size of Striped Bass harvested by anglers has not changed significantly over time (Figure 5). Inland harvest from 1998–2016 has remained around 23 inches total length (average), while Striped Bass harvested in the ocean/bay from 2010–2021 averages around 22 inches. Unfortunately, neither inland nor ocean surveys have historically collected size data on fish that are reported as released, thus it is possible that the size of fish released in the fishery has declined over time. Additionally, creel surveys do not monitor the nighttime Striped Bass fishery, so it is possible that there may be a difference in the size of Striped Bass harvested during the day when compared to what is harvested at night. Currently the Department does not have data to address these questions.

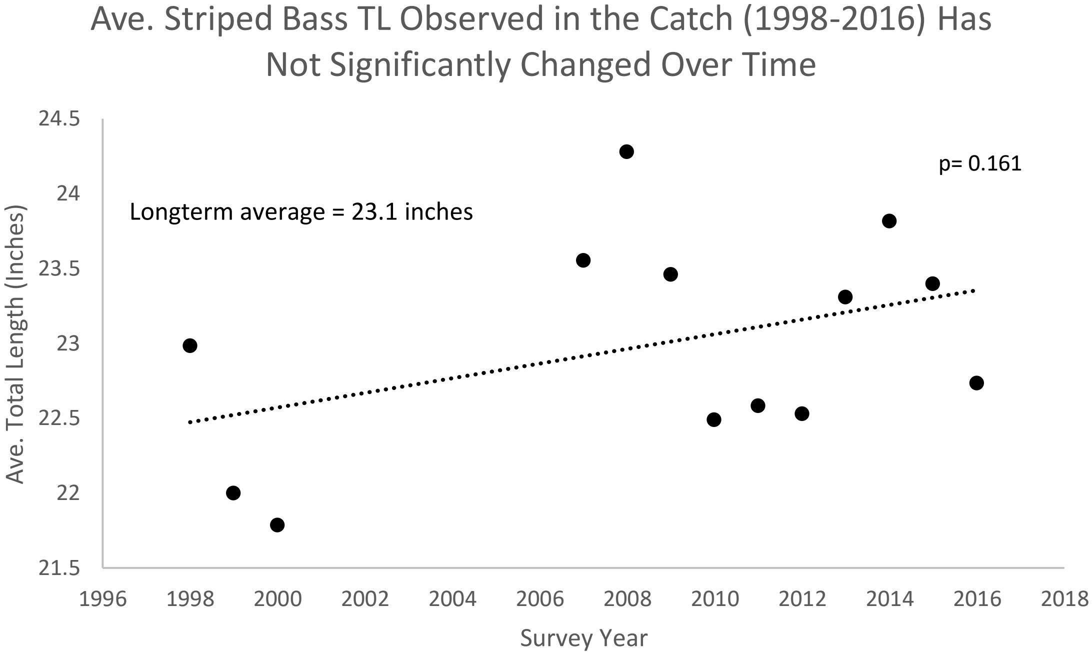


Figure 5. The average size of Striped Bass observed in angler catch by the Survey. The slope of the trend line is not significantly different than 0 (p = 0.161) over the sampling period 1998–2016. Data source: CVAS.

Changes to Striped Bass fishing regulations may have unintended consequences, such as decreased harvest opportunity. For example, an increase to the minimum size for retention may decrease harvest opportunities for all anglers and may disproportionately impact disadvantaged communities that rely on recreational harvest for food security. In a survey commissioned by the California Department of Water Resources (DWR) (Ag. Innovations 2021), 90% of disadvantaged community (DAC) respondents indicated that they or their families consume fish from the Delta four to five times per week. Striped Bass comprised 33% of the catch that DAC anglers reportedly harvested. Currently, Striped Bass harvested in the < 20–inch category represents ~20% of the inland harvest (as reported by CVAS), and ~9% of the ocean/bay harvest (as reported by CRFS). This indicates that Striped Bass anglers are willing to keep smaller fish and may already struggle to catch legal–sized Striped Bass (Figures 6 and 7).

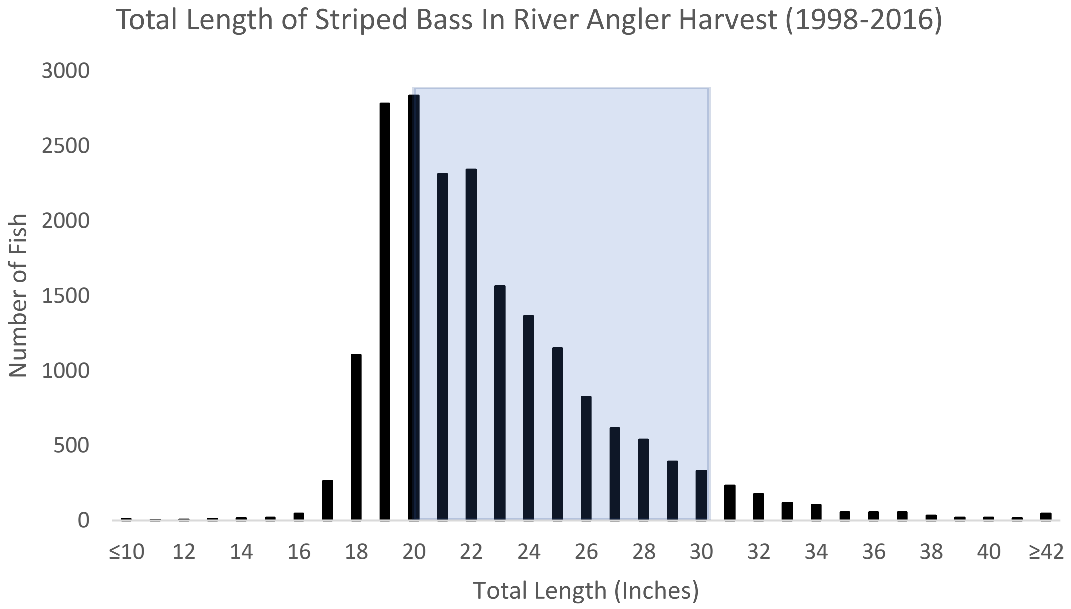


Figure 6. Length–frequency distribution of Striped Bass observed in angler harvest for Central Valley during 1998–2016. Proposed NCGASA slot limit highlighted in blue (74% of reported harvest falls within this range). Data Source: CVAS.

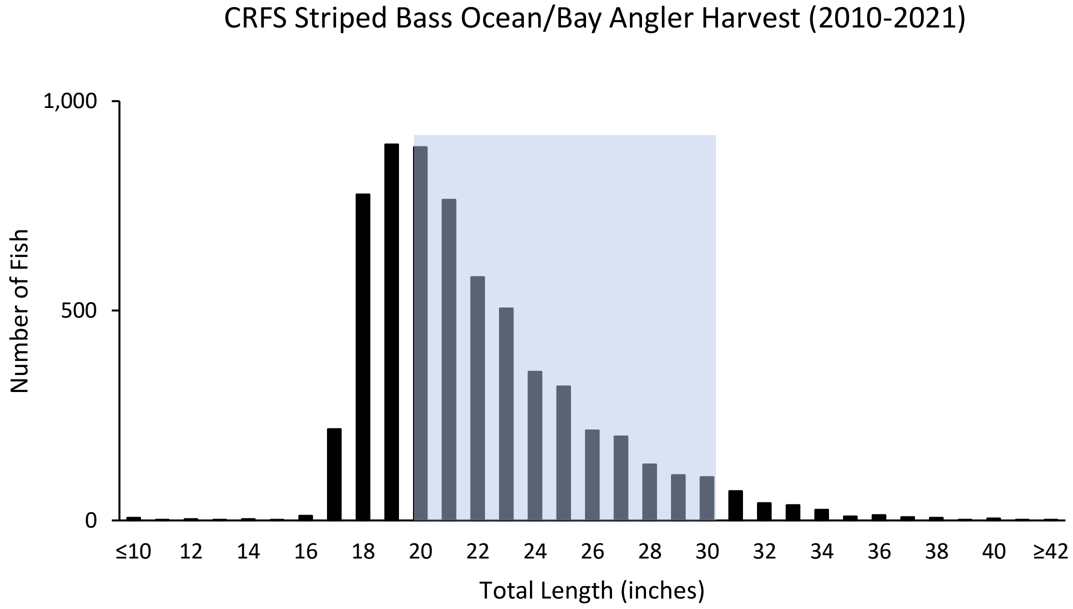


Figure 7. Length–frequency distribution of Striped Bass observed in angler harvest for Ocean/Bay during 2010–2021. Proposed NCGASA slot limit highlighted in blue (87% of reported harvest falls within this range). Data source: RecFIN (CRFS).

Juvenile Abundance Indices

Juvenile abundance for Striped Bass inhabiting the Sacramento–San Joaquin Delta have been indexed using data collected during the Summer Townet Survey (STN, since 1959) and the Fall Midwater Trawl Survey (FMWT, since 1967). These surveys sample the pelagic, open–water habitats of the Delta through San Pablo Bay and target primarily age–0 fish. Age–0 Striped Bass abundance has also been indexed from the San Francisco Bay Study otter and midwater trawls (since 1980), which sample benthic and pelagic open–water habitats from the confluence of the Sacramento–San Joaquin Rivers to South San Francisco Bay. Finally, the UC Davis Suisun Marsh Fish Study (since 1980) also provides a long–term metric of juvenile abundance for Striped Bass inhabiting the sloughs of Suisun Marsh (data available upon request to UC Davis).

All the above–mentioned surveys have documented some level of decline in catch of age–0 or young Striped Bass over their operating history (Figures 8 and 9). These declines are most drastic in the open water surveys (STN, FMWT, SF Bay Study), while the Suisun Marsh Fish Study does not show as steep of a decline (Figure 9). The scale of the decline in the open water surveys may be partially explained by a lateral shift in distribution away from channel habitats to shoal habitats, which are generally not as well surveyed by the STN, FMWT, and San Francisco Bay Study (Sommer et al. 2011). Regardless, the decline in abundance amongst all surveys to some degree indicates reduced spawning success and recruitment to age–0.

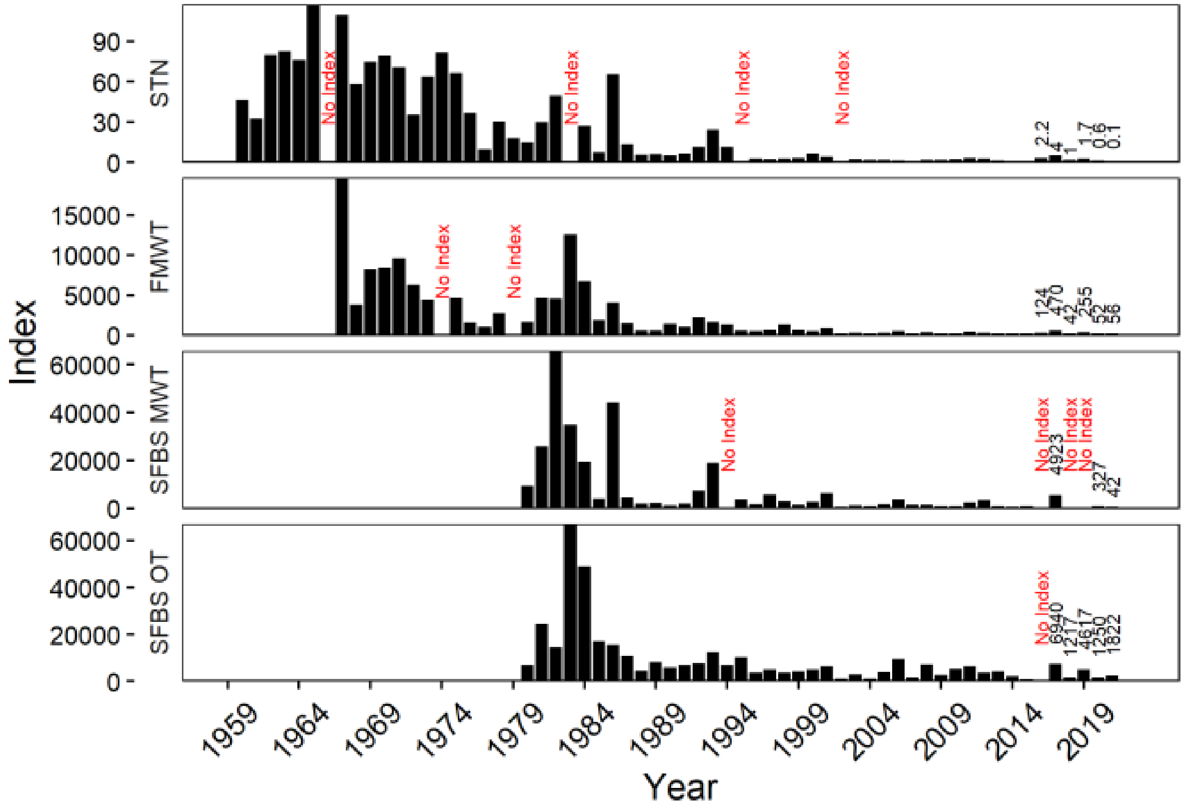


Figure 8. Figure 13 *in* Malinich et al. 2022. Index values for age–0+ (STN, FMWT) and age–0 Striped Bass (SFBS MWT, SFBS OT) from the Summer Townet Survey (STN), Fall Midwater Trawl (FMWT) and San Francisco Bay Study (SFBS) midwater trawl (MWT) and otter trawl (OT). See Malinich et al. (2022) for description of index values.

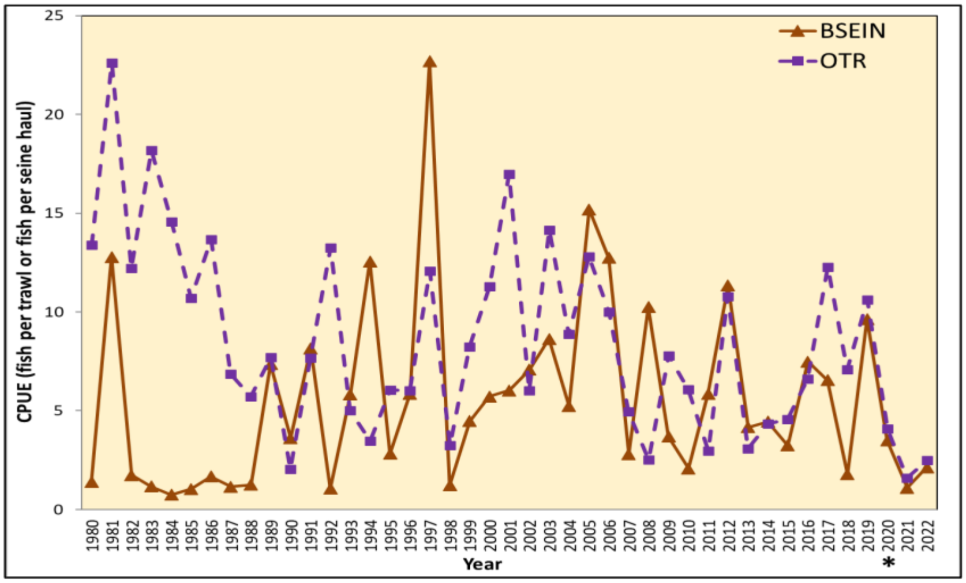


Figure 9. Figure 22 from O'Rear et al. (2022). Catch per unit effort (CPUE) of Striped Bass from the Suisun Marsh Fish Study beach seine (BSEIN) and otter trawl (OTR) surveys. See O'Rear et al. (2022) for description of CPUE calculations.

Adult Population Monitoring

Adult abundance was first estimated in 1969 and continued through the early 2000s. These estimates relied on tagging and subsequent recapture of tagged individuals to generate Lincoln–Petersen population estimates. Estimates show a decline from 1.5–2 million adults in the 1960s and 1970s to fewer than 1 million adults by the late 1990s (Figure 10a). Similarly, age–3 Striped Bass declined from over 600,000 to approximately 100,000 during the same time period (Figure 10b). Harvest rates have also been generated as a product of the adult mark–recapture program. Using high–reward tags and angler tag returns, harvest rates can be calculated from 2011 to 2022. During this time period, harvest rates have averaged 12%, with a low of approximately 4% in 2015 and a high of 29% in 2017 (Figure 11). Decreased funding and an associated reduction in the number of tags released and recovered resulted in the inability to reliably calculate abundance estimates using mark–recapture methods after the early 2000s. However, recent abundance estimates calculated using the combined inland and marine harvest estimated from CVAS and CRFS creel surveys, as well as harvest rate from tag returns, resulted in an average of 1,157,275 legal–sized (> 18–inches TL) Striped Bass estimated from 2011–2016. Abundance estimates during this period ranged from 604,695 legal–sized Striped Bass in 2013 to 2,252,748 in 2015. Abundance estimates using harvest and harvest rate are restricted to this time period due to year–round sampling limitations by CVAS. Additionally, these estimates do not account for harvest in the night fishery or from those fish harvested outside of the CVAS survey area and are therefore biased low.

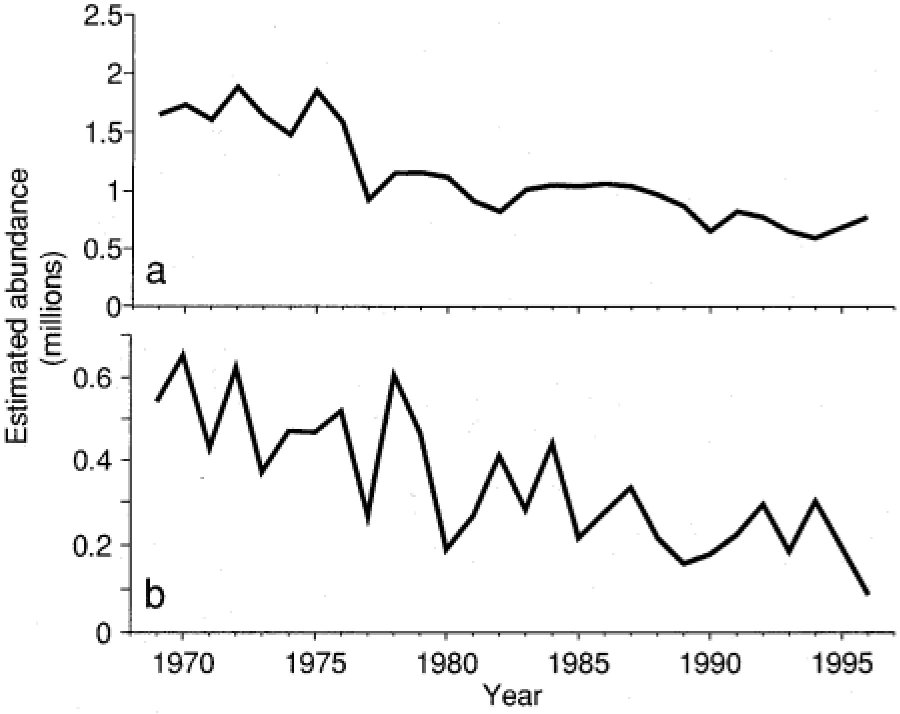


Figure 10. Estimated abundance of a) legal sized Striped Bass (≥ 18inches total length) and b) age–3 Striped Bass in the Sacramento–San Joaquin Watershed from 1969–1996. Figure from Kohlhorst (1999).

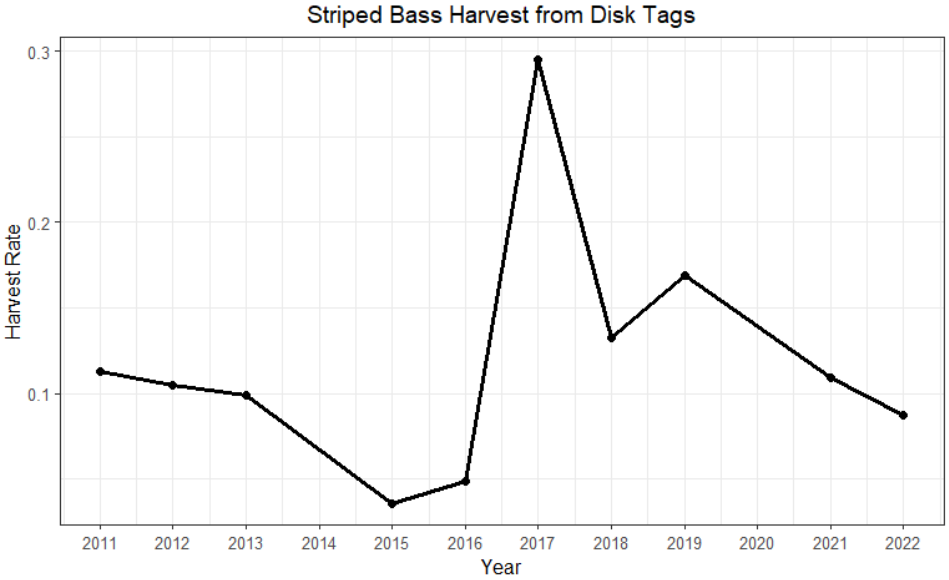


Figure 11. Estimated harvest rate of Striped Bass in the Sacramento–San Joaquin Watershed from 2011–2022.

Population Model

Model overview

To understand potential fishery tradeoffs resulting from proposed regulatory changes to the Striped Bass (*Morone saxatilis*) recreational fishery, we developed a sex–specific age and size–structured population model. The model predicts the sex–specific abundance of growth–type groups for each age at equilibrium as a function of density–dependent recruitment, natural mortality, harvest mortality, and discard mortality. The model accounts for differences in the impact of length–based harvest on females and males by modelling their abundance independently with different average growth rates and contributions to the total fecundity of the stock. Multiple growth–type groups were modelled for each sex to account for inherent variation in fish growth and the cumulative effects of size–selective harvest on the size structure of the stock. We applied the model to evaluate the relative performance of a range of length–based harvest restrictions with a focus on the current MLL and a recently proposed harvest–slot limit (HSL) at meeting fisheries and conservation management objectives. To account for uncertainty in life history, recruitment, and fishery inputs, we simulated the distribution of plausible model outcomes using a Monte Carlo simulation approach. With this approach we evaluated four management priorities, including stock conservation, total harvest, catch of trophy–sized fish, and total catch.

Methods

Model Formulation

We model the number of fish of each sex and growth–type–group recruiting to age–1 at equilibrium ($R_{g,s}$) with a Botsford–modified Beverton–Holt stock–recruitment function (Beverton and Holt 1957, Botsford and Wickham 1979, Botsford 1981a,b) as,

Equation (Eq.) 1

$$R_{g,s} = \dot{p}_s p_g R_0 \left(\frac{CR - \phi_0 / \phi_f}{CR - 1} \right),$$

where CR is the Goodyear recruitment compensation ratio (Goodyear 1977, 1980) that describes the maximum relative increase in juvenile survival as the total fecundity is reduced from the unfished biomass to near zero (Walter and Martell 2004). The parameters ϕ_0 and ϕ_f are the per–recruit fecundity of the unexploited stock and the exploited stock, respectively. The parameter R_0 is the average number of juvenile fish recruiting to age–1 in the unfished stock, which is analogous to the carrying capacity of the stock. The parameter p_g is a vector of fixed proportions that apportion the number of recruits each year to each growth–type–group (g). By apportioning recruits in fixed proportions, the assumption that variation in growth is a non–heritable trait is made explicit. The parameter $\dot{p}_s$ is a fixed sex ratio of recruits.

The fecundity per recruit of the stock in the fished (ϕ_f) and unfished (ϕ_0) condition was calculated as,

Eq. 2

$$\phi = \sum_a \sum_g p_{g,s=f} S_{a,g,s=f} f_{a,g,s=f} \left(1 - e^{-\theta * p_{male}}\right),$$

where $S_{a,g,s=f}$ is finite survival rate for females, and $f_{a,g,s=f}$ is the reproductive biomass of females at age a in growth–type–group g. The term $\left(1 - e^{-\theta * p_{male}}\right)$ modifies the fecundity based on the ratio of reproductive males to females –per Heppel et al. (2006), where the parameter p_{male} represents the per–recruit proportion of mature males in the fished condition and θ represents the relative contribution of male to female reproductive biomass in the reproductive process. This modification to the per–recruit fecundity calculation formalizes the assumption that females are the primary contributors to the annual fecundity of the stock while accounting for the influence of altered sex ratios due to differential effects of size–selective harvest on the male and female components of the stock. The reproductive biomass $f_{a,g,s}$ for both sexes was approximated as the difference between the weight and weight–at–maturation for each age, growth–type–group, and sex.

For each sex and growth–type–group, survivorship S to age a was calculated recursively as,

Eq. 3

$$S_{a,g,s} = S_{a-1,g,s} e^{-M_{a-1,g,s}} \left(1 - \dot{V}_{a-1,g,s} V_{a-1,g,s} U\right)\left(1 - \left(\dot{V}_{a-1,g,s} \dot{U} - \dot{V}_{a-1,g,s} V_{a-1,g,s} U\right) D\right),$$

where $S_{a-1,g,s}$ is the finite annual natural survival rate (i.e., $S_{a,g,s} = e^{-M_{a,g,s}}$) that models the proportion of fish surviving from deaths due to natural causes. The parameter $M_{a,g,s}$ is the instantaneous annual natural mortality rate, and the terms $\dot{V}_{a,g,s}$ and $V_{a,g,s}$ are the length–based vulnerabilities of fish to capture and harvest (respectively). The parameter D models discard mortality rate, which represents the proportion of caught and released fish that die due to the capture and handling process, and $\dot{U}$ and U represent capture and harvest rate, respectively.

We modeled the instantaneous annual natural mortality rate $M_{a,g,s}$ as inversely proportional to fish length per Lorenzen (2000) as,

Eq. 4

$$M_{a,g,s} = M_{ref}\left(\frac{L_{ref}}{L_{a,g,s}}\right),$$

where L_{ref} is a reference length where the natural mortality rate is known to be a given value (i.e., M_{ref}). This formulation describes natural mortality as higher for smaller, younger fish and lower for larger, older fish, which is a pattern that is consistent across fish species (Lorenzen 2000) and is important when determining length–based harvest regulations (Ahrens et al. 2020).

The vulnerability of each sex, age and growth–type–group to capture ($\dot{V}_{a,g,s}$ in Eq. 3) was described as a dome shape with a double logistic model to describe reduced vulnerability of smaller and larger fish relative to moderate sizes as,

Eq. 5

$$\dot{V}_{a,g,s} = \left(\frac{1}{1+e^{-\left(\frac{L_{a,g,s}-L_{low}}{\sigma * L_{a,g,s}}\right)}} - \frac{1}{1+e^{-\left(\frac{L_{a,g,s}-L_{high}}{\sigma * L_{a,g,s}}\right)}}\right),$$

where $L_{a,g,s}$ is the length of fish at age a in growth–type–group g for sex s; L_{low} is the lower total length at which fish are 50% vulnerable to capture; L_{high} is the upper total length at 50% vulnerability to capture; and σ approximates the standard deviation of the logistic distribution. The left terms in Eq. 5 model increasing vulnerability to angling with length, and the right terms models declining vulnerability to angling with length. Values of σ specify the steepness of each side of the dome–shaped vulnerability curve.

The vulnerability of each sex, age and growth–type–group to harvest was modeled as Boolean variables where a value of 1 indicated that fish of age a in growth–type–group g were of size legal to harvest (i.e., within range given the MLL or HSL evaluated) and a value of 0 indicated that they were not. Thus, we specified vulnerability to harvest with a logical test as,

Eq. 6

$V_{a,g,s} = 1$, when $L_{min} < L_{a,g,s} < L_{max}$

$$V_{a,g,s} = 0, \text{ when } L_{min} > L_{a,g,s} \text{ or } L_{max} < L_{a,g,s}$$

Where specified values of L_{min} and L_{max} represent the length–based harvest regulation, with L_{min} as the lower and L_{max} as the upper legal length for harvest.

We modelled the growth of males and female fish in each growth–type–group independently with a standard Bertalanffy (1938) growth model as,

Eq. 7

$$L_{a,g,s} = L_{\infty,g,s}\left(1 - e^{-k(a-t_0)}\right),$$

where $L_{\infty,g,s}$ is the asymptotic (maximum) size of growth–type–group g for sex s, k is the metabolic parameter that determines the rate that $L_{\infty,g,s}$ is attained, and t_0 is the theoretical age at length equal to zero. We simulated variability in growth by assigning each growth–type–group a unique $L_{\infty,g,s}$ based on a range between ± 20% of an average annual asymptotic length $\bar{L}_{\infty,s}$ (Walters and Martell 2004). The weight of fish was calculated with a standard weight/length relationship as:

Eq. 8

$$w_{a,g,s} = a{L_{a,g,s}}^{b},$$

where a is the scaling parameter and b is the allometric parameter that modifies the relationship between length and weight.

Simulation Process

We ran our model as a Monte Carlo simulation in three main steps by, 1) defining a set of MLL and HSL regulations to be evaluated, 2) generating a random sample of input parameter values, and 3) running the model iteratively for the full combination of regulations and inputs to produce a sample of predicted outcomes for each regulation. We defined a set of length–based regulations as the combination of a range of minimum (L_{min}) and maximum (L_{max}) legal–size limits. We achieved this by creating vectors for L_{min} and L_{max} in 1 cm increments from 30 cm to a maximum legal length L_{max}(set at 182 cm, i.e., + 20% the maximum value of $\bar{L}_{\infty}$). The vector for L_{max} ranged from the minimum value of the L_{min} vector +1 (i.e., 31 cm) to 182 cm. All regulations with $L_{max} =$ 182 cm and $L_{min} < 182 \text{ cm}$ represent MLL regulations while all regulations with $L_{min} < L_{max} < 182 \text{ cm}$ represent HSL regulations. All regulations with $L_{min} > L_{max}$ were excluded from the process.

All additional input parameters were either fixed values or drawn randomly from sampling distributions to account for fishery and biological uncertainty.

Distributions for randomly drawn inputs were specified such that the central tendency and variation in parameter values were plausible based on multiple data sources, published values, and life–history theory. The uncertainty associated with key life history and stock recruitment inputs including the density–dependent compensation ratio CR, the average asymptotic length $\overline{L}_{\infty}$, the metabolic growth parameter k, the instantaneous natural mortality rate M_{ref}, and the length at maturation L_{mat} were obtained using the R package *Fishlife* (Thorson et al. 2017, Thorson 2019, Thorson 2022). The R package *Fishlife* was created to provide life history and stock recruitment parameters with measures of uncertainty important for determining sustainable regulations for data–limited fisheries. The package utilizes data from over 10,000 fish populations contained in the Fishbase database (Froese and Pauly 2017) in a hierarchical multivariate generalized linear mixed model to predict mean parameter values and a covariance matrix based on taxonomic relationships. To further inform the estimation process, we used parameter values available in the literature with the model updating feature provided in the package to produce the covariance matrix used for generating these input parameters (e.g., Rudd et al. 2019). All input parameters of the model, mean values, and sampling distributions are defined in Tables 3 and 4, and fully justified in Appendix 2.

Table 3. Average life history and biological parameter input values used for population simulations of Striped Bass. Values in bold were used to update the FishLife analysis.

Parameter	Description	Value		Sampling Distribution
		Male	Female	
Beverton–Holt Stock Recruitment				
R_0 [1]	Average annual unfished recruitment	1	1	Fixed
CR [1]	Recruitment compensation ratio	11.6	11.6	$CR \sim \mathrm{MvN}(\mu, \Sigma)$
Sex ratio				
θ [1]	Fertility function parameter	–	50.4	$\theta \sim \mathrm{U}(a = 20, b = 80)$
Growth				
$L_{\infty,min}$ [2]	Minimum asymptotic length (cm)	96.8	106.3	Derived
$L_{\infty,max}$ [2]	Maximum asymptotic length (cm)	145.2	159.5	Derived

Parameter	Description	Value		Sampling Distribution
		Male	Female	
$\overline{L}_{\infty}$ [3]	Average asymptotic length (cm)	121	132.9	$\overline{L}_{\infty} \sim \mathrm{MvN}(\mu, \Sigma)$
k [3]	von Bertalanffy growth coefficient (yr^{-1})	0.1	0.1	$k \sim \mathrm{MvN}(\mu, \Sigma)$
t_0 [3]	Theoretical age at length 0 (years)	-1.4	-1.4	Fixed
Maturation				
L_{mat} [3]	Length (cm) at maturation (years)	35.1	58	$L_{mat} \sim \mathrm{MvN}(\mu, \Sigma)$
Mortality				
A_{max}	Maximum age (years)	30	30	Fixed
M_{ref} [4]	Natural mortality rate at L_{ref} (yr^{-1})	0.15	0.15	$M_{ref} \sim \mathrm{MvN}(\mu, \Sigma)$
L_{ref} [4]	Reference length where $M = M_{ref}$ (cm)	90	90	Fixed
Length–weight				
a [5]	Length–weight scaling parameter	$4.8*10^{-5}$	$2.7*10^{-5}$	Fixed
b [5]	Length–weight allometric parameter	2.7	2.8	Fixed

[1] Appendix A2h

[2] Appendix A2d

[3] Appendix A2f

[4] Appendix A2g

[5] Appendix A2e

Table 4. Average fishery parameter input values used for population simulations of Striped Bass.

Parameter	Description	Mean Value	Sampling Distribution
L_{troph}	Minimum TL of trophy–size fish (cm)	76	Fixed

Parameter	Description	Mean Value	Sampling Distribution
D [7]	Discard Mortality rate	0.29	$D \sim B(\alpha = 3.75, \beta = 9.25)$
U [8]	Harvest rate	0.14	$U \sim B(\alpha = 5, \beta = 30)$
$\dot{U}$ [8]	Catch rate	0.35	$U/(1 - r_{rate})$
δ [8]	Release rate	0.58	$\delta \sim B(\alpha = 70, \beta = 50)$
L_{low} [9]	Lower bound of length that is 50% vulnerable to capture (cm)	48	$N(\mu = 60, \sigma = 3)$
L_{high} [9]	Upper bound of length that is 50% vulnerable to capture (cm)	79	$L_{low} + \Delta$, $\Delta \sim logN(\mu = \ln(5), \ \sigma = 1)$

[7] Appendix A2b

[8] Appendix A2a

[9] Appendix A2c

Model Outputs

We defined a set of model outputs as management performance metrics relevant to four primary objectives for the Striped Bass fishery. These objectives include three fisheries objectives to 1) maximize harvest, 2) maximize total catch, and 3) maximize catch of trophy–sized fish, and the objective to 4) provide stock conservation. Because the true value of the average number of fish recruiting to age–1 in the unfished condition is unknown, we specified management performance metrics for the fisheries objectives relative to the predicted values for the current MLL. These metrics included the percent change in harvest, total catch, and catch of trophy–sized fish between the evaluated regulation and the current MLL. We calculated harvest, total catch, and catch of trophy–sized fish as,

Eq. 9

$$H = U \sum_{a} \sum_{g} \sum_{s} N_{a,g,s} \dot{V}_{a,g,s} V_{a,g,s}$$

Eq. 10

$$C = \dot{U} \sum_{a} \sum_{g} \sum_{s} N_{a,g,s} \dot{V}_{a,g,s}$$

Eq. 11

$$T = \dot{U} \sum_{a} \sum_{g} \sum_{s} N_{a,g,s} t_{a,g,s} \dot{V}_{a,g,s}$$

where $N_{a,g,s}$ is the predicted abundance of fish for each age, growth–type–group and sex. The parameter $t_{a,g,s}$ in Eq. 11 is a Boolean variable that takes the value of one when $L_{a,g,s}$ (Eq. 7) is greater than or equal to trophy size (L_{troph}, Table 4). The abundance of each sex at age for each growth–type–group was calculated as,

Eq. 12

$$N_{a,g,s} = R_{g,s} S_{a,g,s}$$

where $R_{g,s}$ is the number of fish recruiting to age–1 for each growth–type–group and sex (Eq. 1) and $S_{a,g,s}$ is their survival to each age (Eq. 3).

We used three performance metrics to evaluate the ability of regulations to conserve important components of the reproductive process as measures of stock conservation, which included,1) spawning stock biomass, 2) mature stock sex ratio, and 3) reproduction by older female fish. The conservation of spawning stock biomass was represented as the probability of each regulation resulting in a spawning potential ratio (SPR) ≥ 0.35. The spawning potential ratio is defined as the ratio of fished to unfished stock fecundity and is commonly used to indicate the risk of recruitment overfishing (i.e., exploitation at a rate beyond stock replacement; Goodyear 1990, Mace and Sissenwine 1993). Minimum values of SPR required for stock persistence vary in the literature from values of 0.3 to 0.5 (Walters and Martelle 2004). We adopted the value of SPR ≥ 0.35 from the 2022 Albemarle Sound–Roanoke River Striped Bass stock assessment (Lee et al., 2022) as an indication of spawning stock biomass conservation and calculated the probability of each regulation meeting this criterion as,

Eq. 13

$$SPR_{prob} = \sum_{I} \left(\frac{R\phi_f}{R_0 \phi_0} \geq 0.35 \right) / I_{total},$$

where R is recruitment at equilibrium in the fished condition (Eq. 1), ϕ_0 and ϕ_f is the per–recruit fecundity of the unexploited and exploited stock (respectively, Eq. 2), R_0 is the average number of juvenile fish recruiting to age–1 in the unexploited stock (Table 3), I indicates each model iteration, and I_{total} is the total number of model iterations.

We chose the percent change in mature male sex ratio (r_{male}) between the current and evaluated harvest regulations to account for potential influence of the interaction between variable growth and maturation rates of male and female Striped Bass and length–based vulnerabilities to capture and harvest that may alter the sex ratio (McCleave and Jellyman 2004). In the case of Striped Bass, where females grow and mature at faster rates than males, increased harvest pressure on larger fish may impact the reproductive capacity of the population if exploitation results in disproportionate removal of females. Furthermore, population resilience to exploitation or unfavorable environmental conditions may increase with higher fecundity contribution from larger females. While it is assumed that fecundity scales linearly with body size in individual fishes (i.e. isometric relationship; Walters and Martell, 2004), many marine species demonstrate disproportionately higher reproductive output with body size (i.e. hyperallometric relationship; Barneche et al. 2018). Larger female Striped Bass have been reported to produce larger eggs, larger newly hatched larvae (Monteleone and Houde 1990) and may have higher hatching success than younger females (Zastrow et al. 1990). To capture the impact of regulations on age–specific reproductive output, we used the percent change in the fecundity contribution of females aged ≥ 10 years to the total fecundity of the population between the current and evaluated harvest regulations, calculated as,

Eq. 14

$$\gamma = \frac{\sum_{a\geq 10}\sum_{g} N_{a,g,s=f} f_{a,g,s=f}}{\sum_{a}\sum_{g} N_{a,g,s=f} f_{a,g,s=f}},$$

where $N_{a,g,s=f}$ is the is the predicted abundance (Eq. 12) and $f_{a,g,s=f}$ is the reproductive biomass for females within each age and growth–type–group.

We compared the following three alternative regulations to the results of the current (a) 46–cm TL MLL regulation: (b) 51–76–cm TL HSL, (c) 46–76–cm TL HSL and (d) 70–90–cm TL (Table 5). Regulations (b) and (c) serve as two candidate regulations under consideration as alternatives to the current MLL: (b) was proposed by NCGASA with the goal of increasing opportunities for mature females to spawn before entering into the fishery (by increasing the minimum harvest length), and providing protection for older, more fecund females that escape the fishery (see *Introduction* for more details). Additionally, this regulation has the added benefit of creating a trophy fishery by limiting the maximum harvest size to 76–cm TL. Regulation (c) represents an alternative to regulation (b) to allow for continued harvest at the current MLL while establishing a trophy fishery by limiting the maximum harvest size to 76–cm TL. Lastly, we measure the outcome of the current 46–cm TL MLL against (d) East

Coast Striped Bass regulations to compare results to a conservation–focused management strategy that is currently implemented for Atlantic stocks (Table 5).

Table 5. Current regulations and proposed and alternate slot limit ranges in consideration for the Striped Bass (*Morone saxatilis*, Moronidae) fishery in California.

	Regulation	Description
(a)	46 cm (~18 inches) TL MLL	Current CA Striped Bass regulation
(b)	51–76 cm (~20–30 inches) TL HSL	HSL proposed by NCGASA
(c)	46 – 76 cm (~18–30 inches) TL HSL	Current MLL with upper HSL proposed by NCGASA
(d)	70–90 cm (~28– 35 inches) TL HSL	East coast regulations (for comparison)

Model Results

Conditions that effect overfishing

The probability that length–based harvest regulations resulted in overfishing for Striped Bass varied across several fishery and population conditions (Figure 12). The probability of the model resulting in an SPR < 0.35 (i.e., overfishing) increased as harvest rate (U), catch rate ($\dot{U}$), and discard mortality (D) increased (Figure 12a–f). The probability of overfishing was more variable at high discard mortality rates, likely because (1) these scenarios occurred less frequently in the simulation and (2) high discard mortality conditions that resulted in low probabilities of overfishing included below average values for catch rate (13%) and harvest rate (5%). The probability of overfished conditions occurring declined as the ratio of fecundity contribution of females age ≥10 years (γ) increased (Figure 12i–j), suggesting a relationship between fecundity contribution from larger females and population sustainability. Overfishing was also less likely to occur as release rate (δ) increased (Figure 12g–h), but values never reached zero due to some level of discard mortality present.

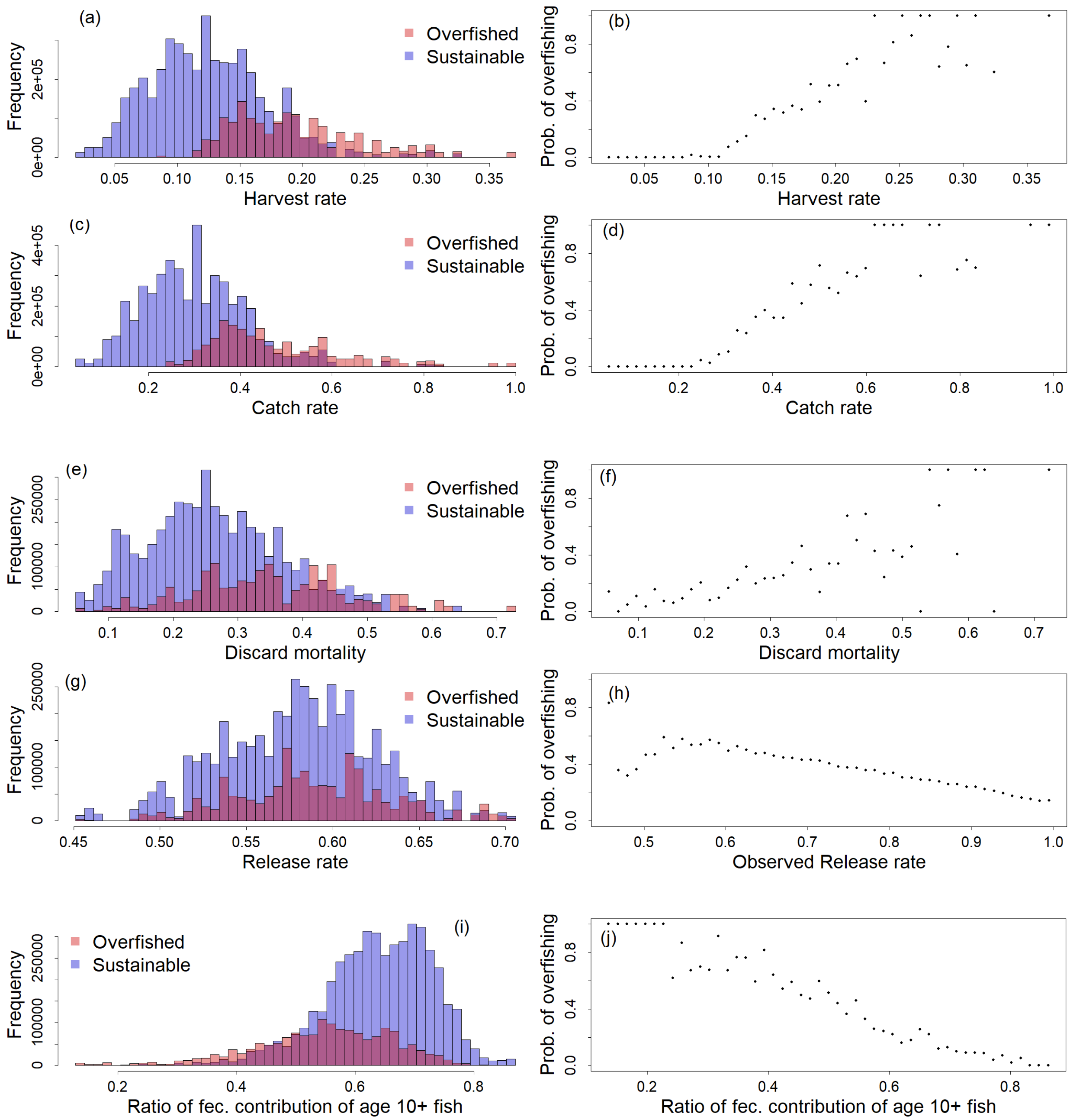


Figure 12. Histograms (left) and scatter plots (right) of simulated values for harvest rate (U, a–b), catch rate ($\dot{U}$, c–d), discard mortality (D, e–f), release rate (δ, g–h), and outputs for fecundity contribution of older (age 10+) fish (γ, i–j) that

result in SPR values representing overfished (SPR < 0.35) and sustainable (SPR ≥ 0.35) conditions.

Performance of MLLs and HSLs for fishery objectives

With the exception of harvest, candidate HSLs outperformed the current MLL for all fishery objectives. The probability of meeting conservation thresholds (SPR ≥ 0.35) under the current 46–cm TL MLL regulation was 47%, compared to 61% and 66% for a HSL with the current MLL 46–76–cm TL and the NCGASA–proposed 51–76–cm TL HSL, respectively. This probability increased to 79% under East Coast regulations (70–90–cm TL HSL) (Figure 13a). The fecundity contribution of older (≥ age 10) fish was higher under HSLs relative to the current MLL, but no differences resulted between the HSLs of interest (Figure 13b). Fecundity contribution of older fish was 6.5% higher than the current MLL under the East Coast HSL, and 8.1% higher under both candidate HSLs (46–76–cm and 51–76–cm) (Figure 13b). Differences in the estimated proportion of mature males in the population between the current and evaluated regulations were minimal, ranging from 1.5–4.5% lower than the current MLL (Figure 13c).

Compared to the three evaluated HSLs (Table 5), the current MLL resulted in the highest harvest per–recruit estimates (Figure 13d). However, the 46–76–cm HSL performed similarly, with harvest only 7.7% lower than that under the current MLL. Harvest estimates decreased by 21.1% under the candidate 51–76–cm HSL and were 73% lower than the current MLL under the East Coast HSL (70–90 cm) (Figure 13d). However, the East Coast HSL resulted in the largest percent increase in catch compared to the current MLL (30.3%), followed by the two candidate HSLs (Figure 13e). Evaluated HSLs performed similarly to each other, resulting in an estimated 8.5% and 13.1% increase in catch per–recruit under the 46–76–cm and 51–76–cm HSL, respectively. Relative to the current MLL, estimates of trophy catch per–recruit were 19% and 24.2% higher under the 46–76– cm and 51–76–cm HSLs (respectively) and 54.6% higher under the East Coast regulation (Figure 13f).

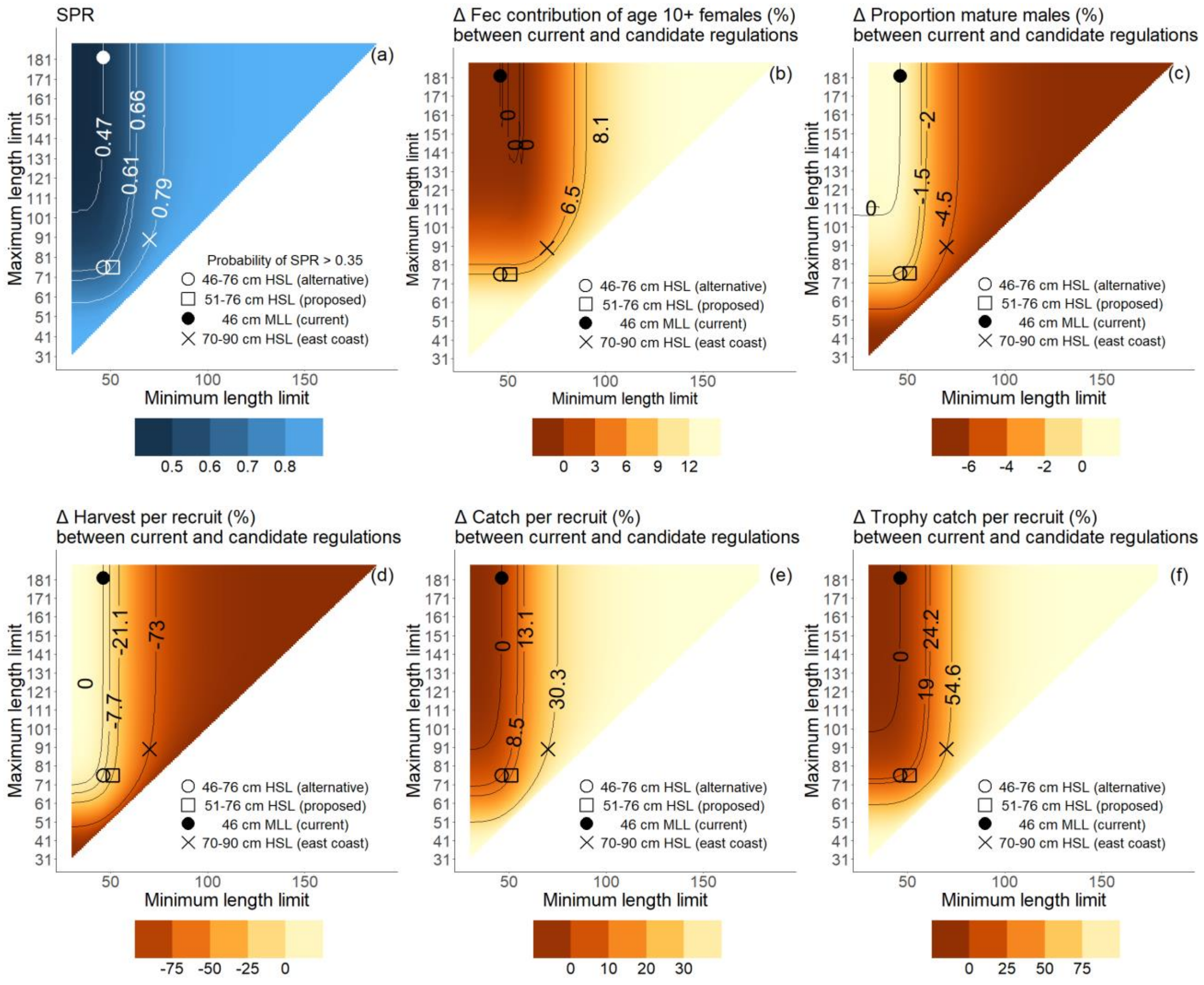


Figure 13. Model results describing (a) the probability of regulations resulting in an SPR ≥ 0.35 and the percent difference in (b) the ratio of fecundity contribution of age 10+ females, (c) the proportion of mature males in the population, (d) harvest per recruit, (e) total catch per recruit, and (f) catch of trophy–sized fish per recruit between current regulations (46–cm MLL) and a continuous range of MLLs and HSLs. The four evaluated regulations (**Table 5**) are denoted by symbols.

Model Discussion

Our simulation procedure produced more favorable outcomes for nearly all management priorities under HSLs compared to the currently enforced 46–cm MLL. The evaluated HSL regulations produced the greatest improvements to the catch of trophy fish and SPR but represented a trade off in harvest numbers. HSLs produced more modest improvements to the total catch, the sex ratio and fecundity contribution of older females. These improvements were similar between the two evaluated HSL regulations; however, the harvest tradeoff was greatest for 51–76–cm HSL compared to 46–76–cm HSL.

These results corroborate a growing body of literature that indicate HSLs as an effective alternative to more common MLLs for promoting stock conservation while maintaining catch and harvest opportunities. For example, Gwinn et al. (2015) demonstrated that protecting both immature and large fish from harvest results in a better compromise among management objectives including harvest, trophy–catch, and stock conservation for both short and long–lived species. Ahrens et al. (2020) advanced this work by accounting for the impacts of density and size–dependent growth, mortality, and fecundity on optimal harvest schedules, finding that harvest slots typically outperformed minimum length limits for harvest and catch–related objectives. This work also highlighted the importance of low discard mortality rates for the benefits of HSLs to be realized. Similarly, the benefits for HSLs have been predicted for individual fisheries such as Murray Cod (*Maccullochella peelii*, Koehn and Tood 2012), Northern Pike (*Esox lucius*, Arlinghaus et al., 2010), Gulf of Mexico Red Snapper (Bohaboy et al., 2022), Gag Grouper (Tetzlaf et al., 2013), as well as East Coast Striped Bass (Carr–Harris and Steinback 2020). This body of literature, including this study, suggests that in the recreational fisheries context, HSLs can provide a better outcome for meeting diverse fisheries objectives.

The efficacy of each HSL of interest ultimately depends on the Department’s management plan for Striped Bass, which is currently defined by broad goals for the fishery as opposed to quantitative measures. A management goal primarily focused on conservation of the species may consider HSLs closer to East Coast regulations (70–90–cm HSL) to ensure harvest policies result in > 75% probability of population sustainability (Figure 13a). However, these more restrictive regulations conflict with The Department’s (CDFW) responsibility to preserve recreational opportunities in the form of harvest, which would decrease by 73% relative to current levels (Figure 13d). Prioritizing harvest numbers above other fishery objectives is best supported by the current MLL, or a wide harvest slot that encompasses the majority of sizes that are vulnerable to catch modeled for the recreational fishery (~46 –100 cm). If the management objective is to enhance recreational fishing opportunities in the form of catch numbers, HSLs better achieve this goal compared to the current MLL. Possibly the most realized benefit of HSLs in terms of catch comes in the form of catch size, as the evaluated HSLs produced substantially higher (19–54%, Figure 13f) numbers of trophy–sized catch compared to the current MLL. Thus, HSLs provide multiple benefits to the angler experience, including higher catch rates and improved quality of catch (as defined by fish size).

Pursuant to section 703 of the California Fish and Game Code, it is the policy of the Fish and Game Commission that the Department takes actions to promote a self–sustaining Striped Bass population in support of a robust recreational fishery while considering the potential impacts of Striped Bass population growth on native species (FGC 2020). Therefore, regulations that balance stock persistence and recreational catch and harvest opportunities are of primary interest to the Department. Based on model results, the current 46 cm MLL may not be sufficient to ensure the long–term sustainability of the population. Model simulations resulted in a 53% probability of recruitment overfishing (SPR < 0.35) under this regulation, versus a 34–39% probability under the evaluated HSLs (51–76–cm and 46–76–cm HSL, respectively) (Figure 13a). While the probability of meeting a SPR target of ≥ 0.35 relative to the current MLL is marginally higher (5%) under a 51–76–cm HSL, this small improvement comes at the cost of harvest opportunities. Harvest was estimated to decrease by about 21% relative to current levels under a 51–76–cm HSL compared to only a ~8% decrease under a 46–76–cm HSL (Figure 13d). These results align with data collected by creel surveys, which show that Striped Bass harvested in the <20–inch category represent ~20% of the inland harvest (CVAS) and ~9% of the ocean/bay harvest (CRFS) (Figures 6 and 7). Thus, when compared to the proposed 51–76–cm HSL, the 46–76–cm HSL results in a more optimal balance between population sustainability and harvest opportunities.

Evaluated HSLs resulted in higher total catch relative to the current MLL, however, improvements were moderate (8.5% and 13.1% increase under 46–76 and 51–76–cm HSL, respectively) and only reached a maximum of ~40% higher under the most restrictive harvest regulations (Figure 13e). This is most likely due to constraints placed on catch by the highly dome–shaped length selectivity curve used in the model (Figure A5). This curve was informed by length selectivity estimated for Atlantic Striped Bass caught in the recreational fishery (Carr–Harris and Steinback 2020) and is supported by the strong dome–shaped selectivity of other large–bodied recreational fish species reported in the literature (see Appendix A2c). The modeled selectivity curve renders larger fish less vulnerable to catch, thus decreasing the risk of fishery mortality from harvest or discard. The dome–shaped vulnerability curve may also moderate the results of trophy catch (Figure 13f) under the candidate HSLs, as a more asymptotic length selectivity curve would have yielded in higher differences in these outcomes relative to the current MLL. While trophy catch (relative to the current MLL) is 5.2% higher under a 51–76–cm HSL compared to a 46–76–cm HSL (Figure 13f), this gain may not be worth the ~13% loss in harvest opportunities that results from increasing the lower HSL from 46 to 51 cm (Figure 13d). Furthermore, higher abundance of trophy–sized fish resulting from the 51–76–cm HSL compared to the 46–76–cm HSL may not be enough to produce differences in the proportion of fecundity contribution from older (age 10+) females (γ) between the two regulations (Figure 13b). In other words, increasing the lower HSL from 46 to 51 cm does not translate into an increase in the proportion of total fecundity that is contributed by older fish.

While modest (8.1%), candidate HSLs improved γ relative to the current MLL (Figure 13b), which may have positive implications on recruitment success and stock conservation for Striped Bass. Lim et al. (2014) found positive correlations between maternal size and offspring size and number within species across a range of taxa, suggesting that energy investment into individual offspring changes with female size. This can have substantial impacts on recruitment, as larger offspring are less vulnerable to size–dependent mortality and therefore typically experience higher survival rates (Conover and Schultz 1997). The importance of preserving large females by way of HSLs is evident in Le Bris et al. (2015), who demonstrated that population resilience to and recovery from perturbations (i.e. exploitation) was most impacted by the relationship between female size and fecundity. They found that preservation of large fish that possessed non–linear mass–fecundity relationships, as suggested for Striped Bass (Zastrow et al. 1990, Cowan and Rose 1991), increased the ability of the population to withstand and recover from high fishing pressure. Therefore, using HSLs to increase the proportion of total fecundity contributed by larger females may help buffer Striped Bass populations against fluctuations resulting from high exploitation rates and environmental stochasticity.

Our results suggest that the performance of the length–based regulations evaluated are highly sensitive to the catch, harvest, and discard mortality rates of the fishery. This finding is consistent with the literature for both MLLs (Coggins et al. 2007) and HSLs (Gwinn et al. 2015, Ahrens et al. 2020). For HSLs to be effective at preventing overfishing and improving trophy fisheries, the cumulative mortality from discards and harvest must be low enough to allow a proportion of legal fish to grow out of the slot and into larger protected size classes. Higher rates of these sources of mortality will require narrower harvest slots to achieve fishery benefits. This highlights the importance of understanding these rates when designing HSL regulations. Considering data limitations on discard mortality for the CA Striped Bass fishery, we ran our simulations with a broad range of values. This uncertainty results in lower resolution for predicting differences in the outcomes among competing regulations. A more refined understanding of this parameter for this particular fishery would increase the ability to distinguish among regulation performances.

Predation Considerations

With the potential to increase Striped Bass population abundance as a result of regulation changes (which requires California Environmental Quality Act [CEQA] permitting), we must consider the impact these changes may have on California Endangered Species Act (CESA) and Federal Endangered Species Act (ESA)–listed prey species the Department is also tasked with managing.

While Striped Bass are known opportunistic predators on salmonid and smelt species, their diets have been found to primarily consist of macroinvertebrates, crayfish, lamprey, and other non–native predator and prey species in aquatic and estuarine habitats (Raney 1952; Callahan et al. 1989; Grossman 2016; Michel et al. 2018; Stompe et al. 2020; Young et al. 2022). Fish become a more important prey item for Striped Bass in the spring and summer (Nobriga and Feyrer 2007; Zeug et al. 2017; Young et al. 2022), which coincides with the seaward migration of salmonids from freshwater habitats.

Observations of salmonids in Striped Bass stomachs vary by life stage and season, but overall remains relatively low (Stevens 1966; Michel et al. 2018; Stompe et al. 2020; Peterson et al. 2020; Brandl et al. 2021). While predation on listed species does occur, there is not enough evidence to support the assertion that Striped Bass predation is the primary contributor to declining salmonid and smelt populations based on available piscivorous predation data in California. Instead, Striped Bass predation impacts should be considered within the broader context of environmental stressors on native fishes, and not necessarily singled out as a significant contributor to salmonid declines.

Striped Bass consume a wide variety of prey species and do not tend to specialize on certain prey items (Zeug et al. 2017; Brandl et al. 2021); however, predation of salmonids and smelt species may be more prevalent in specific size classes of the Striped Bass population based on abundance and spatial/temporal distribution. The profitable prey size for Striped Bass is related to the prey–to–predator size ratio (PPR), where capture success decreases as the PPR ratio increases (Hartman 2000). Fish are unimportant in the diets of YOY Striped Bass, as diet during this life stage is primarily driven by plankton abundance (Heubach 1963). In a diet composition study of large Atlantic Striped Bass, Walter and Austin (2003) found significant relationships between Striped Bass total length and prey length ($p < 0.05$), indicating that larger and older Striped Bass ate larger prey. Poor regression fit (r2 = 0.26) indicated that large fish also consumed small prey, supporting the argument that larger Striped Bass consume a greater size range of prey. Smaller Striped Bass in this study (458–710 mm [~ 18–28 inches]) consumed prey that approached 40% of their total length; however, most prey consumed by all sizes of Striped Bass were smaller, young–of–the–year fishes. This finding is corroborated by Overton (2002), who predicted an optimal prey size to be 21% of the Striped Bass length.

If similar predator–prey dynamics hold true for Striped Bass in California, smolts (ranging from 70–140 mm), as classified by Sturrock et al. (2019) may represent optimal prey size for smaller Striped Bass (13–27 inches). CDFW Fyke trap data show that Striped Bass entering the Sacramento River in the spring are generally < 28 inches (Figure 14), and therefore may exhibit similar feeding patterns to the 'small' Striped Bass in Walter and Austin (2003). Furthermore, Loboshefsky et al. (2012) found that while individual consumption of adult Striped Bass was higher than sub–adults, population total consumption of sub–adults was similar to adults due to greater abundance of sub–adults in the system. A harvest slot may shift the population structure to increase the abundance of older, large fish, yet this still may not have a noticeable impact on salmonid predation due to (1) PPR, (2) high variation in the size of prey consumed, and (3) little evidence of prey specialization. Increasing the minimum length limit from 18–20 inches may have a more noticeable impact on salmonid consumption, however, as this protects a size class of Striped Bass more likely to encounter and consume smolt–sized fishes due to (1) potentially higher delta and freshwater residency of smaller Striped Bass compared to larger, more migratory fish (Dorazio et al. 1994) and (2) more optimal PPR between this size class and smolts.

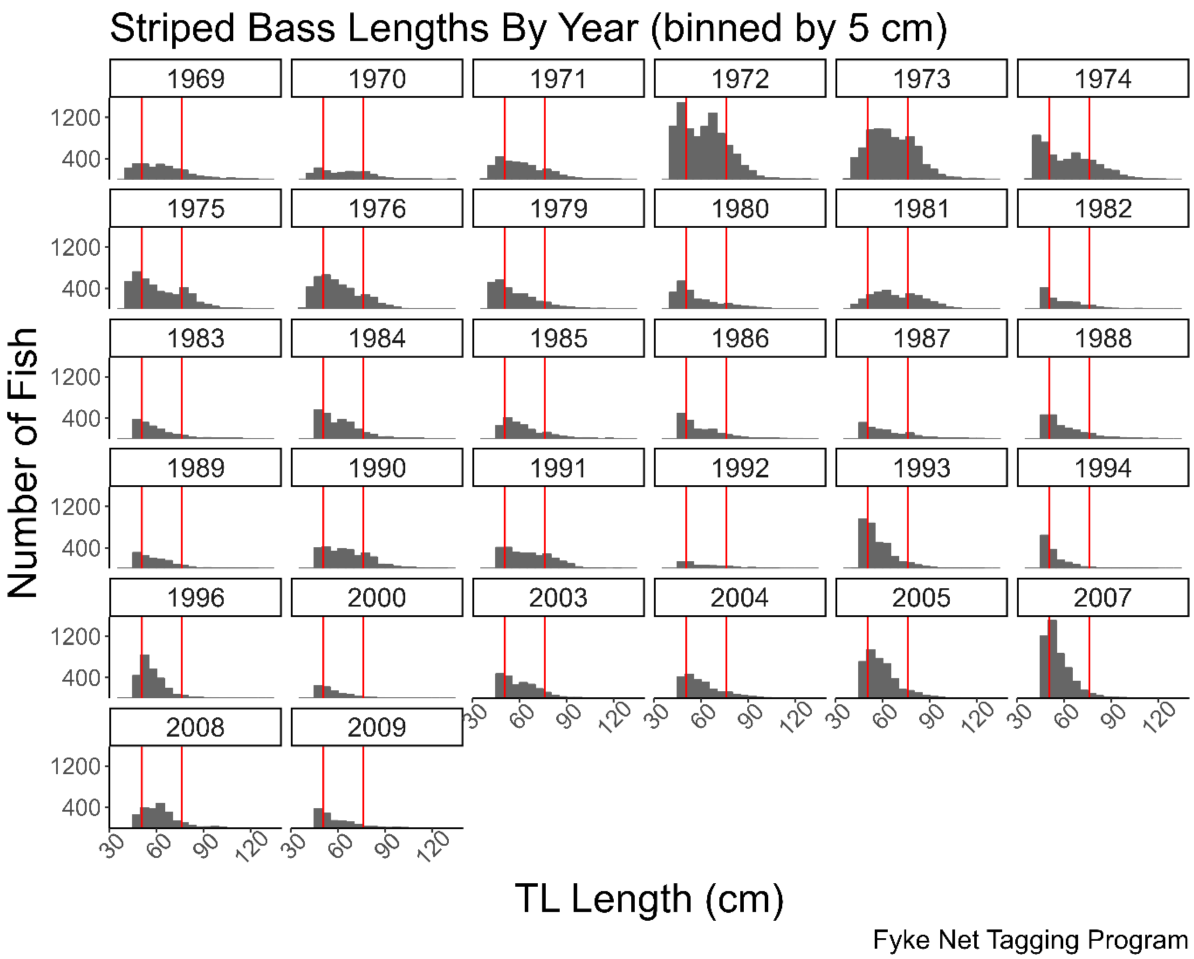


Figure 14. Length–frequency histograms for Striped Bass sampled from fyke nets. Parallel vertical red lines indicate the NCGASA–proposed 20–30 inch total length (51 – 76 cm) slot limit. Note that effort is not accounted for in catch. Data Source: Adult Striped Bass Population Study.

Despite these considerations, the majority of literature reviewed suggests that Striped Bass consumption of salmonids and smelts is relatively low compared to other prey items. That said, Striped Bass are widespread, highly opportunistic, generalist predators that display aggregatory feeding behavior, particularly near manmade structures and habitat pinch–points (Tucker et al. 1998; Sabal et al. 2016). Thus, temporal overlap between Striped Bass and salmonids is an important factor to consider. Decreased precipitation and associated warming water temperatures could elicit earlier Striped Bass spawning migrations, increasing temporal overlap between Striped Bass and out–migrating juvenile salmonids in the Sacramento River system (Goertler et al. 2021). Climate change and the environmental conditions of an increasingly degraded Delta may continue to increase contact between Striped Bass and listed species, and it is difficult to predict the role that protective harvest regulations will play on the predatory impact of Striped Bass in this context. The completed CDFW Predation Literature Review document can be found in Appendix 3.

Informing Broader Management Strategies from East Coast Regulations

When designing fishing regulations, management objectives are generally set as the target. The Department's management goals are guided by the California Fish and Game Commission's Striped Bass Policy (FGC 2020), which states that the Department shall "...emphasize programs that ensure, enhance, and prevent the loss of sport fishing opportunities" and "…strive to maintain a healthy, self–sustaining Striped Bass population in support of a robust recreational fishery." The intended goal of the NCGASA–proposed 20–30–inch harvest slot limit is to increase abundance of Striped Bass as well as protect larger Striped Bass in the population. This desire is consistent with the California Fish and Game Commission's policy, as the policy also supports actions to increase Striped Bass abundance if the actions are consistent with the Department's long–term mission and public trust responsibilities.

For the purposes of this regulation change petition (TN 2022–12) evaluation, the Department evaluated four regulation options for comparison of the NCGASA proposed 20–30–inch slot limit (Table 5). Because the petition requested only one specific HSL and did not include alternative HSL options or other considerations such as changes to season, bag limit, geographic range, the Department's evaluation specifically focused on the proposed 20–30–inch HSL. If the Department had independently determined that the status and trends observed in the Striped Bass fishery warranted regulatory changes to preserve and improve the fishery, multiple regulatory strategies beyond a pre–defined HSL would have been evaluated to determine which strategy, or combination of strategies, would be the most effective to determine or maintain biological and management objectives.

Within Striped Bass native ranges, Atlantic states have adopted various regulatory practices to meet their management goals (Figure 15, ASMFC 2022). In many states, freshwater (rivers) and marine environments have different regulations to protect migratory and spawning Striped Bass while also providing fishing opportunity. The majority of the Atlantic states' coastlines, as well as the ocean, have a 28–35–inch HSL. However, several areas (particularly in producer areas) enforce slot limits or smaller minimum sizes that allow the harvest of smaller Striped Bass, starting at 18–20 inches depending on the state. There are no regions that include a 20–30–inch slot limit comparable to the NCGASA proposal (K. Drew, ASMFC, personal communication, January 23, 2023).

Atlantic States management (regulations) are based on female spawning stock biomass and fishing mortality targets for the migratory stock complex, which represent the best available scientific information. There are a number of different combinations of size limits and harvest levels that would allow them to achieve the desired spawning stock biomass target and management objectives, and stakeholder needs are considered when they set the size limits and other regulations (ASMFC 2019). The coastal/ocean minimum size limit of 28 inches represents the size at full maturity for Atlantic coast Striped Bass, and therefore fisheries with lower size limits are harvesting immature fish. Those fisheries occur in the producer areas where mature Striped Bass are only available during the spawning season. The Atlantic States Marine Fisheries Commission (ASMFC 2022) allows harvest of those smaller fish and forgoes yield of larger fish in order to create more equitable access to the resource between stakeholders in the ocean region and stakeholders in the producer areas, based on historical fishing patterns (K. Drew, ASMFC, personal communication, January 23, 2023).

In response to the 2015 mandate by the ASMFC to decrease harvest, many coastal and Chesapeake Bay states decreased the recreational bag limit from two to one fish, ≥ 28 inches TL (ASMFC 2014). While these changes successfully hit coast–wide harvest reductions goals, they failed to translate into improvements in the female spawning stock biomass (ASMFC, 2016b, 2017; NEFSC 2019).

To understand the immediate economic and biological trade–offs resulting from harvest restrictions that favor larger Striped Bass, Carr–Harris and Steinback (2019) evaluated the effect of 36 alternative recreational Striped Bass fishing policies (Table 6 *in* Carr–Harris and Steinback 2019) on (1) expected angler welfare (measured as the level of compensation required to hold anglers' expected utility constant after a policy–induced change in fishing trip quality), (2) total recreational removals, and (3) mature female recreational removals relative to the simulated outcome of the actual 2015 policy of one fish, ≥ 28–inches TL. Simulations revealed that policies that decreased the baseline minimum from 28 to 20 or 24 inches (thus directing harvest toward frequently encountered yet lower–valued smaller Striped Bass) while constraining harvest of rarely encountered yet higher–valued large Striped Bass resulted in increases of recreational harvest that were incommensurate with concurrent welfare gains (Carr–Harris and Steinback 2019). The one fish 28–36–inches TL HSL regulation was the sole policy analyzed that resulted in a non–trivial reduction in recreational removals relative to the actual 2015 MLL policy (one fish ≥ 28–inches

TL). This policy resulted in only a slight reduction in angler welfare due to the relatively low frequency at which Striped Bass ≥ 36 inches are encountered in the fishery (Carr–Harris and Steinback 2019).

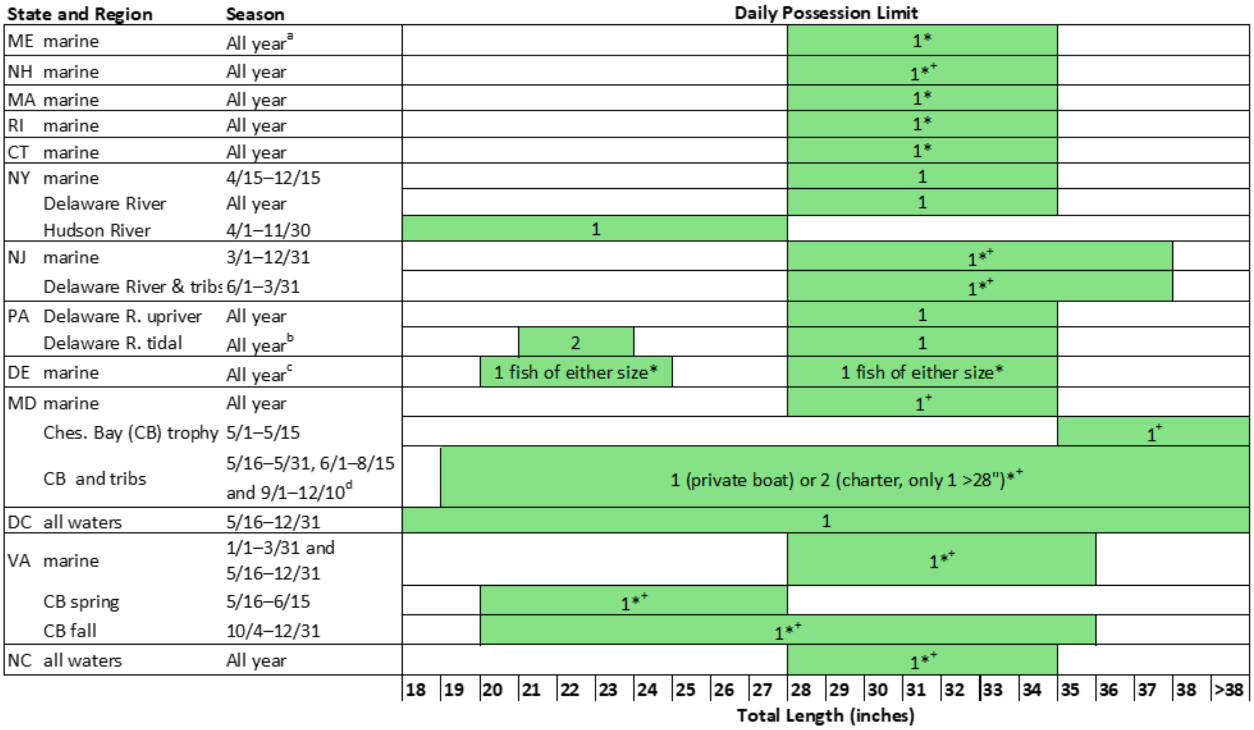
While the effect of length–based regulation changes on angler welfare was not incorporated into the Striped Bass population model presented here, we interpret angler harvest opportunity as a proxy for angler satisfaction. Results from the Striped Bass Angler Preference Questionnaire indicate that 51% of respondents fish for Striped Bass to catch and eat (Question 10, Appendix 1). Furthermore, an Environmental Justice Community Survey conducted for the California Department of Water Resources showed that the overwhelming majority (90%) of the self–identified disadvantaged community (DAC) members surveyed eat fish from the Delta four or more times per week (Ag. Innovations 2021). Aside from those that chose 'other or not specified' (35%), the majority of DAC respondents (51%) indicated that they catch Striped Bass (Ag. Innovations 2021). These results suggest that Striped Bass is an important food source for California anglers, and that failing to maintain harvest opportunities may present an issue for the communities that depend on this resource as a part of their diet.

Compared to the proposed 20–30–inch HSL, our model of the California Striped Bass population estimated that an 18–30–inch HSL would result in a smaller decrease in total harvest relative to current regulations while maintaining the same fecundity contribution of older females in the population (see Population Model section). As with the 'most efficient' regulation of one 28–36–inch fish identified in Carr–Harris and Steinback (2019), an 18–30–inch HSL maintains the lower length limit at the status quo while only excluding harvest opportunity for size classes infrequently encountered in the fishery (see Figure 6 and Figure 7). Thus, we can infer that this regulation may have a similarly low impact on angler welfare as estimated in Carr–Harris and Steinback (2019).

As observed on the East Coast, there are several combinations of harvest size and bag limits that, in concept, could be implemented in California to be more protective of the female spawning biomass and may contribute to increased spawning success compared to the current regulations. However, increasing Striped Bass abundance and size of fish may not be possible through changes to angling regulations alone due to environmental constraints, carrying capacity, and/or other factors. Examples of management strategies observed on the East Coast (Figure 15) that could be applied to the California Striped Bass fishery (if deemed appropriate) include, but are not limited to:

- Harvest slot limits (as evaluated in this petition)
- Lower or higher minimum size limits
- Split slot limit(s)

- Seasonal closures / Seasonal regulation changes
- Geographic closures (seasonal and/or permanent)
- Increased or decreased bag limits
- Gear Restrictions
- Regulations specific to marine and/or freshwater locations
- Regulations specific to charter boats and private boats
- Combination of more than one option



Daily Possession Limit

State and Region	Season	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	>38
ME marine	All year[a]											1* 🟩	🟩	🟩	🟩	🟩	🟩	🟩					
NH marine	All year											1*[+] 🟩	🟩	🟩	🟩	🟩	🟩	🟩					
MA marine	All year											1* 🟩	🟩	🟩	🟩	🟩	🟩	🟩					
RI marine	All year											1* 🟩	🟩	🟩	🟩	🟩	🟩	🟩					
CT marine	All year											1* 🟩	🟩	🟩	🟩	🟩	🟩	🟩					
NY marine	4/15–12/15											1 🟩	🟩	🟩	🟩	🟩	🟩	🟩					
Delaware River	All year											1 🟩	🟩	🟩	🟩	🟩	🟩	🟩					
Hudson River	4/1–11/30	1 🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩												
NJ marine	3/1–12/31											1*[+] 🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩		
Delaware River & tribs	6/1–3/31											1*[+] 🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩		
PA Delaware R. upriver	All year											1 🟩	🟩	🟩	🟩	🟩	🟩	🟩					
Delaware R. tidal	All year[b]				2 🟩	🟩	🟩					1 🟩	🟩	🟩	🟩	🟩	🟩	🟩					
DE marine	All year[c]			1 fish of either size* 🟩	🟩	🟩	🟩	🟩				1 fish of either size* 🟩	🟩	🟩	🟩	🟩	🟩	🟩					
MD marine	All year											1[+] 🟩	🟩	🟩	🟩	🟩	🟩	🟩					
Ches. Bay (CB) trophy	5/1–5/15																		1[+] 🟩	🟩	🟩	🟩	🟩
CB and tribs	5/16–5/31, 6/1–8/15 and 9/1–12/10[d]		1 (private boat) or 2 (charter, only 1 >28")*[+] 🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
DC all waters	5/16–12/31	1 🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
VA marine	1/1–3/31 and 5/16–12/31											1*[+] 🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩				
CB spring	5/16–6/15			1*[+] 🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩												
CB fall	10/4–12/31			1*[+] 🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩				
NC all waters	All year											1*[+] 🟩	🟩	🟩	🟩	🟩	🟩	🟩					

Total Length (inches)

* Non-offset circle hooks required when fishing bait

[+] Spearfishing permitted, all other size and take limits apply

[a] Spawning areas closed 12/1–4/30 and C&R only 5/1–6/30

[b] The 21-24" slot is only open 4/1–5/31

[c] Spawning areas C&R only 4/1–5/31. 20-25" slot is only open 7/1–8/31 in Delaware River, Bay, and tribs

[d] C&R only 1/1–3/31, 12/11–12/31, additional area closures apply

Figure 15. Overview of 2022 recreational Striped Bass fishing regulations in Atlantic coast states. Additional geographic and gear restrictions apply in many of the fisheries. Figure adapted from Table 6 *in* ASMFC 2022.

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