Bycatch Estimation Methodologies Used for the U.S. National Bycatch Report Database

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U.S. Department of Commerce
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Executive Summary

Accounting for bycatch is necessary for the sustainable management of fisheries. NOAA's National Marine Fisheries Service (NOAA Fisheries) published a U.S. National Bycatch Report (NBR) First Edition in 2011, which, among other things, documented bycatch estimates for all fisheries for which bycatch estimates were available as of 2005. The 2011 report included extensive documentation of bycatch estimation methods in use as of the late 2000s. However, bycatch estimation methodologies change and improve over time as new estimation models are developed and new monitoring programs are created. This report documents NBR estimation methods developed (or utilized or applied) by six NOAA Fisheries regional science centers and/or regional offices from 2005 to 2023. As bycatch estimation methods continue to be modified and improved, NOAA Fisheries will publish annual update reports describing those changes, unless no changes to bycatch estimation methods occurred in the previous year.

For Pacific Islands fisheries in the NBR, the Hawai'i-based shallow-set longline fishery has 100% observer coverage, which alleviates the need for a bycatch estimation methodology. Pacific Islands Fisheries Science Center (PIFSC) staff use the Horvitz-Thompson Estimator (HTE) or the generalized ratio estimator (GRE) to estimate bycatch totals for the Hawai'i-based deep-set longline fishery. In addition, PIFSC staff generally use synthetic combined ratio estimators or separate ratio estimators to estimate bycatch for the American Samoa-based longline fleet. In response to observer coverage gaps during the COVID-19 pandemic, PIFSC staff developed approaches to estimate bycatch that involved pooling observations across multiple years.

For Alaska fisheries, Alaska Fisheries Science Center (AFSC) staff use ratio estimators to compute at-sea discard rates, which are the at-sea discards for a given species divided by the total retained groundfish of all species. For prohibited and non-groundfish species, AFSC staff calculate at-sea discards as the ratio estimate of the at-sea discard rate applied to total groundfish catch in each sampling stratum, summed over the strata. To estimate the number of marine mammal interactions with groundfish fisheries that resulted in mortality or serious injury, AFSC staff use a stratified ratio estimator that involves multiplying a bycatch ratio, defined for a stratum as the number of animals bycaught divided by some measure of fishing effort, times the total fishing effort in the stratum. As with fish bycatch estimates, AFSC staff produce seabird bycatch estimates for the groundfish and halibut fisheries using a ratio estimator.

Northwest and Southwest Fisheries Science Center staff utilize a variety of bycatch estimation techniques for West Coast fisheries in the NBR, and these techniques vary by fishery (or fishery group) and taxon group (i.e., fish, marine mammals, and seabirds). For the groundfish fisheries, fish bycatch estimation methods have varied between fishery sectors due to differences in data availability, management, and observer coverage levels. Implementation of a groundfish catch share program in 2011 required 100% monitoring of trips and led to changes in methods for estimating bycatch. Observer program analysts estimate the composition of the rare instances when tows, hauls, or sets are unsampled by apportioning unsampled bycatch to specific species using ratio estimators derived from average observed species-specific discard proportions. Similar ratio estimation methods are used to estimate bycatch of Chinook, coho, chum, pink, sockeye, and unspecified salmon. Likewise, bycatch of green sturgeon and eulachon are estimated using ratio estimators. In 2016 and 2017, bycatch estimation methods for protected species in a number of fisheries changed from ratio estimators to model-based methods,

including the use of classification and regression trees to estimate bycatch of marine mammals, sea turtles, and seabirds in the California drift gillnet fishery.

Multiple bycatch estimation techniques are used for Southeast fisheries, which include the highly migratory species pelagic longline, coastal migratory pelagic troll, Southeastern Atlantic snapper-grouper, Gulf of Mexico reef fish, commercial shark, Southeastern coastal gillnet, and Southeast shrimp trawl fisheries. For example, scientists estimate dead fish discards in the pelagic longline fishery using a stratified delta lognormal estimator, and they calculate the mean and variance of catch rates for marine mammals and turtles observed in longline sets using a delta lognormal estimator. In addition, scientists developed Bayesian hurdle generalized linear mixed models to obtain seabird bycatch estimates for the pelagic longline fishery. For the Southeast shrimp trawl fishery, analysts use ratio estimation for analyses of species-specific fish bycatch rates. Analysts estimated marine mammal bycatch using observer data and stratified shrimp fishery effort models in the shrimp trawl fishery, and for sea turtle bycatch estimates for 2014 and 2015, analysts estimated sea turtle bycatch by applying integrated Bayesian models to observer data.

In the Greater Atlantic Region, bycatch estimation methods varied more through time for protected species than those for fish and invertebrates. Annual bycatch estimates of federally managed fish and invertebrate species were calculated using a combined ratio estimator and broad fleet stratification for previous editions of the NBR. Bycatch of fish and invertebrates were estimated at the level of individual fisheries, rather than at the fishery group level. Starting in 2017, bycatch estimation methods for fish and invertebrates were improved to better accommodate data gaps but still involved using a ratio estimator for observer-monitored trips, while a model-based estimate was applied to expand bycatch estimates from electronic monitoring data. Different model-based and ratio estimator techniques were used to estimate protected fish, marine mammal, sea turtle, and seabird bycatch in Greater Atlantic Region fisheries. For example, scientists estimated bycatch of Endangered-Species-Act-listed Atlantic sturgeon by modeling sturgeon takes using a generalized linear model framework with quasi-Poisson assumption. In addition, analysts have estimated bycatch for 10 species of seabirds in 6 Greater Atlantic fixed and mobile gear types using a Bayesian hierarchical approach.

For upcoming NBR annual updates, NOAA Fisheries is developing an enhanced NBR database as the central vehicle for sharing bycatch estimates for NBR fisheries, along with periodic online reports summarizing new bycatch data, fisheries, estimation methods, and trends. This new NBR database approach should support timely communication of bycatch reduction progress to Congress, stakeholders, and the public.

1. Introduction

Fishing gear, for the most part, is not perfectly selective. Therefore, fishers tend to catch fish and other living marine resources that they do not want to keep or that they are not allowed to keep. This discarded catch is commonly referred to as bycatch, and accounting for bycatch is necessary for the sustainable management of fisheries throughout the world (Crowder and Murawski, 1998; Hall et al., 2000; Lewison et al., 2004). NOAA's National Marine Fisheries Service (NOAA Fisheries) has coordinated federal fisheries observer programs to gather scientific data on U.S. commercial fisheries since 1971 (Brooke, 2014). Observers are professionally trained biological technicians who collect data on catch and discards on U.S. commercial fishing vessels. They also track interactions with marine mammals, sea turtles, and seabirds. NOAA Fisheries uses these observer data to monitor federal fisheries, assess populations of fish and protected species, set fishing quotas, and inform sustainable fisheries management. Bycatch estimation is a central component of all of these activities. Federal fisheries observer programs are authorized by the Magnuson-Stevens Fisheries Conservation and Management Act (MSA), the Marine Mammal Protection Act (MMPA), and the Endangered Species Act (ESA) to collect essential data for the agency to meet its regulatory requirements under these environmental laws. Brooke 2014 describes the various authorizing laws and how they influence observer program operations.

1.1 National Bycatch Report History

Following the publication of a review of fish and invertebrate discarding in the marine fisheries of the United States (Harrington et al., 2005), NOAA Fisheries developed the U.S. National Bycatch Report (NBR) First Edition (NOAA Fisheries, 2011), which documented bycatch estimates, using observer data and self-reported logbook data, for all commercial fisheries for which this information was available in 2005. NOAA Fisheries subsequently published three updates to the NBR:

- Update 1 (NOAA Fisheries, 2013), which included bycatch estimates based on 2010 data.
- Update 2 (NOAA Fisheries, 2016a), which included three sets of bycatch estimates based on data from 2011, 2012, and 2013.
- Update 3 (Benaka et al., 2019), which included two sets of bycatch estimates based on data from 2014 and 2015.

The NBR includes fish, protected resources (PR) fish, marine mammal, sea turtle, and seabird bycatch estimates for dozens of U.S. fisheries with bycatch monitoring programs that are based on (or incorporated to a large extent into) observer and/or electronic monitoring (EM) data. Marine mammal bycatch estimates in the NBR only include animals determined to be dead or seriously injured. Appendix 1 lists the NBR fisheries as of NBR Update 3 (Benaka et al., 2019) and shows how those NBR fisheries relate to fisheries in the Marine Mammal Protection Act List of Fisheries as well as federal fishery management plans (FMPs).

In 2017, NOAA Fisheries leadership created a NBR Review Working Group composed of NOAA Fisheries Science Center and Regional Office staff to develop options for the NBR and communications related to fish and invertebrate bycatch estimates. After collecting feedback from internal NOAA Fisheries staff and external users of the NBR, the working group highlighted concerns about misinterpretation of the bycatch estimates due to the lack of detailed discussion of bycatch estimation methods and appropriate data caveats in the NBR. The working group also concluded that there are limited users of the NBR because the time necessary to compile a large, comprehensive report results in estimates that are out of date when the report is published. As a result, the working group recommended that the NBR should provide a compilation of existing bycatch estimates as a query-able database that is updated as new estimates become available. They also emphasized that strong language about the need to understand the caveats of individual estimates should be provided.

1.2 Purpose of This Report Summarizing Bycatch Estimation Methods

The creation of this technical report summarizing bycatch estimation methods for fish, PR fish, marine mammals, sea turtles, and seabirds in future releases of the NBR is in direct response to the feedback from the NBR Review Working Group. The U.S. NBR First Edition (NOAA Fisheries, 2011) included extensive documentation of NBR bycatch estimation methods in use as of the late 2000s. However, bycatch estimation methodologies change and improve over time as new estimation models are developed and as new monitoring programs are created (Benaka et al., 2021). NOAA Fisheries is providing updated documentation of NBR bycatch estimation methods in this report to clearly explain in one place how NOAA Fisheries scientists estimate bycatch for species and fisheries included in the NBR database. As bycatch estimation methods are modified and improved, NOAA Fisheries will update the methods in the NBR database and publish a summary of changes online (see Section 7: The Future of the National Bycatch Report).

1.3 Overview of Changes in Bycatch Estimation Methodologies

NOAA Fisheries scientists estimate bycatch by expanding the data collected by observer and EM programs to the total fishing effort recorded in logbooks or landings records using model-based or design-based estimators. Model-based bycatch estimation methods typically employ generalized linear models with varying combinations of predictor variables, such as year, season, depth, and gear type (Babcock et al., 2023). The model with the best set of variables for predicting bycatch events is generally chosen using information criteria (e.g., Akaike Information Criterion or Bayesian Information Criterion). Design-based bycatch estimation methods include stratified ratio estimators and delta-lognormal estimators (Babcock et al., 2023). Stratification variables are specified based on the observer or EM program sampling design such that within a stratum, the relationship between the chosen metric of fishing effort and bycatch occurrence is expected to be stationary.

At the time of the NBR First Edition (NOAA Fisheries, 2011), NOAA Fisheries scientists and managers frequently used design-based bycatch estimation methods, especially ratio estimators, to derive bycatch estimates for fish and protected species. As of the publication of NBR Update 3 (Benaka et al., 2019), scientists more frequently used model-based bycatch estimation methods to estimate protected species bycatch, but continued to use design-based methods for fish bycatch estimation.

According to Carretta and Moore (2014), ratio estimators can be biased when bycatch events are rare, which is a common scenario for many marine mammals and other protected species with low population densities. As a result, scientists in recent years have used Bayesian time series models (Jannot et al., 2022), random forest classification trees (Carretta, 2023), Poisson process models (Benson et al., 2021), and other approaches to estimate bycatch of protected species including marine mammals, sea turtles, and seabirds.

The COVID-19 pandemic caused observer coverage data gaps for multiple NOAA Fisheries regions. On March 20, 2020, NOAA Fisheries issued an emergency action (85 FR 17285) to waive observer coverage under various circumstances including those when there are no qualified observers available for placement due to health, safety, or training issues related to COVID-19 (Benaka, 2022). This waiver policy generally continued until June 17, 2021, when NOAA Fisheries revised COVID-19-related observer coverage policies by stating that vessels would no longer be eligible for release from observer or monitor coverage if a fully vaccinated or quarantined and sheltered-in-place observer was available (Benaka, 2023). The waivers resulted in the suspension of observer coverage in Greater Atlantic fisheries, almost all Southeast fisheries, and two out of three observed Pacific Islands fisheries from March 2020 through June 2021.

However, observer programs on the West Coast, in Alaska, and the Pacific Islands with 100% observer coverage requirements continued to provide observer coverage during the pandemic. For example, Alaska's North Pacific Observer Program and the Hawai'i Fisheries Observer Program reengineered their observer logistic processes including observer training classes and briefing and debriefing protocols in order to enable successful observer deployment during the COVID-19 pandemic in a majority of its fisheries. In addition, the West Coast Groundfish Observer Program developed a 1:1 deployment approach for observers so that an observer would only be deployed to the same vessel when selected for monitoring coverage to reduce COVID-19 risks (Benaka, 2023).

The following chapters for Pacific Islands, Southeast and Greater Atlantic fisheries describe how some analysts have dealt with the data gaps to estimate bycatch for those time periods.

2. Pacific Islands Region

The Western and Central Pacific Ocean (WCPO) supports large fisheries for tunas and swordfish. Within the WCPO, NOAA Fisheries's Pacific Islands Region includes the U.S. Exclusive Economic Zone (EEZ) around American Samoa, the Commonwealth of the Northern Mariana Islands, Guam, Hawai'i, and the U.S. possessions in the Western Pacific region. Update 3 to the NBR included fish, marine mammal, sea turtle, and seabird bycatch estimates for pelagic longline fleets that are based out of Hawai'i and American Samoa (Benaka et al., 2019).

2.1 Fisheries Overview

The Hawai'i longline fleet includes a deep-set longline (DSLL) fishery that targets tunas and a shallow-set longline (SSLL) fishery that targets North Pacific swordfish (*Xiphias gladius*). The DSLL fishery is the largest of all commercial pelagic fisheries in Hawai'i, representing 89% of total commercial pelagic catch and accounting for about 91% of the estimated ex-vessel value of total commercial fish landings in the state in 2021. The fleet mostly fishes north and south of the Hawai'ian Islands. The fishery operates year-round, with the greatest amount of effort occurring during the winter and spring months. The DSLL fleet deploys its gear at depths of around 400 meters, using a mainline that is typically 25 to 45 nautical miles long. Tunas comprised 78% of the overall pelagic catch in Hawai'i in 2021, and billfish made up 11% of the total catch. The remaining catch consisted of other pelagic management unit species, including opah (*Lampris guttatus*). There were 146 active Hawai'i-permitted DSLL vessels in 2021, and vessels made 1,690 trips and 22,192 sets in 2021 (WPRFMC, 2022).

The SSLL fishery operates mainly in the first half (winter and spring months) of the year, and is comprised of 17 vessels that made 57 trips and 703 sets in 2021 (WPRFMC, 2022). The fishery operates almost entirely north of Hawai'i and deploys its mainlines at depths of between 20 and 75 meters. A typical SSLL set uses between 700 and 1,000 hooks.

The U.S. longline fishery for South Pacific albacore tuna (*Thunnus alalunga*) is conducted primarily in the American Samoa EEZ year-round. This American Samoa longline (ASLL) fishery is smaller than the Hawai'i longline fishery. The fishery grew rapidly in the early 2000s, from seven permitted longline vessels in 2000 to 38 in 2003. The ASLL fleet consisted of 11 active vessels in 2021 (WPRFMC, 2022), which is less than half of the estimated fleet size of 24 in 2010 (McCracken, 2019a). The fishery experienced its lowest effort and catch in 2020 since the start of the fishery, but effort and catch rebounded slightly in 2021. Vessels shorter than 40 feet average 350 hooks per set, while vessels over 50 feet can set from 1,750 to 2,100 hooks. In 2020, the 11 vessels that fished made 40 trips and deployed 1,484 sets (WPRFMC, 2022).

2.2 Data Sources

Observer and logbook data comprise the data sources for the Pacific Islands' longline fisheries with bycatch estimates in the NBR. The NBR only includes bycatch estimates for the three longline fisheries because they are the only three regional fisheries monitored by observer programs. The SSLL fishery has 100% observer coverage. The DSLL has an observer coverage goal of 20%, which is not always met due to funding constraints. The ASLL fishery also has an observer coverage goal of 20%, which has not been met in recent years due to COVID-19-related logistical challenges (McCracken and Cooper, 2022a).

During an observed trip, observers record various data related to the trip (e.g., vessel name, operator name, and trip start and end dates), catch, bycatch, and characteristics of bycaught protected species. This information is entered into a database called the Longline Observer Data System (McCracken, 2019b).

After each trip, a vessel representative must submit completed logbooks describing characteristics of the trip to NOAA Fisheries. NOAA Fisheries analysts enter logbook data into the American Samoa longline logbook database (McCracken, 2019a) or the Hawai'i longline logbook database (McCracken, 2019b).

2.3 Bycatch Estimation Methods for Years with Expected Observer Coverage

During the years with expected observer coverage in the Pacific Islands region (i.e., 2019 and earlier), bycatch estimation methods vary based on fishery and taxon group. Below, we include brief descriptions of these methods and reference the publications with more detailed explanations of the methodologies. Table 1 provides a summary of the methods used to estimate bycatch of different taxon groups by fishery and year.

Table 1. Summary of estimation methods used for the NBR to estimate bycatch in three Pacific Islands fisheries.

NBR Fishery	Taxon Groups	Method Shorthand	Years Applied	Reference(s)
American Samoa Longline	Marine mammals,	Separate ratio estimator; synthetic combined ratio estimator	2010-2019	McCracken and Cooper, 2022c
	Fish, protected resource (PR) fish, sea turtles, seabirds	Separate ratio estimator; combined ratio estimator	2010-2019	McCracken, 2019a
	Marine mammals	Model-based ratio estimator based on average bycatch for each calendar day of year	2020	McCracken and Cooper, 2022c
	Fish, PR fish, sea turtles, seabirds	Model-based ratio estimator based on average bycatch for each calendar day of year	2020	McCracken and Cooper, 2022a
Hawai'i-Based Deep-Set Longline	Marine mammals, fish, PR fish	Generalized ratio estimator	2005-2019	McCracken, 2019b
	Sea turtles, seabirds	Horvitz-Thompson estimator	2005-2019	

NBR Fishery	Taxon Groups	Method Shorthand	Years Applied	Reference(s)
	Marine mammals,	Generalized ratio estimator and synthetic estimator	2020	McCracken and Cooper, 2022b
	Fish, PR fish	Generalized ratio estimator and synthetic estimator	2020	McCracken and Cooper, 2021a
	Sea turtles, seabirds	Horvitz-Thompson estimator and synthetic estimator	2020	McCracken and Cooper, 2021b
Hawai'i-Based Shallow-Set Longline	Marine mammals,	Census observer coverage, no estimation required	2005-2020	McCracken and Cooper, 2022b
	Sea turtles, seabirds	Census observer coverage, no estimation required	2005-2020	
	Fish, PR fish	Census observer coverage, no estimation required, numbers of fish converted to weight	2005-2019	
	Fish, PR fish	Mean imputation of missing bycatch for one trip	2020	Cooper and McCracken, 2021

American Samoa Pelagic Longline Fishery Bycatch Estimation Methods

Fish bycatch has been calculated for the ASLL fishery using synthetic combined ratio estimators or separate ratio estimators (McCracken, 2019a). McCracken 2019a lists various considerations regarding the appropriateness of available methods to estimate bycatch in the ASLL fishery, including the complexity of the problem, and the limitations of historical data and knowledge.

McCracken (2019a) describes how the ASLL fleet is sampled to estimate bycatch of sea turtles and other ESA-listed species including giant manta rays (*Morbula birostris*) and oceanic whitetip sharks (*Carcharhinus longimanus*). According to McCracken (2020), NOAA Fisheries derived sea turtle and seabird bycatch estimates for 2016-2019 using the synthetic combined ratio estimator.

Hawai'i-Based Deep-Set Pelagic Longline Fishery Bycatch Estimation Methods

A vessel owner or operator must notify the Pacific Island Regional Observer Program (Program) at least 72 hours prior to an intended departure date and declare the intended trip type, either shallow- or deep-set. The Program draws a sample of DSLL trips for observer deployment from a list of these notifications. Generally, for the 20% targeted coverage established for the DSLL fishery, the Program draws a systematic sample at 15%.

The Program utilizes a "systematic-plus" (SYSPLUS) design to monitor bycatch in the DSLL fleet. This complex adaptive sample design has a two-stage protocol. First, a systematic sample is drawn at approximately 5% lower coverage than the targeted observer coverage level. Drawing a systematic sample at this level seems to provide the maximal percent coverage by the systematic sample in which few selected trips are missed (McCracken, 2019b). The systematic sample is a probability sample of the fleet that is equivalent to a one-stage cluster sample where all elements in the selected clusters are sampled. The second stage of this protocol involves drawing the additional samples required to achieve the targeted coverage level. These additional samples are selected from vessel trip notifications that were not selected by the first stage systematic sample (McCracken, 2019b).

The Horvitz-Thompson Estimator (HTE) or the generalized ratio estimator (GRE) are used to estimate bycatch totals. McCracken (2019b) describes when and how HTEs or GREs may be used with appropriate inclusion probabilities to estimate bycatch.

Hawai'i-Based Shallow-Set Pelagic Longline Fishery Bycatch Estimation Methods

The SSLL fishery has 100% monitoring coverage (achieved via deployment of human observers and EM) on every haul and trip, and therefore, a bycatch estimation methodology is not required. Bycatch reported for marine mammals, sea turtles, and seabirds represents a census of interactions with the SSLL fishery between 2005 and 2020. In addition, there was no estimation of counts for bony fish, shark, and ray bycatch between 2005 and 2019 (McCracken, 2019).

2.4 Bycatch Estimation Methods for Years with Lower-Than-Expected Observer Coverage

Hawai'i-Based Shallow-Set Pelagic Longline Fishery Bycatch Estimation Methods

As mentioned above, the SSLL fishery has 100% observer coverage and does not typically require a bycatch estimation methodology. However, in 2020, observer records for one trip were stolen before they were entered into the database. The observer confirmed no bycatch of marine mammals, seabirds, or sea turtles on the trip, so NOAA Fisheries considered the bycatch totals for these taxa for that trip to be known with no estimation required. Pacific Island Fisheries Science Center (PIFSC) analysts estimated bony fish, shark, and ray bycatch totals for this trip via a mean imputation methodology. Briefly, fish bycatch for five proxy trips was averaged to estimate the bycatch for the trip with missing data. The bycatch estimates for the missing trip were then added to the observed totals to yield the bycatch estimates for the entire fishery for 2020 (Cooper and McCracken, 2021).

Hawai'i-Based Deep-Set Pelagic Longline Fishery Bycatch Estimation Methods

McCracken and Cooper (2021a) describe how PIFSC estimated bony fish, shark, and ray bycatch for 2020 DSLL trips in light of two gaps in observer coverage for late 2019 and 2020. In late 2019 and in 2020, observer coverage fell below the 15% average coverage of the systematic sample. The late 2019 gap in 15% observer coverage was due to only two of six selected notifications being sampled by observers. The 2020 gap was caused by concerns with the spread of COVID-19. NOAA Fisheries used an emergency rule (85 FR 17285) to waive observer coverage due to the COVID-19 pandemic, which resulted in trips not being fully sampled for bycatch from March 10 through May 12, 2020. Outside of the gaps in observer coverage, the SYSPLUS sampling protocol was followed, and the standard bycatch estimation methods described in the previous section were applied. McCracken and Cooper 2021a describes how bycatch was estimated for 2020 DSLL trips while McCracken and Cooper 2022b describes how PIFSC estimated bycatch in light of these two gaps. For the 2019 gap, bony fish, shark, ray, sea turtle, and seabird bycatch estimates were calculated using a synthetic estimator (McCracken and Cooper, 2021a; McCracken and Cooper, 2021b). Bycatch during the COVID gap was estimated using a synthetic estimator similar to the estimator used for the 2019 gap. These estimators were selected to estimate bycatch during periods with lower observer coverage because they could be used across species to fulfill annual bycatch reporting requirements.

American Samoa Pelagic Longline Fishery Bycatch Estimation Methods

For the ASLL fishery, using a sample-based estimator to estimate bycatch was inappropriate for 2020 due to a general lack of observer coverage that year. COVID-19 affected the deployment of observers in the ASLL fleet in 2020 primarily due to the American Samoa government restricting air travel in and out of the territory to reduce potential viral infections. As a result, only one observed trip occurred in 2020. In addition, no logbook data were available for approximately 23% of the 48 ASLL trips that landed fish in 2020 (McCracken and Cooper, 2022a). In addition, lack of available data limited the ability of analysts to create an appropriate model-based estimator. Therefore, analysts used a straightforward bycatch estimator that could be used across species (McCracken and Cooper, 2022a; McCracken and Cooper, 2022c). For each calendar day of the year, the average bycatch over all observed trips was computed for species of interest, whether they were seabirds, sea turtles, bony fish, sharks, and rays (McCracken and Cooper, 2022a), or marine mammals (McCracken and Cooper, 2022c). Then, analysts multiplied each day's average by the number of unobserved trips. The sum of these products over all days was the estimated bycatch for unobserved trips, which was added to the bycatch levels from observed trips to yield the total estimated bycatch for the fleet (McCracken and Cooper, 2022c). Under these data-poor circumstances, NOAA Fisheries used observations from the Longline Observer Data System over years 2012-2020 to derive seabird, sea turtle, bony fish, shark, and ray bycatch estimates for 2020 (McCracken and Cooper, 2022a).

3. Alaska Region

The U.S. EEZ off Alaska covers nearly 1.5 million square nautical miles, and Alaska fisheries produce more than half the fish caught in U.S. coastal waters (NOAA Fisheries, 2020). Three of the six U.S. ports with the highest-value landings were in Alaska in 2020 (NOAA Fisheries, 2022). Update 3 to the NBR included bycatch estimates for 20 Alaska groundfish fisheries covering multiple gear types in the Gulf of Alaska (GOA) and Bering Sea and Aleutian Islands (BSAI), as well as several crab pot fisheries and a state salmon drift gillnet fishery (Benaka et al., 2019).

3.1 Fisheries Overview

The North Pacific Fishery Management Council (NPFMC) collaborates with the NOAA Fisheries Alaska Regional Office (AKRO) to manage Alaska groundfish fisheries, with separate FMPs for BSAI and GOA fisheries. These fisheries target groundfish including walleye pollock (*Gadus chalcogrammus*), Pacific cod (*Gadus macrocephalus*), flatfish including Pacific halibut (*Hippoglossus stenolepis*), sablefish (*Anoplopoma fimbria*), and rockfish using gear including longlines, trawls, and pots. Groundfish vessels operating in the BSAI fall into a variety of sectors, and these sectors fish at different times of the year. For example, catcher processor (CP), inshore, and mothership[1] vessels fishing under the limited access American Fisheries Act (AFA) pollock cooperatives generally fish from January to March and from June to early October. Hook-and-line CP vessels targeting Pacific cod actively fish year-round. Vessels that catch rock sole in the BSAI actively fish from mid-January to late April. In the GOA, active fishing for pollock and Pacific cod generally occurs from January to March and in September, whereas vessels that are part of the Central GOA Rockfish Program (a harvest privilege program[2]) actively fish from April through June and then typically fish again in the late fall. The NPFMC has published an online document that characterizes the various groundfish (and other) fishing fleets and sectors, as well as the gears they use.[3]

The International Pacific Halibut Commission (IPHC) and the NPFMC jointly manage the Pacific halibut fixed gear (longline) fishery via an individual fishing quota program. The IPHC establishes total annual catch limits and other conservation measures, and the NPFMC and AKRO develop regulations to govern the fishery including limited access and allocation decisions. Pacific halibut are targeted using longline or pot gear and are also captured in large numbers by vessels using trawl, pot, and longline gear that are targeting groundfish. Observers are deployed on both groundfish and Pacific halibut vessels and gather information regarding the amount of Pacific halibut caught and the condition of Pacific halibut at release.

The NPFMC's BSAI King and Tanner Crab FMP provides a management framework for Alaska crab fisheries. The Alaska Department of Fish and Game (ADFG) administers in-season management for these fisheries. The period of greatest fishing activity for these crabs occurs in the winter, spring, and fall months. Pots used in this fishery generally measure seven feet by seven feet by three feet and are set one pot per line or with longlines. Pot soak times average around 60 hours for some fleets.

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[1] Motherships are large processing vessels that are not tied to a single geographic location.

[2] The Rockfish Program allocates harvest privileges to holders of License Limitation Program (LLP) groundfish licenses with a history of Central GOA rockfish legal landings.

[3] https://www.npfmc.org/wp-content/PDFdocuments/resources/FleetProfiles412.pdf

The Alaska Southeast salmon drift gillnet fishery, which is divided into five ADFG districts (as well as smaller sub-districts and statistical areas), operates from June to October in five main fishing areas off Southeast Alaska. The fishery soaks its drift gillnet gear from 20 minutes to 3 hours, during the day and at night, with around 6–20 sets per day. The ADFG manages this fishery, and NOAA Fisheries monitors marine mammal interactions in segments of this fishery in some years based on the availability of NOAA Fisheries funding for this purpose.

3.2 Data Sources

Fishing industry reports and observer or EM data from the NOAA Fisheries North Pacific Observer Program comprise the main data sources for the estimation of total catch and bycatch in federal groundfish fisheries off Alaska. These data feed into the AKRO Catch Accounting System (CAS), which estimates total groundfish and halibut catch, including at-sea discards, as well as estimates of bycatch of other species including seabirds (Tide and Eich, 2022).

Fishing industry reports include landings and production information reported by shoreside processing facilities, CPs, and motherships that are used to assess catch, fishing effort location, and other characteristics. Fishing industry reports also include logbook information reported by vessel operators that include data about effort, total catch, and location (Cahalan et al., 2014).

The North Pacific Observer Program deploys observers and EM systems on groundfish and halibut fleets based on two categories: (1) full coverage and (2) partial coverage. With a few exceptions, all CPs and motherships are in the full coverage category and must carry at least one observer and a compliance monitoring EM system while fishing. Catcher vessels (CVs) that are participating in catch share programs with transferable bycatch allocations are also in full coverage and have an observer or EM system on every trip. All other CVs fall under the partial coverage category.

Each year, NOAA Fisheries prepares an Annual Deployment Plan (ADP) that describes the science-driven method for deployment of observers and EM systems to support statistically reliable data collection in the partial coverage category. Observer and EM deployment outlined in the ADP is based on three steps. First, the selection method to accomplish random sampling involves observers and EM being deployed through a trip selection model in all ports throughout Alaska. Second, the population of partial coverage trips is stratified into selection pools or strata. Last, deployment is allocated among the strata. For more information, see NOAA Fisheries, 2023.

Fishery observers assigned to fishing vessels or shoreside processing facilities collect information on catch, fishery discards, biological information on fish, and data concerning protected resources such as seabird and marine mammals and their interactions with fisheries. In addition, observers record important information about fishing effort and fishing locations that they derive from vessel logbooks. EM systems used on fixed gear vessels in lieu of observers provide data on catch and discards. On trawl vessels, EM systems monitor compliance with maximized retention regulations and ensure that shoreside observers have access to complete, unsorted trip-level catch to account for catch and to sample for biological data collection. EM is also used in conjunction with observers on CP vessels and motherships to ensure that vessels comply with catch handling regulations and that observers have access to unsorted catch.

Managers use observer and EM data to manage groundfish and prohibited species[4] catch within established limits and to document and reduce fishery interactions with protected resources. Scientists use fishery-dependent data to assess fish stocks, provide scientific information for fisheries and ecosystem research and fishing fleet behavior, assess marine mammal and seabird interactions with fishing gear, and assess fishing interactions with habitat.

In September 2021, NOAA Fisheries approved Amendment 51 to the BSAI King and Tanner Crab FMP (86 FR 51833), which clarified language regarding bycatch data for this fishery. NOAA Fisheries requires vessel operators in these crab fisheries to maintain a federal logbook in which vessel operators must record information on at-sea discards of king (or red king) crab (*Paralithodes camtschaticus*) and Tanner crab (*Chionoecetes bairdi*), as well as other species. Otherwise, NOAA Fisheries delegates all other bycatch reporting requirements to the State of Alaska, which coordinates a BSAI Crab Observer Program that provides the primary data for bycatch estimation. Specifically, the State requires an onboard observer on all CP or floating-processor vessels processing king or Tanner crab, on a portion of CVs participating in the BSAI king or Tanner crab fisheries, and on all vessels participating in the Aleutian Islands red or golden king crab (*Lithodes aequispinus*) fisheries. The observers provide effort data and data on the amount and type of bycatch occurring in each fishery, including estimates of crab bycatch by species, sex, size, and shell condition/shell hardness.

The NOAA Fisheries Alaska Marine Mammal Observer Program (AMMOP) monitors marine mammal and seabird interactions with the State of Alaska's salmon fisheries. The AMMOP was last implemented in 2012 and 2013 in the Southeast salmon drift gillnet fishery. AMMOP observers have not been deployed directly onto fishing vessels but rather onto independent vessels positioned near fishing operations to collect data regarding fishing at and below the water's surface. In 2012 and 2013, AMMOP provided observer coverage for approximately 6.5% of catch in the districts being observed (Manly, 2015). Specifically, AMMOP operated in three fishing districts that represented 16% of overall fish landed, and bycatch estimates from these three districts were not extrapolated to the other fishing districts representing 84% of overall landings.

In 2018, NOAA Fisheries transferred administration of the AMMOP from the NOAA Fisheries Alaska Regional Office to the NOAA Fisheries Alaska Fisheries Science Center (which also manages the North Pacific Observer Program) to gain administrative efficiencies and increase AMMOP viability over time. The North Pacific Observer Program expects to implement the AMMOP again by 2025 through an initial scoping effort that would include observation of all ADFG districts in Southeast Alaska at a relatively low level of effort (e.g., one week of effort in each district) on a rotating basis while a core area would be observed at higher rates. This scoping effort also would include dockside interviews at all major ports to collect information from State of Alaska salmon fishers about fishing effort and marine mammal interactions. In the future, AMMOP may include EM and other technologies, in addition to observers, to monitor bycatch of protected resources.

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[4] Some FMPs for Alaska fisheries designate certain incidentally caught species as "prohibited species" when the species are targeted by other Alaska fisheries. Prohibited species catch include Pacific halibut, Pacific herring (*Clupea pallasii*), Pacific salmon, king crab, and Tanner crab.

3.3 Bycatch Estimation Methods

Table 2 provides a brief overview of bycatch estimation techniques in Alaska fisheries and references. The following sections provide more detail for the groundfish and halibut, crab, and salmon drift gillnet fisheries.

Table 2. Summary of estimation methods used to estimate bycatch in Alaska fisheries for the NBR.

NBR Fishery or Fisheries	Taxon Groups	Method Shorthand	Years Applied	Reference(s)
Groundfish and Halibut*	Marine mammals	Stratified ratio estimator	2010-2015	Perez, 2006; Breiwick, 2013
	Fish, protected resource fish	Ratio estimator	2010-present	Cahalan et al., 2014
	Seabirds	Ratio estimator	2010-present	Cahalan et al., 2014; Tide and Eich, 2022
Crab**	Fish (crab only)	Ratio estimator	2014-2015	Daly and Stichert, 2022
Southeast Salmon Drift Gillnet***	Marine mammals	Ratio estimator	2012-2013	Manly, 2015

*This fishery group includes the following NBR fisheries: BSAI CP Longline, BSAI CV Longline, BSAI Groundfish Pot, BSAI Non-Pollock Trawl, BSAI Pollock Trawl, BSAI Trawl Limited Access, GOA Halibut Longline, GOA Nonpelagic Trawl, GOA Pacific Cod Longline, GOA Pollock Trawl, GOA Pot, GOA Rockfish Nonpelagic Trawl, GOA Rockfish Pelagic Trawl, GOA Sablefish Longline, and GOA Sablefish Trawl. Slightly different fishery names and groups are associated with marine mammal estimates for these fisheries, as described in Section 3.3.
**This fishery group includes the following NBR fisheries: Bering Sea Snow Crab Pot, Bering Sea Tanner Crab Pot, Bristol Bay Red King Crab Pot, and St. Matthew Island Blue King Crab Pot.
***This fishery was also called “Alaska Statewide Salmon Fisheries” in the NBR.

Groundfish and Halibut Fisheries Bycatch Estimation Methods

For vessels in the full coverage category, NOAA Fisheries uses observer data entirely to estimate the amount of groundfish discarded at sea in the CAS. The at-sea discard weight for any given fishery is the sum of the haul estimates of the at-sea discard weight for the fishery (Cahalan et al., 2014). For CVs delivering their catch to plants on shore (both in the full and partial coverage categories), the AKRO applies observer-based at-sea discard rates to the total retained catch based on industry reports (which include shoreside discards reported by the plant; Cahalan et al., 2014). NOAA Fisheries uses the ratio estimator method to compute at-sea discard rates, which are the at-sea discard for a given species divided by the total retained groundfish of all species (Cahalan et al., 2014). For prohibited fish and non-groundfish species, at-sea discards are calculated as the ratio estimate of at-sea discard rate applied to total groundfish catch in each sampling stratum, summed over the strata (Cahalan et al., 2014). Several full coverage fisheries, including non-pollock trawl vessels falling under the Amendment 80 management system,[5] Community Development Quota pollock and non-pollock trawl vessels,[6] and AFA pollock trawl CPs, have 200% observer coverage, and nearly all hauls are sampled. NBR fish bycatch estimates assume 100% mortality except for Pacific halibut, for which NOAA Fisheries applies mortality rates based on area, gear, and sector.

The NOAA Fisheries Alaska Fisheries Science Center (AFSC) Marine Mammal Laboratory (MML) and North Pacific Observer Program have compiled and analyzed information collected by observers on marine mammal interactions with groundfish fisheries since the early 1970s (Perez, 2006). At-sea observers collect a variety of data on marine mammal interactions, including whether the interaction involved an incidental mortality or injury, the species name, species condition, and probable cause of any mortalities (e.g., killed by gear, killed by the vessel's propeller, or "previously dead" prior to coming into contact with gear). Most recently, the MML has used a stratified ratio-estimation method that involves multiplying a bycatch ratio, defined for a stratum as the number of animals bycaught divided by some measure of fishing effort, times the total fishing effort in the stratum (Breiwick, 2013). NOAA Fisheries analyzes marine mammal bycatch by post-stratifying data with post-strata defined by year; fishery (based on target species, gear type, and NOAA Fisheries statistical area as described in the FMP); marine mammal species involved in an interaction (resulting in a mortality or serious injury); NOAA Fisheries statistical area; time period; and vessel class (based on vessel length) (Breiwick, 2013).

In the NBR, the definition of Alaska fisheries for marine mammal estimates differs from the definition of fisheries with fish estimates. For example, the NBR has included marine mammal bycatch estimates for multiple non-pollock fisheries (BSAI Atka mackerel trawl, BSAI flatfish trawl, BSAI Pacific cod trawl, and BSAI rockfish trawl), whereas the NBR has included fish bycatch estimates for the BSAI non-pollock trawl fishery, which is not broken into multiple species-specific fisheries as it is for marine mammal estimates.

For the GOA, the NBR has provided marine mammal estimates for a single rockfish trawl fishery, which is separated into nonpelagic and pelagic rockfish trawl fisheries for fish bycatch estimates. For GOA non-rockfish trawl fisheries, the NBR has provided marine mammal bycatch estimates for the GOA pollock trawl, flatfish trawl, and Pacific cod fisheries. However, the NBR does not include fish bycatch estimates for these two fisheries but rather includes fish bycatch estimates for the related GOA non-pelagic trawl fishery.

The AKRO produces seabird bycatch estimates using a ratio estimator in the CAS (Cahalan et al., 2014). Specifically, in the CAS, the AKRO uses observer data to create seabird bycatch rates, which are a ratio of the estimated bycatch to the estimated total catch in sampled hauls (Tide and Eich, 2022). The AKRO creates bycatch rates from observed trips that are applied to unobserved trips. This extrapolation is based on varying levels of aggregated data, as described in Cahalan et al. (2014). For bycatch reporting purposes, the AKRO often consolidates species categories identified through observer and EM data into larger groups, such as albatross, shearwaters, and unidentified gulls. The AKRO assumes 100% mortality for all seabird bycatch estimates. The

[5] Bering Sea and Aleutian Islands Amendment 80 Groundfish Trawl Fishery in Alaska. Available online at: https://www.fisheries.noaa.gov/alaska/sustainable-fisheries/bering-sea-and-aleutian-islands-amendment-80-groundfish-trawl-fishery

[6] Community Development Quota (CDQ) Program. Available online at: https://www.fisheries.noaa.gov/alaska/sustainable-fisheries/community-development-quota-cdq-program

CAS provides seabird bycatch estimates as numbers of seabird bycatch per metric ton of catch, which differs from the international reporting standard of number of birds per 1,000 hooks (Tide and Eich, 2022).

Crab Fisheries Bycatch Estimation Methods

NBR bycatch estimates for BSAI-directed crab fisheries are limited to crab species and include a variety of assumed mortality rates that are applied to observer data from Alaska's BSAI Crab Observer Program. These rates range from 20.0% to 32.1%, as opposed to higher crab discard mortality rates assumed for groundfish fisheries, which range from 50% for pot and longline gear to 80% for trawl gear (Daly and Stichert, 2022). The crab bycatch estimation process includes several steps (Daly and Stichert, 2022):

1. Calculation of total catch, based on observer data on crab pot catch per unit effort times total fishery effort times mean crab weight.
2. Calculation of discards by subtracting retained catch from total catch.
3. Calculation of discard mortality by applying assumed mortality rates to discards.

The NBR does not include marine mammal or seabird bycatch estimates for Alaska crab fisheries.

Southeast Salmon Drift Gillnet Fishery Bycatch Estimation Methods

The most recently implemented AMMOP used a ratio estimation method to estimate marine mammal and seabird bycatch. (The NBR published the marine mammal estimates, but not the seabird estimates, although Manly (2015) includes the seabird bycatch estimates.) The ratio estimation procedure involved using observer data for a sub-district to estimate the bycatch of a species per day of fishing and multiplying the bycatch per day by the total number of days of fishing by permit holders for the whole season in the sub-district to derive estimated bycatch levels. This methodology used bootstrap methods to obtain estimates of coefficients of variation and percentile bootstrap confidence limits because of the low observed bycatch numbers in 2012 and 2013 (Manly, 2015). Southeast Alaska harbor porpoise (*Phocoena phocoena*) bycatch estimates were corrected following the publication of the third NBR update due to an error in the assignment of injury severity for two of the bycaught individuals (Young et al., 2023).

4. West Coast Region

The NOAA Fisheries West Coast region covers 317,690 square miles of ocean that support important groundfish, Pacific whiting (or hake) (*Mercluccius productus*), rockfish, sablefish, salmon, and migratory species fisheries. Oregon's port Astoria had the 6th largest amount of U.S. commercial fisheries landings by volume in 2020 (NOAA Fisheries, 2022). The region also features a wide variety of protected species including marine mammals, sea turtles, seabirds, and protected fish species including salmon. Update 3 to the NBR included fish bycatch estimates for 13 fisheries operating off of California, Oregon, and Washington (Benaka et al., 2019). The NBR contained marine mammal and seabird estimates for a subset of those fisheries, and sea turtle estimates for one California-based fishery because sea turtles have only been observed bycaught in this fishery.

4.1 Fisheries Overview

The Pacific Fishery Management Council (PFMC) collaborates with the NOAA Fisheries West Coast Regional Office (WCRO) to manage the West Coast groundfish fishery through the Pacific Coast Groundfish FMP. The management encompasses multiple sectors, including two trawl sectors:

1. Shorebased Individual Fishing Quota (IFQ) Sector: This sector, created in 2011 through the trawl catch share program, allows each member of the sector to manage their catch through quota share allocations, with vessels in the sector targeting whiting and rockfish species using mid-water trawls, bottom trawls, and fixed gears.
2. At-Sea Whiting Sectors: These sectors are made up of CPs (9 vessels in 2019) and motherships (6 motherships with 19 catcher vessels in 2019) that are managed through cooperatives and receive allocations for various rockfish species that can constrain the sectors.

The groundfish fishery also features two non-trawl sectors:

1. Limited Entry Fixed Gear (LEFG) Sector: This sector comprises vessels fishing with a sablefish-endorsed LEFG permit and vessels fishing under an LEFG permit without a sablefish endorsement.
2. Open Access (OA) Sectors: These sectors include fisheries such as pink shrimp (*Pandalus jordani*) and salmon troll fisheries that catch groundfish while targeting non-groundfish species, as well as an OA federal fishery that targets groundfish.

The NOAA Fisheries Northwest Fisheries Science Center's West Coast Groundfish Observer Program (WCGOP) and At-Sea Hake Observer Program (A-SHOP) monitor the groundfish sectors. The A-SHOP observes the hake fleets that process catch at sea, while the WCGOP observes a number of fleets that deliver catch shoreside for processing, including sectors that target and incidentally impact groundfish. The WCGOP specifically focuses on at-sea discard estimates, and the level of WCGOP observer coverage and sampling can vary greatly between fisheries, years, and spatial strata. For more information on coverage rates, see Somers et al., 2023b. PFMC (2022a) contains additional general information about the West Coast groundfish fishery.

Fisheries for highly migratory species (HMS) occur off the West Coast as well, mainly in the Southern California Bight in the fall and winter (PFMC, 2022b). The California Drift Gillnet fishery has been the most prominent HMS fishery since the 1980s and is the only HMS fishery with bycatch estimates in the NBR. This fishery historically has targeted swordfish and thresher sharks (*Alopias vulpinus*), although primarily swordfish since the 1990s. This fishery has been in decline in recent years due to state and federal restrictions, with total landings falling from over 200 metric tons in 2016 to less than 100 metric tons per year as of 2019 (PFMC, 2022b). As the California Drift Gillnet fishery has decreased in effort, deep-set buoy gear (DSBG) has increased through the PFMC's support for using an alternate gear type under the authority of exempted fishing permits (EFPs). Landings using DSBG, which is designed to target swordfish with less bycatch than drift gillnet gear, have increased from 12 metric tons in 2015 to 125 metric tons in 2020 (PFMC, 2022b). Although the most recent edition of the NBR did not include bycatch estimates for the DSBG fleet, the NBR will include estimates in the future based on the observer coverage associated with the EFPs.

The WCGOP has provided observer coverage for state fisheries, including the following NBR and other fisheries: California Halibut Trawl, Washington/California/Oregon Pink Shrimp, California Ridgeback Prawn, and California Sea Cucumber. Observer coverage of these state fisheries allows for bycatch estimation of species including eulachon (*Thaleichthys pacificus*), salmon, and groundfish, which provides important context to coastwide management of federal fisheries. The commercial fishery for California halibut (*Paralichthys californicus*) has occurred mainly off central California since 1980, with over 64% of its landings in the San Francisco area (Matthews et al., 2022). Trawl gear has accounted for 71% of California halibut landings since 1992 (Matthews et al., 2022). Vessels from California, Oregon, and Washington target pink shrimp, while some vessels from California also target ridgeback prawn (*Sicyonia ingentis*). Pink shrimp trawl vessels range in size from 38 to 105 feet, with an average length of 65 feet, and can use single and double-rigged shrimp trawl gear. The sea cucumber trawl fishery predominantly targets the California sea cucumber (*Apostichopus californicus*) and occurs only in Southern California, from Point Conception to San Diego, operating at an average depth of 270 feet.

The PFMC and the WCRO manage Pacific salmon fisheries, including the NBR's West Coast salmon troll fisheries, through its Pacific Coast Salmon FMP. Most salmon trolling occurs within 15 to 20 nautical miles from shore, including both state and federal waters (PFMC, 2022c). Fishers in California, Oregon, and Washington fish for salmon using limited entry permits, and the PFMC may change quotas, size limits, and/or fishing seasons annually based on management considerations. Trollers fish for salmon by towing lures or baited hooks through the waters. Fishing depth, troll speed, type of lure, and area fished determine the number and species of salmon caught. Fishing primarily occurs during the summer and fall, with the majority of effort taking place in the central and northern coast. Pacific Coast federal salmon fisheries focus on Chinook (*Oncorhynchus tshawytscha*) and coho (*Oncorhynchus kisutch*) salmon. Ocean salmon fisheries are divided into geographic areas, and the commercial ocean tribal fishery is conducted only north of Cape Falcon, Oregon. The primary bycatch that occurs is bycatch of non-targeted salmon species (NOAA Fisheries, 2011).

4.2 Data Sources

The data used to estimate groundfish bycatch in commercial fisheries come from landing receipts, fisheries observer records, and EM data, and discard logbooks (Somers et al., 2023a). Landing receipts (i.e., fish tickets) are sales receipts issued to vessels from fish buyers that aggregate species or species groups at the trip level (Somers et al. 2023a). The small amount of discarding that occurs shoreside is assumed to be accounted for in the landings data. Fisheries observers deployed by the WCGOP and the A-SHOP collect observations and samples from discarded and retained catch at-sea in the commercial groundfish fishery sectors described in Section 4.1. Details of data collection methods used by fisheries observers can be found in the WCGOP manual (NWFSC, 2023) and the A-SHOP observer manual (Tuttle et al., 2023). Camera systems record at-sea discards on vessels participating in the EM sector. After an EM trip, the vessel operator submits EM data (typically a hard drive) and a discard logbook to the EM service provider. The EM service provider in turn sends the logbook directly to NOAA Fisheries via a web application.[7]

The Groundfish Management Team, which advises the PFMC on evaluations of management performance and alternative management measures for groundfish fisheries along the U.S. West Coast, proposes discard mortality rates (Somers et al., 2023a). Upon review by the Scientific and Statistical Committee and adoption by the PFMC, the NWFSC applies these rates to discard estimates for the NWFSC's annual groundfish discard and catch reports (e.g., Somers et al., 2023a).

The NBR has included fish, marine mammal, sea turtle, and seabird bycatch estimates for the California Drift Gillnet fishery. Bycatch estimation for all taxa requires a combination of observer program data and estimates of overall fishing effort. Observer data may include information on the number of fishing sets observed, bycatch per set, fishing location, and oceanographic variables such as sea surface temperature. Fishing effort data may come directly from vessel logbooks, dock surveys of vessel activity, landing receipts, systematic tallies of fishing effort by the observer program contractor with the cooperation of the fishers, or a combination of all of these sources (NOAA Fisheries, 2011). The NOAA Fisheries Southwest Fisheries Science Center uses regression tree bycatch models to estimate bycatch of marine mammals, sea turtles, and seabirds in the California Drift Gillnet fishery. These models require data that can be used as predictors of bycatch, in addition to the observer and logbook data. Analysts test oceanographic, location, and gear variables as predictors in the models, but the specific predictors included vary by species (Carretta, 2023).

Observer data collected by the WCGOP for the California Halibut Trawl, California Ridgeback Prawn, Washington/California/Oregon Pink Shrimp, and California Sea Cucumber fisheries are critical to bycatch estimation. Observer coverage for the California Halibut Trawl fishery featured an average of 20% coverage of catch in this fishery from 2018 to 2022 (Matthews et al., 2022). Shrimp fisheries experienced an 11% observer coverage rate in 2022 (Somers et al., 2023b). Observer coverage for the ridgeback prawn fishery totaled 5.5% in 2020 (Somers et al., 2021). The sea cucumber trawl coverage rate was 14% of the landings observed in 2017 (Somers et al., 2018).

[7] For more information, see the EM Program Manual for West Coast Groundfish: https://media.fisheries.noaa.gov/2021-05/2021_EM_ProgramManual_Final_1.0_0.pdf

Sampling and monitoring programs conducted in various ports along the West Coast provide data used to assess salmon bycatch in the ocean salmon fishery. Programs document data from the commercial salmon troll fisheries on commercial landing receipts and reported in an electronic fish ticket system (PFMC, 2021). At the state level, the Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife verify landed salmon data recorded on fish tickets during the fishing season. The California Department of Fish and Wildlife (CDFW) monitors commercial salmon landings at all major salmon ports in California and verifies salmon landings on selected vessels. The CDFW also conducts interviews with fishers to gather data on the number of sublegal-sized Chinook salmon released during selected trips (PFMC, 2021).

4.3 Bycatch Estimation Methods

NOAA Fisheries West Coast Region utilizes a variety of bycatch estimation techniques for West Coast fisheries in the NBR. Table 3 provides a brief overview of these techniques and references. The following sections provide more detail for the groundfish, California drift gillnet and halibut trawl, and salmon troll fisheries.

Table 3. Summary of estimation methods used for the NBR to estimate bycatch in West Coast fisheries.

NBR Fishery or Fisheries	Taxon Groups	Method Shorthand	Years Applied	Reference(s)
West Coast Groundfish Non-Trawl Gear Fisheries; CA Halibut Trawl; CA/OR Nearshore Rockfish; WA/OR/CA Pink Shrimp	Fish	Ratio estimator	2010-2021	Somers et al., 2023a
West Coast Groundfish Non-Trawl Gear Fisheries; CA Halibut Trawl; CA/OR Nearshore Rockfish; WA/OR/CA Pink Shrimp	Protected resource (PR) fish	Ratio estimator	2002-2021	Richerson et al., 2022a; Richerson et al., 2022b; Gustafson et al., 2023
West Coast Groundfish Non-Trawl Gear Fisheries; CA Halibut Trawl; CA/OR Nearshore Rockfish; WA/OR/CA Pink Shrimp	Marine mammals	Bayesian time-series model	2002-2019	Jannot et al., 2018; Jannot et al., 2022

NBR Fishery or Fisheries	Taxon Groups	Method Shorthand	Years Applied	Reference(s)
West Coast Groundfish Non-Trawl Gear Fisheries; CA Halibut Trawl; CA/OR Nearshore Rockfish; WA/OR/CA Pink Shrimp	Seabirds	Bayesian time-series model	2002-2018	Jannot et al., 2021
West Coast Groundfish Non-Trawl Gear; Non-Endorsed Fixed Gear	Sea turtles	Ratio estimator	2002-2021	Benson et al., 2023
West Coast Limited Entry Bottom Trawl Fisheries; West Coast Mid-water Trawl for Whiting, At-Sea Processing	Fish	100% of trips monitored with observers or electronic monitoring (EM), with ratio estimators used for rare unsampled tows or sets. EM began in 2015, slightly changing the methodology.	2011-2021	Somers et al., 2023a
West Coast Limited Entry Bottom Trawl Fisheries; West Coast Mid-water Trawl for Whiting, At-Sea Processing	Marine mammals, seabirds	Bayesian time-series model	2002-2018	Jannot et al., 2021; Jannot et al., 2022
West Coast Limited Entry Bottom Trawl Fisheries; West Coast Mid-water Trawl for Whiting, At-Sea Processing	PR fish	Ratio estimator	2002-2021	Richerson et al., 2022a; Richerson et al., 2022b; Gustafson et al., 2023
West Coast Salmon Troll, Non-Tribal Ocean, WA/OR waters; West Coast Salmon Troll, Tribal Ocean	PR fish	Preseason expected catch and mortality scaled to observed catch.	2011-2021	PFMC, 2021

NBR Fishery or Fisheries	Taxon Groups	Method Shorthand	Years Applied	Reference(s)
West Coast Salmon Troll, Non-Tribal Ocean, CA waters	PR fish	Interviews with fishers to assess the number of sublegal-sized salmon released, with totals expanded based on the sampling rate in each sampling cell. Total bycatch mortality calculated by applying a mortality rate to the number of released fish.	2011-2021	PFMC, 2021
California Large-Mesh Drift Gillnet Fishery	Marine mammals, sea turtles, seabirds	Classification and regression trees	1990-2022	Carretta, 2023
Ridgeback Prawn Trawl, Directed Pacific Halibut	Fish, PR Fish	Ratio estimator	2017-2021	Gustafson et al. 2023; Richerson et al., 2022a, 2022b; Somers et al., 2023a
Ridgeback Prawn Trawl, Directed Pacific Halibut	Marine mammals, seabirds	Bayesian time-series model	2017-2021	Jannot et al., 2022; Jannot et al., 2021
Sea Cucumber Trawl	Fish, PR fish	Ratio estimator	2017	Gustafson et al. 2023; Richerson et al., 2022a, 2022b; Somers et al., 2023a
Sea Cucumber Trawl	Marine mammals, seabirds	Bayesian time-series model.	2017	Jannot et al., 2022; Jannot et al., 2021

Groundfish Fisheries Bycatch Estimation Methods

The WCGOP monitors a variety of vessels that target groundfish or regularly encounter groundfish incidentally. WCGOP analysts expand observed fish and protected resource fish (e.g., salmon) discard rates for these vessels to estimate the total amount of discarded catch by species or taxon group. The coefficient of variation of the discard ratio for each species or taxon group measures statistical uncertainty. Specifically, analysts first calculate the standard error (SE) of the observed discard ratio (Pikitch et al., 1998) and then divide the SE of the discard ratio by the discard ratio itself to yield the coefficient of variation.

Because of the COVID-19 pandemic, vessels were not required to carry observers from April 16 to 30, 2020, to reduce potential virus transmission. Observer requirements resumed in May after additional safety protocols were implemented to protect fishers and observers. Although these additional safety measures decreased the efficiency of observer deployment, NOAA Fisheries maintained observer coverage rates within historical limits for all fisheries except the directed Pacific halibut fishery (Somers et al., 2021).

Fish bycatch estimation methods have varied between fishery sectors due to differences in data availability, management, and observer coverage levels (ranging from <5% to 100%). Implementation of the IFQ groundfish catch share program in 2011 required 100% monitoring of trips and led to changes in methods for estimating bycatch. WCGOP analysts estimate composition of the rare instances when tows, hauls, or sets are unsampled (e.g., due to observer illness) by apportioning unsampled bycatch to specific species using ratio estimators derived from average observed species-specific discard proportions (Somers et al., 2023a). That is, analysts calculated the estimated discard weight of a species for an unsampled haul or set as the sum of unsampled discard weight within a stratum multiplied by the species' discard weight (summed across sampled hauls within a stratum) divided by the total weight of all species discarded in all sampled hauls within a stratum. Analysts added estimated species-level discard weights from unsampled or partially unsampled hauls to the sampled discard weight of each species within a stratum to estimate the total discard weight for each species in a stratum. During the cessation of observer coverage in April 2020, analysts estimated discards using observed discard rates in the corresponding strata during the rest of 2020 (Somers et al., 2023a). Similar ratio estimation methods are used to estimate bycatch of Chinook, coho, chum, pink, sockeye, and unspecified salmon in West Coast Fisheries (Richerson et al., 2022a). Likewise, bycatch of green sturgeon (*Acipenser medirostris*) and the ESA-listed southern Distinct Population Segment of eulachon are estimated using ratio estimators to estimate bycatch in each fishery, using a nonparametric bootstrap procedure to quantify uncertainty in fisheries with less than 100% observer coverage (Richerson et al., 2022b; Gustafson et al., 2023).

Shorebased IFQ sector vessels utilizing EM submit logbooks with self-reported discard estimates as well as video to PSMFC. PSMFC video reviewers use these two datasets to estimate weights of the IFQ species that are allowed to be discarded at sea, as well as any unsampled discards. WCGOP analysts use this dataset, PacFIN fish ticket landings, and scientific observer data to fully estimate discards in the shorebased IFQ sector (Somers et al., 2022, 2023a).

In 2016 and 2017, bycatch estimation methods for protected species in a number of fisheries changed from ratio estimators to model-based methods, as shown in Table 3. For the vessels that target groundfish or regularly incidentally catch groundfish, analysts used Bayesian time series models to estimate bycatch of marine mammals and seabirds, which improved the accuracy of bycatch estimates and allowed for better estimation of uncertainty in those estimates. For seabirds, analysts modeled the bycatch rate as a constant or time-varying, and they inferred annual expected mortality based on the specified level of effort (Jannot et al., 2021). Analysts also formally compared different effort metrics, time-varying to constant bycatch rates, and bycatch-generating models (Poisson vs. negative binomial) (Jannot et al., 2021). In addition, analysts estimated fleetwide bycatch using observer coverage rates, defined as observed landings divided by total landings.

For marine mammals, analysts compared models with different combinations of effort metrics, potential bycatch rates, and bycatch-generating processes (Jannot et al., 2022). Analysts chose the optimal model that best fit the data for each fishery-species-gear type combination comparing leave-one-out information criteria (LOOIC) and selecting the preferred model with the lowest LOOIC estimate (Jannot et al., 2022). Because observer coverage is less than 100% in some groundfish sectors, analysts expanded the estimated bycatch for observed vessels to the entire fleet, which included unobserved vessels. This process accounted for uncertainty in the expansion by estimating the posterior predictive distribution of unobserved bycatch, given unobserved effort and estimated parameters (Jannot et al., 2022).

For the vessels that target groundfish or feature groundfish as an important component of their bycatch, NOAA Fisheries estimated sea turtle bycatch estimates only for the single fishery where a take has ever been observed: the NBR West Coast Groundfish Non-Trawl Gear; Non-Endorsed Fixed Gear fishery. For the 5-year period containing the bycatch event, analysts explored estimating bycatch of sea turtles in this fishery with a Poisson process model where the rate is either fixed or treated as a random variable (Benson et al., 2021). Because only one take of a sea turtle was observed recorded as bycatch in this fishery, analysts returned to using more simplified statistical models for estimates in more recent years (Benson et al., 2023), in contrast to models used for marine mammals and seabirds (Jannot et al., 2022).

West Coast Salmon Troll Fisheries Bycatch Estimation Methods

For the West Coast Salmon Troll, Non-Tribal Ocean fishery, the NBR only includes estimates of salmon discards but not bycatch of marine mammals, sea turtles, seabirds, and other fish. Salmon bycatch estimation methods differ between states. In Washington and Oregon waters, analysts scale preseason expected catch and mortality to the observed catch (PFMC, 2021). Because of the lack of information on released salmon from these fisheries, as well as the lack of independent estimates of observed Chinook and coho bycatch and bycatch mortality, analysts produce bycatch estimates based on historical retained species contact information and projected abundances. Analysts use these same methods to estimate salmon bycatch for the West Coast Salmon Troll, Tribal Ocean fishery.

In California waters, analysts conduct interviews with fishers to assess the number of sublegal-sized Chinook salmon released during a trip. Analysts then expand interview totals based on the sampling rate in each sampling cell. They produce estimates of total salmon bycatch for each time-area cell by expanding interview totals by that cell's sampling expansion. Analysts then calculate total bycatch mortality for each species by applying a hook-and-release mortality rate to the number of released fish and adding in the number of estimated losses resulting from drop-off mortality (PFMC, 2021).

California Drift Gillnet Fishery Bycatch Estimation Methods

In order to estimate fish and invertebrate bycatch in the California Drift Gillnet fishery in earlier editions of the NBR (NOAA Fisheries, 2013), the NOAA Fisheries Southwest Regional Office (which became part of the West Coast Region) used a mean per-unit or ratio estimator to extrapolate bycatch observations from a small percentage of overall fishing effort to an entire fishery (Larese and Coan, 2008). The critical assumption in this method is that fishing methods are homogeneous across all vessels and areas in the fishery. For this reason, the observer program selects vessels at random to obtain a representative sample of fishing effort. Some vessels in a fishery are not observable because they may lack berthing space for an observer. In these cases, the observer program may employ alternative methods of observation, such as EM systems.

Analysts in recent years have estimated bycatch of marine mammals, sea turtles, and seabirds in the California Drift Gillnet fishery with classification and regression trees. Carretta (2023) used random forest classification trees to select variables for inclusion in the bycatch models, where the response variable was bycatch presence or absence for an observed fishing set. Carretta (2023) also used random forest regression tree models to estimate bycatch in unobserved fishing sets. For species (with the exception of beaked whales) observed as bycatch less than or equal to five times, Carretta (2023) used a default set of predictive variables (latitude, longitude, and days) in the regression tree models. Carretta (2023) used other variables in regression tree models for species with six or greater instances of bycatch observed in the dataset. Carretta (2023) calculated the mean annual predicted bycatch per fishing set for each species in a given year as the mean predicted bycatch for all observed sets in that year. Carretta (2023) multiplied these predicted bycatch rates by the number of unobserved sets and then added them to the sum of observed bycatch of each species in a given year to yield mean annual estimates of bycatch for each species from regression trees. This method assumes that observer data are representative of the fishery.

California Halibut, California Ridgeback Prawn, Washington/Oregon/California Pink Shrimp, and California Sea Cucumber Bycatch Estimation Methods

The WCGOP randomly samples catch in fisheries for California halibut and WA/OR/CA pink shrimp, as well as California ridgeback prawn and California sea cucumber fisheries in years when the prawn and sea cucumber fisheries are observed. Analysts calculate discard ratios for these fisheries by dividing the observed discard weight of each species or species complex by the observed retained weight (Somers et al., 2023a). Then, analysts compile fleetwide landings to use the landings as a multiplier with the observed discard ratios to obtain the total discard estimate for a given species. Fish bycatch is estimated using ratio estimators, while marine mammal and seabird bycatch is estimated using Bayesian time-series models (Table 3).

5. Southeast Region

The NOAA Fisheries Southeast Region encompasses ecologically diverse ecosystems with hundreds of fish species and a variety of habitats. The Southeast Region also is home to over 90 stocks of dolphins, whales, and sea turtles, as well as other protected fish species. Louisiana was home to the fifth largest fishery landings by volume in 2020, and shrimp (most of which are landed in the Southeast) represented the fifth highest-value species group for commercial U.S. fisheries in 2020 (NOAA Fisheries, 2022). Update 3 to the NBR included fish bycatch estimates for 12 Southeast fisheries and/or gear types, including pelagic longline, coastal migratory pelagic (CMP), snapper-grouper/reef fish, shark, gillnet, and shrimp trawl fisheries. The NBR contained sea turtle bycatch estimates for a subset of those fisheries, and it included marine mammal and seabird bycatch estimates only for one fishery: the Atlantic HMS pelagic longline (Benaka et al., 2019).

5.1 Fisheries Overview

The South Atlantic Fishery Management Council (SAFMC), Caribbean Fishery Management Council (CFMC), and the Gulf of Mexico Fishery Management Council (GMFMC), in collaboration with the NOAA Fisheries Southeast Regional Office (SERO), manage the fisheries of the Southeast. In addition, the Atlantic HMS Management Division within the NOAA Fisheries Office of Sustainable Fisheries manages the HMS pelagic longline fishery.

The Atlantic HMS pelagic longline fishery targets tunas, swordfish, sharks, and billfish. The fleet operates along the entire Atlantic coast and in the Gulf of Mexico, but the primary scientific program supporting the management of Atlantic HMS, including the pelagic observer program, is administered by the NOAA Fisheries Southeast Fisheries Science Center (SEFSC). The HMS fishery historically has several distinct segments including the Gulf of Mexico yellowfin tuna fishery, South Atlantic swordfish fishery, and Mid-Atlantic and New England tuna and swordfish fishery. The Gulf of Mexico fishery segment generally operates year-round, with the main ports in Florida and Louisiana. The South Atlantic segment of the fishery consists of small- to medium-sized vessels that generally fish year-round and are based mostly out of South Carolina and Florida, with trips lasting around 12 days on average. Fishing trips for the Mid-Atlantic and New England segment, which also operates year-round, last around 18 days on average. The pelagic longline fleet overall has around 200 participants. Pelagic longline gear is composed of several parts, including a mainline that can range from 5 to 40 miles in length with approximately 20 to 30 hooks per mile (NOAA Fisheries, 2006).

The CMP troll fishery operates in the South Atlantic and the Gulf of Mexico. The fishery targets king mackerel (*Scomberomorus cavalla*) and Spanish mackerel (*Scomberomorus maculatus*), which are split into an Atlantic migratory group and Gulf migratory group for management purposes (GMFMC, 2014). The NBR includes bycatch estimates for the South Atlantic fishery and for the Gulf of Mexico fishery. King mackerel fishers traditionally have used hook-and-line and gillnet gear off the west coast of Florida and only hook-and-line gear off Alabama, Mississippi, Louisiana, and Texas. Fishers troll during the winter months along the east and south coast of Florida, and they use run-around gillnets mostly in the Florida Keys during January (GMFMC and SAFMC, 2011). In the Atlantic, king mackerel are a major commercial target species in Florida and North Carolina, as well as a major target species for the private and charter recreational components throughout the South Atlantic region. Allowable gear includes automatic reel, bandit gear, handline, and rod and reel. Gillnets are authorized gear for the directed commercial harvest of king mackerel north of Cape Lookout, North Carolina (GMFMC and SAFMC, 2011). In the Gulf of Mexico, most Spanish mackerel are harvested by gillnets in Florida state waters, while in the South Atlantic, run-around gillnets, cast nets, and handline gear account for the majority of the landings (GMFMC and SAFMC, 2011). Authorized cobia (*Rachycentron canadum*) gear for the Gulf of Mexico and South Atlantic includes automatic reel, bandit gear, handline, rod and reel, and pelagic longline (GMFMC and SAFMC, 2011).

The snapper-grouper fishery occurs along the U.S. EEZ off the Atlantic Coast of the United States from North Carolina to Florida. The snapper-grouper fishery includes multiple species of snappers, groupers, tilefish, and jacks (Overstreet et al., 2018). Commercial permits for this fleet numbered 579 in 2021, and vessels holding these permits use primarily vertical line but also bottom longline gear, as well as other methods including traps/pots and diving, to target fish (SAFMC, 2023; Overstreet et al., 2018). Vessels fishing off Florida range from 20 to 30 feet in length, and vessels fishing off North Carolina, South Carolina, and Georgia range from 30 to 40 feet in length (MacLauchlin, 2018).

The Gulf of Mexico commercial reef fish fishery consists of approximately 800-900 federally permitted vessels (Peterson et al., 2023). These vessels primarily use vertical line, bottom longline, and rod and reel gear to target the 31 different species managed through the FMP for Reef Fish Resources of the Gulf of Mexico. These 31 species include snappers such as red snapper (*Lutjanus campechanus*), groupers including gag grouper (*Mycteroperca microlepis*), tilefishes, wrasses, jacks, and triggerfish (GMFMC, 2020). Between 2014 and 2018, reef fish vessels landed an average of 66% of their fish in Florida and 17% in Texas, with 13% landed in Louisiana and less than 3% each in Mississippi and Alabama (GMFMC, 2020). An average of 64 to 65 vessels use bottom longline gear Gulf-wide, and although these longline vessels represent approximately 12% of the vessels that annually land reef fish, they account for almost a third of annual landings of reef fish by weight (Peterson et al., 2023).

The Atlantic HMS Division within the NOAA Fisheries Office of Sustainable Fisheries manages commercial shark fisheries in the Atlantic and Gulf of Mexico. The shark bottom longline fishery targets large coastal sharks including Atlantic blacktip shark (*Carcharhincus limbatus*) and small coastal sharks including Atlantic sharpnose (*Rhizoprionodon terraenovae*) off the Southeast coast of the United States through the Gulf of Mexico. Vessels in this fishery have an average length of 50 feet and deploy longline gear with 5 to 15 miles of mainline and 500 to 1,500 hooks. In 2007, the Atlantic HMS Division created a shark research fishery, which selects a limited number of commercial shark vessels annually to collect sandbar shark data. As of 2020, about 229 fishers held permits to target sharks in the Atlantic Ocean and Gulf of Mexico (Mathers et al., 2019).

The Southeast gillnet fishery operates from North Carolina to Florida and in the Gulf of Mexico, using a variety of gillnet types including drift and sink gillnets. Some fishers also actively set nets around schools of fish, a method called strike-netting. These gillnet fishers land mackerel, pompano, and bluefish (*Pomatomus saltatrix*), as well as small and large coastal shark species and Atlantic spiny dogfish (*Squalus acanthias*). Most vessels in this fishery are less than 30 feet in length. Vessels have targeted much fewer sharks and more finfish over the past 10 years (Mathers et al., 2020a).

Shrimp trawl fisheries occur year-round in the Atlantic Ocean from North Carolina through Florida and in the Gulf of Mexico from Florida through Texas. A little over 1,700 vessels comprise this fishery (Benaka, 2023). These fisheries utilize mainly skimmer and otter trawls to catch brown, white, and pink shrimp species. The otter trawl fishery operates year-round in the Gulf of Mexico, with the highest effort occurring May through December (Scott-Denton et al., 2020). Vessels catch brown shrimp (*Farfantepenaeus aztecus*) primarily in offshore waters off the coasts of Texas and Louisiana in depths between 20 and 40 fathoms, with white shrimp (*Litopenaeus setiferus*) typically captured in waters of about 10 fathoms in the same areas (Scott-Denton et al., 2020). Pink shrimp (*Farfantepenaeus duorarum*) occur in waters of about 35 fathoms, predominantly off southwestern Florida in the winter months (Scott-Denton et al., 2020). In the northern Gulf of Mexico, the skimmer trawl fishery typically captures brown shrimp from May through July and white shrimp from August through December (Scott-Denton et al., 2020).

5.2 Data Sources

The Atlantic HMS pelagic longline fishery managers and analysts use a variety of data sources to estimate bycatch. These data sources include mandatory self-reported logbook data, at-sea observer data, mandatory recreational fish landings reports, online reporting of dead discards of western Atlantic bluefin tuna (*Thunnus thynnus*) in the commercial harpoon and hook and line fisheries, and survey data (NOAA Fisheries, 2021b). Additionally, some HMS including prohibited shark species may be considered bycatch in non-HMS fisheries. Managers and scientists use self-reported logbooks and observer coverage from other fisheries in the Northeast and Southeast to learn about these bycaught species (NOAA Fisheries, 2021b).

Scientists and managers use self-reported data to support bycatch estimation for CMP troll fisheries. Specifically, the SEFSC selects fishers who are required to maintain and submit fishing records through the SEFSC Commercial Logbook. The SEFSC uses a Supplemental Discard Logbook to collect discard data and sends this discard logbook to a 20% stratified random sample of the active commercial permit holders in the fishery (SAFMC, 2022). Data uncertainty in the self-reported discard rates can be quite high, particularly for species that are difficult to identify (e.g., sharks), with coefficients of variation routinely exceeding 100%, and discards are not always identified to species. Errors in form completion may lead to some odd results when expanding to the fishery as a whole. In addition, non-reporting is an increasing issue. Captains can send back a form that indicates “no discards” and still be in compliance, and these reports have been increasing. The percentage of “no discards” reports when the discard logbook program began was 30-40%. This percentage increased to 60-70% in recent years. To better estimate discards, some non-reporters are eliminated from the computations of discard rates (SAFMC, 2022). The SEFSC’s Southeast Gillnet Observer Program, which deploys observers on any active fishing vessel reporting shark drift gillnet effort, monitors the CMP vessels that use gillnet year. Specifically, the Southeast Gillnet Observer Program covers all anchored (sink, stab, set), strike, or drift gillnet fishing, regardless of species targeted, from Florida to North Carolina and in the Gulf year-round (SAFMC, 2022).

As with the CMP fishery, logbooks have been the primary data source for the South Atlantic snapper-grouper fishery bycatch estimates published in the NBR. The SEFSC uses a Supplemental Discard Logbook sent to a 20% stratified random sample of the active commercial permit holders in the fishery to collect discard data. The self-reporting data uncertainty and “no discard” issues encountered for the CMP fishery are also present for the snapper-grouper fishery. The SEFSC has collected bycatch data through limited observer coverage of the commercial snapper-grouper fishery. However, NOAA Fisheries announced in 2022 that it was increasing observer coverage of the South Atlantic snapper-grouper fishery, expanding coverage to all gear types rather than only vertical line gear, which was the only gear type with observer coverage previously. This coverage increase aimed to increase observer coverage to 2.75% of overall fishing effort and increase the number of vessels selected for coverage from an average of 92 vessels per year to 400 vessels per year. This increased observer coverage should support snapper-grouper bycatch estimates based on observer data.

Managers and analysts rely on logbook and observer data to support bycatch estimates for the Gulf of Mexico commercial reef fish fishery. As with the South Atlantic snapper-grouper fishery, the SEFSC requires commercial reef fish fishers, if selected, to report data on discarded fish (including sea turtles and ESA-listed fish) and the reasons for those discards using a Supplemental Discard and Gear Interaction Trip Report Form. The SEFSC selects a stratified, random sample of the commercial reef fish permit holders (20% coverage) for this requirement (GMFMC, 2022). The self-reporting data uncertainty and "no discard" issues encountered for the snapper-grouper fishery are also present for the reef fish fishery. In 2006, the SEFSC initiated an observer program for the commercial reef fish fishery under Amendment 22 to the Reef Fish FMP, which dictated mandatory observer coverage. This program uses a random selection process stratified by gear and season, and observers report all catch and bycatch, including bycatch of all protected resources (i.e., turtles, ESA-listed fish, marine mammals, and seabirds). The SEFSC increased observer coverage levels for the bottom longline portion of the reef fish fishery in the eastern Gulf of Mexico starting in February 2009 due to concerns regarding sea turtle bycatch. In 2011, additional funding allowed enhanced coverage of both the vertical line and bottom longline sectors through 2014. Observer coverage levels have remained relatively low and inconsistent since then (0.9% to 4.3% between 2015 and 2019) as a result of limited funding during those years (GMFMC, 2022).

Observer data support bycatch estimates for the HMS shark fishery targeting large coastal sharks and small coastal sharks. In 1994, the HMS shark bottom longline observer program was established and requires observers to record targeted catch, bycatch, and incidental catch of all protected resources (GMFMC, 2022). This program covered 6.5% of sea days fished in 2021 (Benaka, 2023). The shark bottom longline observer program provides some additional coverage of Gulf reef fish bottom longline sets. All trips in the Atlantic HMS shark research fishery are covered by observers, which in turn requires no estimation of bycatch.

An observer program initiated in 1993 has supplied observer data to support bycatch estimates for the Southeast gillnet fishery. In 2021, the observer program covered 15% of sea days for the increasingly small fleet of boats that target sharks, and the program covered 8% of sea days for the large fleet of boats targeting finfish (Benaka, 2023).

Managers and scientists use logbooks, observer data, and vessel monitoring systems to estimate overall bycatch for Southeast shrimp trawl fisheries. In the South Atlantic, observers cover approximately 1% of penaeid shrimp and <1% of rock shrimp (*Sicyonia brevirostris*) trips (SAFMC, 2022). The SEFSC uses observer data, strandings data, and other data to monitor sea turtle mortalities resulting from shrimp fishery interactions. Scientists and managers also use observer and effort data collected through the observer program to monitor fishery interactions with ESA-listed fish species. The low levels of observer coverage produce bycatch rates that are generally accurate for common bycatch species. However, this coverage level results in highly variable and uncertain estimates for more rarely caught ESA-listed species (e.g., smalltooth sawfish and giant manta ray) and sea turtles (SAFMC, 2022).

A combination of electronic logbook and observer data supports the estimation of fish and sea turtle bycatch for Gulf of Mexico shrimp trawl fisheries. Vessels selected to carry electronic logbooks provide effort data that can be used by scientists and managers to calculate catch-per-unit-effort. Vessels selected for the program also must provide the size and number of shrimp trawls deployed for each set and the type of bycatch reduction device or turtle excluder device used. Observer coverage in Gulf of Mexico shrimp trawl fisheries has averaged 2.2% between 2016 and 2019. As with the South Atlantic shrimp trawl fishery, this relatively low level of observer coverage produces bycatch rates that are generally accurate for common bycatch species. However, this coverage level likewise results in highly variable and uncertain estimates for rarely caught ESA-listed species and sea turtles (GMFMC, 2022).

5.3 Bycatch Estimation Methods

Scientists at the SEFSC and partner organizations utilize a variety of bycatch estimation techniques for Southeast fisheries in the NBR. Table 4 provides a brief overview of these techniques and references. The following sections provide more detail for the HMS pelagic longline, CMP troll, Southeastern Atlantic snapper-grouper, Gulf of Mexico reef fish, commercial shark, Southeastern coastal gillnet, and Southeast shrimp trawl fisheries. In addition, the NOAA Fisheries Southeast Regional Office and SEFSC have supported the development of the BycatchEstimator[8], an open-access R package that uses both model-based and design-based procedures to estimate total annual bycatch by expanding a sample, such as observed bycatch events stored in a database, to total effort from logbooks or landings records. This package is designed to enable standardized, automated, transparent, and transferable bycatch estimation for any fishery where there is an observer program and a broader effort estimate (e.g., from a logbook).

[8] BycatchEstimator. Available at https://ebabcock.github.io/BycatchEstimator/

Table 4. Summary of estimation methods used to estimate bycatch in Southeast fisheries for the NBR.

NBR Fishery or Fisheries	Taxon Groups	Method Shorthand	Years Applied	Reference(s)
Atlantic and Gulf of Mexico (GOM) HMS Pelagic Longline	Fish, protected resource (PR) fish	Stratified delta lognormal estimator	1993-present	Beerkircher et al., 2002; NOAA Fisheries, 2011
	Marine mammals	Stratified delta lognormal-based ratio estimator	1992-2015	Garrison and Stokes, 2017
	Sea turtles	Stratified delta lognormal-based ratio estimator	1992-2015	Garrison and Stokes, 2017
	Seabirds	Random-year-effect delta model; Bayesian hierarchical hurdle model	1992-2012; 1992-2017	Li and Jiao, 2013; Li et al., 2016; Bi et al., 2021
GOM and Southeastern Atlantic CMP Troll	Fish	Ratio estimator	2005-2015	NOAA Fisheries, 2011
Southeastern Atlantic Snapper-Grouper*	Fish	Ratio estimator	2005-2015	NOAA Fisheries, 2011; Mathers, 2020b
	Sea turtles	Ratio estimator	2005-2015	NOAA Fisheries, 2016b
GOM Reef Fish**	Fish	Ratio estimator	2005-2015	Scott-Denton et al., 2011
	Fish	Discard estimation enhancement via comparison of annual total landed catch from logbook data to the estimated observer annual total landed catch	1993-2017	Smith et al., 2020
	Sea turtles	Delta lognormal approach (for the bottom longline portion of the fishery); binomial model/delta lognormal (for the vertical line portion of the fishery)	2005-2015	SEFSC, 2009a; SEFSC, 2009b

NBR Fishery or Fisheries	Taxon Groups	Method Shorthand	Years Applied	Reference(s)
Southeastern Atlantic and GOM Shark Bottom Longline	Fish, PR fish, marine mammals, sea turtles	Delta lognormal	2005-2018	Richards, 2007; NOAA Fisheries, 2011; Mathers et al., 2019
Southeastern Atlantic and GOM Shark Bottom Longline Research Fishery	Fish, sea turtles	Census observer coverage; no estimation required	2007-2018	Mathers et al., 2019
Southeastern Atlantic Coastal Gillnet (including North Carolina and GOM)	Fish, PR fish, marine mammals, sea turtles	Ratio estimator	2005-2018	NOAA Fisheries, 2011; Kroetz et al., 2020; Mathers et al., 2020a
Gulf of Mexico Shrimp Trawl	Fish	Ratio estimator		Scott-Denton et al., 2012; Scott-Denton et al., 2020
	Marine mammals	Ratio estimator with stratified annual fishery effort data and aggregate bycatch rates		Soldevilla et al., 2021
	Sea turtles	Ratio estimator	2005-2013	Epperly et al., 2002
	Sea turtles	Integrated Bayesian model	2014-2015	Babcock et al., 2018
Southeastern Atlantic Shrimp Trawl	Fish	Ratio-based estimator		Scott-Denton et al., 2012; Scott-Denton et al., 2020
	Sea turtles	Ratio estimator	2005-2013	Epperly et al., 2002
	Sea turtles	Integrated Bayesian model		Babcock et al., 2018

*This fishery includes the NBR Southeastern Atlantic Snapper-Grouper Bottom Longline and Southeastern Atlantic Snapper-Grouper Vertical Line fisheries.
**This fishery includes the NBR GOM Reef Fish Bottom Longline and GOM Reef Fish Vertical Line fisheries.

Atlantic and Gulf of Mexico (GOM) HMS Pelagic Longline Fishery Bycatch Estimation Methods

Scientists estimate dead fish discards in the Atlantic and GOM HMS Pelagic Longline fishery using observer program bycatch rate estimates and effort data from the mandatory fishery logbook system and a stratified delta lognormal estimator. Specifically, they use three different approaches based on the number of observed sets in a particular area or stratum (NOAA Fisheries, 2011). Scientists multiply the general linear model estimated catch rate by the reported number of hooks to estimate the total number of discards, which then is converted to weights using average weight (median in the case of swordfish) estimated from data collected by the observer program. Because several shark species are caught in very low numbers, scientists group shark bycatch estimates for the NBR into two categories–large coastal sharks and pelagic sharks–to improve the accuracy of the estimates (NOAA Fisheries, 2011). Fish bycatch estimates in the NBR only include discarded managed HMS species. Scientists estimate dead discards of bluefin tuna, as described in Brown (2001), by pooling catch rate samples as necessary across strata to achieve a minimum sample size of 30 observations. Scientists then convert the estimates of bluefin tuna dead discards to weight using relevant observer data (if available) or comparable gear/area data (NOAA Fisheries, 2011).

Scientists calculate the mean and variance of catch rates for marine mammals and turtles observed in longline sets using a delta lognormal estimator, using number of hooks as the unit of effort. The estimation process involves stratifying the bycatch estimates by fishing area and quarter to reflect the design (i.e., variable coverage levels) of the observer program (Garrison and Stokes, 2017). The delta estimator approach is more appropriate than the simple mean because catch rates are generally log-normally distributed, and bycatch events (i.e., positive sets) are rare. Garrison and Stokes (2017) describe the equations used to estimate the bycatch rate for each analytical stratum.

Scientists used several methods to estimate seabird bycatch in the Atlantic HMS pelagic longline fishery, including delta random-year-effect models (RYEMs; Li and Jiao, 2013; Li et al., 2016) and a Bayesian hurdle model (Bi et al., 2021). Li et al. (2016) compared their RYEM estimates for three contiguous high bycatch areas (Mid-Atlantic Bight, Northeast Coast, and South Atlantic Bight) to estimates from a Spatial Expansion Model (SEM) applied to the three areas separately. The SEM estimates were higher but had much higher CVs. Most recently, Bi et al. (2021) used observer data (where only 1% of sets indicated “positive” seabird bycatch) to develop Bayesian hierarchical hurdle models, applying those models to logbook data to obtain seabird bycatch estimates for each longline set. Li and Jiao (2013) and Li et al. (2016) used bootstrapping techniques to estimate uncertainties of bycatch estimates. Bi et al. (2021) estimated uncertainty based on the approximated posterior distribution for each longline set. Their CVs for the three high bycatch areas were much lower than those from the SEM.

GOM and Southeastern Atlantic CMP Troll Fishery Bycatch Estimation Methods

Because there is no dedicated observer program for CMP troll fisheries, analysts calculate fish discard rates based on information reported to the SEFSC’s discard logbook program and apply ratio estimation techniques. Scientists establish discard rates for each species as the reported number of discards of a species per hook–hour fished for each trip. Analysts then determine mean discard rates for each species by year, along with coefficients of variation. Then, analysts extrapolate total discards to the fishery by multiplying total hook–hours fished (taken from the SEFSC’s coastal logbook program) by the number of species-specific mean discards per hook–hour (NOAA Fisheries, 2011). Because the data underlying this methodology is self-reported, coefficients of variation for these estimates are high.

Southeastern Atlantic Snapper-Grouper Fishery Bycatch Estimation Methods

As with the CMP troll fishery, bycatch estimates published in the NBR for the Southeastern Atlantic snapper-grouper fishery have relied on self-reported data, following the same general approach used for the CMP troll fishery (NOAA Fisheries, 2011). This approach has resulted in highly imprecise estimates. In recent years, the SEFSC has been able to provide limited observer coverage (e.g., 0.8% of sea days in 2021) for this fleet (Benaka, 2023). The SEFSC increased this observer coverage to 2.75% of the overall fishing effort in 2022, but has not yet published bycatch estimates and estimation methodologies used as a result of this increased observer coverage.

Mathers et al. (2020b) describe preliminary results of limited observer coverage implemented for the vertical line component of this fleet from 2018 to 2020. On these trips, observers completed three forms, including an "Animal Log" that records all species caught; catch condition (e.g., alive, dead, or damaged); and final disposition (e.g., kept, released alive, or discarded dead). Mathers et al. (2020b) presented observed bycatch in units of numbers and did not extrapolate observed discards across the entire fleet. This program experienced low compliance, for example, due to fishers not contacting the organization administering this program upon receipt of selection letters and/or when making a fishing trip, as required.

NOAA Fisheries has gathered bycatch data about sea turtles in this fishery via a variety of limited observer programs, including (NOAA Fisheries, 2016b):

- The shark bottom longline observer program that at times covers vessels targeting fish from the snapper-grouper complex using bottom longline gear;
- An exempted fishing permit issued by the NOAA Fisheries Southeast Regional Office to the North Carolina Division of Marine Fisheries to allow observing of some snapper-grouper bottom longline fishing effort;
- Southeastern supplemental discard data; and
- Gulf of Mexico reef fish bottom longline observed sea turtle bycatch data from 2011 through 2014.

On the basis of these data sources, SERO was able to estimate sea turtle bycatch for the snapper-grouper fishery by multiplying a capture rate per unit effort by total effort, based on a best sea capture rate estimate and a best estimate of effort levels (NOAA Fisheries, 2016b).

Gulf of Mexico Reef Fish Fishery Bycatch Estimation Methods

NOAA Fisheries SEFSC has developed fish bycatch estimates for the GOM Reef Fish fishery based on data availability and analytical capability. Observer data from the GOM Reef Fish Fishery Observer Program supported bycatch estimates in NBR Update 1 (NOAA Fisheries, 2013), logbook data were used to estimate fish bycatch for the NBR First Edition (NOAA Fisheries 2011), NBR Update 2 (NOAA Fisheries, 2016), and NBR Update 3 (Benaka et al., 2019). For logbook-based estimates, analysts calculated discard rates from discard reports made to the SEFSC's discard logbook program. Analysts defined the discard rate for each species as the reported number of discards of a species per hook fished for each trip. They determined a mean discard rate for each species by year along with coefficients of variation. Analysts calculated total effort (in hooks fished) for the fishery from the SEFSC coastal logbook program database, and then they extrapolated total discards to the fishery by multiplying total hooks fished by species-specific mean discards per hook (NOAA Fisheries, 2011). When observer data were used to calculate fish discards, analysts calculated effort by multiplying the number of hooks set at each location by soak time to derive hook-hours. Analysts calculated catch rates as the number of fish per hook-hour. Data collected through the observer program on fish kept and discarded allowed analysts to use ratio estimation to analyze species-specific catch rates (Scott-Denton et al., 2011).

Smith et al. (2020) applied new discard estimation methods for Gulf of Mexico red grouper (*Epinephelus morio*), gray triggerfish (*Balistes capriscus*), vermilion snapper (*Rhomboplites aurorubens*), and cobia (*Rachycentron canadum*). The analysts conducted discard estimation separately for two gears, vertical line and bottom longline. A verification step compared annual total landed catch from logbook data with the estimated observer annual total landed catch. Once verified, analysts estimated cobia annual total discards in weight and number for the observer data period 2007-2018 and then hindcasted the estimates for the period 1993-2006 (Smith et al., 2020).

The SEFSC calculated sea turtle bycatch estimates for the GOM Reef Fish fishery through mandatory observer coverage established in 2006, an electronic monitoring pilot program in 2008, and increased observer coverage for the bottom longline sector in 2009 (Scott-Denton et al., 2011). Analysts extrapolated observed sea turtle bycatch using fishery effort data and a delta lognormal approach (frequently used to estimate the mean and variance of observations where there is a high frequency of zero catch data) to produce sea turtle bycatch estimates for the bottom longline portion of the fishery (SEFSC, 2009a). For the vertical line portion of the fishery, analysts also used a delta lognormal approach, which combined a binomial model (frequency of occurrence) for the total observations by hook-hour with the average density for the non-zero catch per unit effort data, which are assumed to be lognormally distributed. However, because the average density of non-zero catches was always one, the model used was effectively a binomial model based on presence/absence data (SEFSC, 2009b).

Commercial Shark Fishery Bycatch Estimation Methods

The Southeast Shark Bottom Longline Observer Program collects data that support the estimation of bycatch in the Southeastern Atlantic and GOM Bottom Longline Shark fishery, as well as the related research fishery. Observers are deployed on all research fishery trips, so bycatch estimation is unnecessary for this fishery. For the commercial fishery, analysts use observed takes to estimate the mean shark bycatch per hook per set and then multiply that by total hook effort extracted from logbooks to yield total fishery bycatch (NOAA Fisheries, 2011). Deployed observers complete three forms, including an “Animal Log” that records all species caught; catch condition (e.g., alive, dead, or damaged); and final disposition (e.g., kept, released alive, or discarded dead) (Mathers, 2020b). A 2017 NOAA Technical Memorandum (Gulak et al., 2017) provided individual-to-weight conversion factors for particular species captured in longline fisheries, and analysts applied these conversion factors for NBR Update 3 (Benaka et al. 2019) to estimate bycatch weights for this fishery .

Southeastern Atlantic Coastal Gillnet Fisheries Bycatch Estimation Methods

The Southeast Gillnet Observer Program provides data supporting bycatch estimation for the Southeastern Atlantic Coastal Gillnet fisheries. Analysts use a simple ratio estimator (number of animals/number of observed sets) to calculate bycatch rates, and they derive estimates for three gear types: drift, strike, and sink gillnet. Then, analysts extrapolate to estimate total bycatch by multiplying bycatch rates by total effort (number of sets) extracted from logbooks (NOAA Fisheries, 2011). Using this approach as a basis for estimation and analysis, Mathers et al. (2020a) describe bycatch for these fisheries for 2018, and Kroetz et al. (2020) describe factors influencing protected species bycatch in this fishery.

Southeast Shrimp Trawl Fishery Bycatch Estimation Methods

Since 1992, a long-standing voluntary and then mandatory observer program has provided data for the estimation of bycatch in the Southeast shrimp trawl fishery (Scott-Denton, 2007). The SEFSC's observer program places NOAA Fisheries-approved observers on randomly selected vessels in the Gulf of Mexico based on the previous full year of effort stratified by area, depth, and season. The SEFSC uses shrimp landings data to allocate sampling effort for South Atlantic vessels proportionally (Scott-Denton et al., 2020). For the Gulf of Mexico shrimp trawl fleet, observers recorded 14 other species of commercial, recreational, and ecological importance, including Atlantic croaker (*Micropogonias undulatus*), black drum (*Pogonias cromis*), king mackerel, lane snapper *(Lutjanus synagris*), longspine porgy (*Stenotomus caprinus*), red drum (*Sciaenops ocellatus*), seatrout (*Cynoscion* spp.), southern flounder (*Paralichthys lethostigma*), and Spanish mackerel. Observers classify the remaining finfish species into a "grouped finfish other" category. From 2007 through 2008, observers grouped all shark species. However, beginning January 2009, observers began to identify some shark species. The observer program developed similar selection lists and methods for the South Atlantic penaeid and rock shrimp fisheries (Scott-Denton et al., 2012). Species total weights, extrapolated from subsample weight using the total catch weight, were based on all sampled nets (sampling unit) per tow. Analysts derived total weight extrapolations by multiplying the sample weight of the species of interest by the total weight of the sampled net, divided by the subsample weight for that net. For rare species and red snapper, observers removed all specimens from the net, which necessitated no extrapolation. Analysts used ratio estimation for analyses of species-specific bycatch rates (Scott-Denton et al., 2020).

Although the shrimp trawl fishery includes southeastern U.S. Atlantic and Gulf of Mexico waters, more than 90% of observer program effort and all observed marine mammal takes have occurred in the Gulf of Mexico (Soldevilla et al., 2021). Therefore, the NBR has included marine mammal bycatch estimates only for the Gulf of Mexico shrimp trawl fleet. Analysts estimated marine mammal bycatch using observer data and stratified shrimp fishery effort models. They calculated bycatch rates under two stratification scenarios and two species identification assumptions. Analysts calculated annual mortality estimates using the ratio estimator with stratified annual fishery effort data for 2015 to 2019 and aggregate bycatch rates for 2000 to 2019. For each of the five years, analysts calculated five-year unweighted mean mortality estimates for Gulf of Mexico dolphin stocks (Soldevilla et al., 2021).

For the NBR First Edition (NOAA Fisheries, 2011), analysts used a ratio estimator to estimate bycatch rates of sea turtle species in both the Southeast Atlantic shrimp trawl and Gulf of Mexico shrimp trawl fisheries. Analysts used expansion factors based on logbook data (Epperly et al., 2002; NOAA Fisheries, 2002). For the 2014 and 2015 sea turtle bycatch estimates published in NBR Update 3 (Benaka et al., 2019), Babcock et al. (2018) applied integrated Bayesian models to the observer data to estimate sea turtle bycatch. Analysts also estimated sea turtle mortality, defined as the total number of sea turtles that were caught in shrimp trawls and died at the time of capture. They estimated total bycatch mortality by multiplying the probability of mortality for turtles caught in shrimp trawl nets by the total bycatch estimated from a linear model of catch per unit effort (CPUE) per stratum (area, season, depth zone, and time period), multiplied by the total effort in each stratum. For rare species, analysts estimated the bycatch rate by modeling CPUE of all species together and multiplying this by the species composition to get species-specific CPUE. Babcock et al. (2018) estimated total bycatch mortality separately for the Gulf of Mexico and the Southeastern Atlantic shrimp trawl fisheries, as well as for standard shrimp otter trawl nets versus “try” nets, which are small nets fishers deploy in front of the primary nets to test catch rates. Babcock et al. (2018) found that about 30% of sea turtles caught in standard nets were dead, while less than 1% of sea turtles caught in try nets were dead.

6. Greater Atlantic Region

The NOAA Fisheries Greater Atlantic Region covers approximately 100,000 square miles of the Northwest Atlantic Ocean, from the coast of Maine to Cape Hatteras, North Carolina. Greater Atlantic waters provide habitat for valuable natural resources, from scallops, lobster, and summer flounder to the endangered North Atlantic right whale. Massachusetts is home to New Bedford, the top-ranked U.S. port in terms of landings value (NOAA Fisheries, 2022).

Update 3 to the NBR (Benaka et al. 2019) included fish bycatch estimates for over 40 Greater Atlantic fisheries, including numerous gear types (e.g., gillnet, trawl, and purse seine) targeting the following fish:

- Northeast multispecies groundfish
- Golden tilefish (*Lopholatilus chamaeleonticeps*)
- Monkfish (*Lophius americanus*)
- Atlantic spiny dogfish
- Atlantic mackerel (*Scomber scombrus*), squid, and butterfish (*Peprilus triacanthus*)
- Summer flounder (*Paralichthys dentatus*), scup (*Stenotomus chrysops*), and black sea bass (*Centropristis striata*)
- Skate
- Atlantic herring (*Clupea harengus*)
- Atlantic surfclam (*Spisula solidissima*) and ocean quahog (*Arctica islandica*)
- Atlantic sea scallop (*Placopecten magellanicus*)
- American lobster (*Homarus americanus)*

Update 3 to the NBR also included marine mammal bycatch estimates for Greater Atlantic gillnet, trawl, and purse seine fisheries, as well as sea turtle bycatch estimates for sink gillnet gear, and seabird bycatch estimates for gillnet, trawl, and scallop dredge fisheries (Benaka et al., 2019).

6.1 Fisheries Overview

Greater Atlantic fisheries with bycatch estimates that have been included in the NBR and its updates comprise a wide variety of fisheries managed by the New England Fishery Management Council (NEFMC), Mid-Atlantic Fishery Management Council (MAFMC), and Atlantic States Marine Fisheries Commission (ASMFC), in collaboration with the NOAA Fisheries Greater Atlantic Regional Office (GARFO). The NEFMC's Commercial Fishing Performance Measures interactive website[9] features the most current effort and economic data for most of these fisheries.

The NEFMC's Northeast Multispecies (Groundfish) FMP describes management for 13 species including Atlantic cod (*Gadus morhua*), Atlantic halibut (*Hippoglossus hippoglossus*), haddock (*Melanogrammus aeglefinus*), Atlantic pollock (*Pollachius virens*), yellowtail flounder (*Limanda ferruginea*) , and winter flounder (*Pseudopleuronectes americanus*). The NEFMC also separately manages hake species with GARFO through a series of "exemptions" from the Northeast Multispecies (Groundfish) FMP. These groundfish species are demersal, living near the ocean

[9] Commercial Fishing Performance Measures. Available at https://apps-nefsc.fisheries.noaa.gov/socialsci/pm/index.php

bottom and feeding on benthic organisms (NEFMC and MAFMC, 2015). Fishers primarily use otter trawls and gillnets with varying mesh sizes to target these species. Vessels fishing for groundfish using gear with larger mesh sizes generally are based in Massachusetts (Gloucester, New Bedford, Boston, and Chatham) as well as Portland, Maine. Vessels using gear with smaller mesh sizes generally are based in Massachusetts (New Bedford and Gloucester); Point Judith, Rhode Island; Montauk, New York; and New London, Connecticut (NEFMC and MAFMC, 2015). Most vessels in this fleet range from 30 to 50 feet in length (NEFMC, 2020). The multispecies groundfish fishery encompasses several NBR fisheries, which are listed in Appendix 1.

The golden tilefish fishery occurs north of the Virginia/North Carolina border, and fishers almost exclusively use longline gear to harvest golden tilefish (NEFMC, 2020). This fishery is small, consisting of less than 15 vessels, and its bycatch corresponds to the Mid-Atlantic Bottom Longline NBR fishery (NEFMC and MAFMC, 2015). For more background information about this fishery, see MAFMC 2022a.

The monkfish fishery predominately utilizes bottom trawls and gillnets for harvesting. The main ports for monkfish landings include New Bedford, Gloucester, and Boston, Massachusetts, as well as Barnegat Light, New Jersey, and Point Judith, Rhode Island (NEFMC and MAFMC, 2015). The monkfish fishery encompasses several NBR fisheries, including New England and Mid-Atlantic Otter Trawl fisheries, Mid-Atlantic Gillnet fisheries, and the New England Bottom Longline fishery. For more background information about this fishery, see NEFMC and MAFMC 2023a.

The Atlantic spiny dogfish fishery primarily utilizes gillnets, bottom longlines, and otter trawls. The main ports for spiny dogfish landings include Gloucester, Chatham, and New Bedford, Massachusetts, as well as ports in Virginia, North Carolina, New Hampshire, and New Jersey (NEFMC and MAFMC, 2015). The spiny dogfish fishery encompasses several NBR fisheries, including New England and Mid-Atlantic Otter Trawl fisheries, New England and Mid-Atlantic Gillnet fisheries, and the New England Bottom Longline fishery.

The Atlantic mackerel, including Atlantic chub mackerel (*Scomber colias*), squid, and butterfish fishery mostly occurs in Southern New England and Mid-Atlantic waters. Fishers use small-mesh otter trawls to harvest squid, mid-water and bottom otter trawls to harvest butterfish, and mid-water otter trawls to harvest Atlantic mackerel (NEFMC, 2020). Fishing for Atlantic mackerel occurs year-round, although most fishing activity occurs from January through April. The squid fishery, which consists of shortfin squid (*Illex illecebrosus*) and longfin squid (*Doryteuthis pealeii*), occurs largely from June to October for shortfin squid and from October to April for longfin squid. Butterfish are landed year-round. The primary ports for Atlantic mackerel include North Kingston, Rhode Island, and Gloucester and New Bedford, Massachusetts, while the primary butterfish ports include Point Judith, Rhode Island, and Montauk, New York. In addition, the primary squid ports include ports in Rhode Island, New York, and New Jersey (NEFMC and MAFMC, 2015). The Atlantic mackerel, squid, and butterfish fishery encompasses several NBR fisheries, including New England and Mid-Atlantic Otter Trawl fisheries and the Mid-Atlantic Twin Trawl fishery.

The summer flounder, scup, and black sea bass fishery primarily occurs primarily from Cape Cod, Massachusetts, to Cape Hatteras, North Carolina. Fishers use bottom otter trawls primarily to harvest summer flounder and scup and use both bottom otter trawls and pots and traps in almost equal measure to harvest black sea bass (NEFMC and MAFMC, 2015). The main summer flounder ports range from Rhode Island to North Carolina, while primary ports for scup include Point Judith, Rhode Island, and Montauk, New York. Primary black sea bass ports range from Massachusetts to Maryland (NEFMC and MAFMC, 2015). The summer flounder, scup, and black sea bass fishery encompasses several NBR fisheries, including New England and Mid-Atlantic Otter Trawl fisheries, New England and Mid-Atlantic Hand Line fisheries, and New England and Mid-Atlantic Pots and Traps fisheries. The New England Hand Line (including rod and reel) fishery has included 258 vessels taking an average of 11 trips per year, lasting less than a day per trip on average. The Mid-Atlantic Hand Line fishery has included 208 vessels taking an average of 21 trips per year, lasting less than a day per trip on average. The New England fish pot fishery has included 34 vessels taking an average of 20 trips per year, lasting less than a day per trip on average. Mid-Atlantic fish pot vessels have averaged 65 vessels fishing per year, taking an average of 22 fishing trips each per year, lasting less than a day per trip on average. The New England and Mid-Atlantic fish trap fleets are small, with 4 and 7 vessels, respectively, taking an average of 33 to 37 trips annually, with each trip lasting less than a day (NEFMC and MAFMC, 2015). For more background information about this fishery, see MAFMC 2022b.

The fish and conch pot and trap fishery features the same number of vessels, trips, and trip lengths as those of the summer flounder, scup, and black sea bass fishery. The fish and conch pot and trap fishery, in addition to catching summer flounder, scup, and black sea bass, also catches relatively small amounts of channeled whelk (*Busycotypus canaliculatus*) in New England waters and tautog (*Tautoga onitis*), American lobster, channeled whelk, eels, and Jonah crab (*Cancer borealis*) in Mid-Atlantic waters (NEMFC and MAFMC, 2015).

The Northeast skate fishery occurs in the Gulf of Maine, Georges Bank, and Southern New England, although some species are fished as far south as the Chesapeake Bight (NEFMC and MAFMC, 2015). Fishers primarily use otter trawls but also use gillnets to harvest skates. Massachusetts and Rhode Island are home to the primary skate ports (NEFMC and MAFMC, 2015). The Northeast skate fishery encompasses several NBR fisheries, including New England and Mid-Atlantic Otter Trawl fisheries, as well as New England Gillnet fisheries.

The Atlantic herring fishery occurs off Maine to North Carolina. Fishers use mid-water trawls or purse seines to harvest Atlantic herring, with fishing most active during winter months south of New England and during summer and early fall in Georges Bank. Maine and Massachusetts host the primary Atlantic herring ports (NEFMC and MAFMC, 2015). The Atlantic herring fishery encompasses several NBR fisheries, including the New England Purse Seine and New England Mid-Water Trawl fisheries. The New England Purse Seine fishery has included an average of just over 17 vessels per year, with each vessel taking an average of 19 trips per year lasting less than a day each on average. The New England Mid-Water Trawl fishery has averaged 21 vessels per year, with each vessel taking an average of 22 fishing trips per year, with most trips lasting from 1 to 4 days (NEFMC and MAFMC, 2015). For more background information about this fishery, see NEFMC 2019.

For the Atlantic surfclam and ocean quahog fishery, fishers harvest Atlantic surfclams on Georges Bank, south of Cape Cod, off Long Island, southern New Jersey, and the Delmarva Peninsula, and fishers harvest ocean quahogs in offshore waters south of Nantucket to the Delmarva Peninsula. They use hydraulic clam dredges to harvest Atlantic surfclams and ocean quahogs. New Jersey, Massachusetts, Maryland, New York, and Maine are home to the primary ports for this fishery (NEFMC and MAFMC, 2015). The Atlantic surfclam and ocean quahog fishery corresponds to the New England and Mid-Atlantic Clam/Quahog Dredge NBR fisheries. The New England Clam/Quahog Dredge fishery has an average of 15 vessels taking an average of 10 to 30 trips per vessel per year. The Mid-Atlantic fishery has an average of 34 vessels taking an average of 19 to 30 trips per vessel per year (NEFMC and MAFMC, 2015). For more background information about this fishery, see MAFMC 2022c.

Fishers in the Atlantic sea scallop fishery overwhelmingly use dredges (and to a small extent trawls) to harvest Atlantic sea scallops in the Gulf of Maine, eastern Georges Bank, the Great South Channel (between Nantucket and Georges Bank), the New York Bight, and the waters adjacent to Delaware, Maryland, and Virginia. Most scallop vessels are based in Massachusetts, Virginia, New Jersey, and North Carolina, and the primary scallop ports are located in New Bedford, Massachusetts, Cape May, New Jersey, and Newport News, Virginia (NEFMC and MAFMC, 2015). The Atlantic sea scallop fishery corresponds to the New England and Mid-Atlantic Scallop Dredge NBR fisheries, as well as the Mid-Atlantic Scallop Trawl NBR fishery. The New England Scallop Dredge fishery has averaged 354 vessels taking an average of over 13 trips per year, with trips having an average length of just over 4 days. The Mid-Atlantic Scallop Dredge fishery has averaged 342 vessels taking an average of 22 fishing trips per year, with trips lasting an average of 2.5 days. The Mid-Atlantic Scallop Trawl fishery has 33 vessels taking an average of 26 trips per year, with trips averaging just over 1 day (NEFMC and MAFMC, 2015). For more background information about this fishery, see NEFMC 2021.

The ASMFC manages the American lobster fishery in collaboration with NOAA Fisheries and the following states: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Virginia. Fishers harvest lobsters in the waters of the Gulf of Maine, Georges Bank, and Southern New England. These states issue permits for lobster fishing in state waters, and GARFO issues permits for fishing in federal waters. An average of 11,396 vessels based in states from Maine to New Jersey were issued commercial lobster permits each year between 2009 and 2013 (NEFMC, 2020). The majority of fishing effort occurs in the Gulf of Maine, where boats averaging 22 to 42 feet in length take day trips within 12 miles offshore. Georges Bank fishing is conducted by larger boats (55 to 75 feet in length) that take multi-day trips. The Southern New England fleet consists of a small vessel dayboat sector and an offshore sector that takes multi-day trips (NEFMC, 2020). The American lobster fishery corresponds to the New England and Mid-Atlantic Lobster Pot fisheries. For more background information about this fishery, see ASMFC 2023.

The MAFMC and ASMFC work cooperatively with GARFO to develop fishing regulations for bluefish off the east coast of the United States. The recreational sector has accounted for 70% of the bluefish total catch by weight over the past 20 years. Recreational fishers mainly use rod and reel gear to catch bluefish. In the commercial sector, fishers use gillnets as the principal gear to harvest bluefish, along with hook and line gear and trawls.

The NEFMC manages the Atlantic deep-sea red crab (*Chaceon quinquedens*) fishery. The red crab commercial fishery is relatively small, consisting of medium to large fishing vessels that fish in deep water (400 – 800 meters). Fishers set their red crab pots in strings of 75–180 pots per string (NEFMC, 2002). Observer data from 2016–2022 indicate minimal bycatch of non-target species in the red crab fishery, including but not limited to Jonah crabs, lobster, white hake (*Urophycis tenuis*), and monkfish (NEFMC and MAFMC, 2023b).

6.2 Data Sources

The NOAA Fisheries Northeast Fisheries Science Center (NEFSC) administers a comprehensive Northeast Fisheries Observer Program (NEFOP) to collect data to support the estimation of fish and invertebrate bycatch as described in the revised Standardized Bycatch Reporting Methodology (SBRM) Amendment (NEFMC and MAFMC, 2015). NEFOP and At-Sea Monitoring (ASM) observer data, electronic monitoring data (NEMIS), dealer data, and vessel trip report (VTR) data support the calculation of fish and invertebrate bycatch estimates for the NBR. Observer data include information on species encountered during fishing activities, gear characteristics, fishing effort, economic data, and biological samples. Analysts also use information in the Days-At-Sea database to assign fishing trips to a fishery sector. In addition, analysts use data from the Vessel Monitoring System (VMS) and Allocation Management System (AMS) databases to stratify VTR data into fleets. Analysts also use commercial landings data (from the Greater Atlantic Region dealer database) to validate the discard estimation methods and inform landings totals for unobserved trips (Wigley et al., 2008; Blaylock et al., 2013; Blaylock et al., 2015). The Catch Accounting and Monitoring System (CAMS), a joint venture between the NOAA Fisheries Greater Atlantic Regional Office and NEFSC, will support bycatch estimation for upcoming NBR products. CAMS incorporates all commercial fisheries data sources including dealer, VTRs, VMS, observer data, and EM data, which are linked and stratified based on regulations and variables such as gear, mesh size, area definitions, and sectors (for groundfish) (GARFO and NEFMC, 2023). In addition to the data provided from federal observer programs, the ASMFC requires commercial harvesters to report data on their fishing activities, including spatial and temporal effort data, in part to understand where fishing effort may overlap with endangered North Atlantic right whales (ASMFC, 2018).

Data sources for estimating bycatch of marine mammals in Mid-Atlantic Gillnet, Midwater Trawl, and Bottom Trawl fisheries and New England Gillnet, Midwater Trawl, and Bottom Trawl fisheries include observer data collected from a sample of the fishing fleet by NEFOP, as well as Southeast fisheries observer programs (up until 2016) and the Northeast Fisheries ASM Program. Observer data include commercial fishing locations and practices, fish catch and discard composition, vessel and trip characteristics, and incidental bycatch of protected species. These data are combined with commercial fishery trip data collected by VTRs, North Carolina and Virginia trip tickets, and dealer weigh-out slips to support estimation of marine mammal bycatch (Lyssikatos, 2015; Chavez-Rosales et al., 2017; Orphanides and Hatch, 2017; Lyssikatos and Garrison, 2018).

The NEFSC has supported the estimation of sea turtle bycatch for a variety of Greater Atlantic gear types, including gillnet (Murray, 2009; Murray, 2013; Murray, 2018; Murray, 2023); scallop dredge (Murray, 2011; Murray, 2015a); and bottom trawl (Warden, 2011; Murray, 2020). In order to estimate and characterize sea turtle bycatch in U.S. mid-Atlantic gillnets for 1995 to 2006, Murray (2009) used sea surface temperature (SST) data, as well as observer data, which included characteristics of each trip, gear set, and haul, information on kept and discarded fish catch, and incidental bycatch of protected species. Murray (2009) also used commercial landings data to estimate mid-Atlantic gillnet sea turtle bycatch, including VTRs, dealer landing reports, and North Carolina Division of Marine Fisheries (NCDMF) data. To characterize and estimate sea turtle bycatch in this same fishery for 2007 to 2011, Murray (2011) again used SST data, NEFOP data (including data collected by independent vessels positioned near fishing operations), and, to a much lesser extent, ASM data. Murray (2011) also used primarily VTR data to quantify fishing effort, supplementing the VTR data to a limited extent with NOAA

Fisheries Greater Atlantic dealer data and NCDMF data. The NEFSC also estimated sea turtle bycatch for Greater Atlantic sink gillnet gear for 2012 to 2016 (Murray, 2018) and for 2017 to 2021 (Murray, 2023) using NEFOP and ASM data, as well as VTR and NCDMF data. The NEFSC used a wide variety of data to estimate sea turtle bycatch in the scallop dredge fishery for 2001 to 2008 (Murray, 2011), 2009 to 2014 (Murray, 2015a), and 2015 to 2019 (Murray, 2021), including interaction rates[10] based on NEFOP data, VTR data, SST and depth data, and whether the vessel used a chain mat.[11] The NEFSC estimated sea turtle bycatch in bottom trawl fisheries for 2005 to 2008 (Warden, 2011), 2009 to 2013 (Murray, 2015b), and 2014 to 2018 (Murray, 2020), using NEFOP, ASM, and VTR data, along with latitude, depth, and SST data.

Sigourney et al. (2019) used at-sea observer and monitoring data from the NEFOP and ASM programs, as well as total commercial fishing effort from mandatory VTRs, to estimate bycatch for 10 species of seabirds in 6 Greater Atlantic gear types.

6.3 Bycatch Estimation Methods

NOAA Fisheries has applied two estimation methods to estimate fish and invertebrate bycatch in all Greater Atlantic fisheries over the past 20 years. Estimation methods used for protected species including marine mammals, sea turtles, and seabirds in grouped gillnet and trawl fisheries have varied over the past 20 years. Table 5 provides an overview of these techniques and references.

[10] Observable interaction rates were based on turtles captured in or on the dredge gear or observed interacting with the gear.

[11] A chain mat is a scallop dredge gear modification designed to prevent sea turtle captures and injury in a vessel's scallop dredge bag.

Table 5. Summary of estimation methods used to estimate bycatch of fish, invertebrates, marine mammals, sea turtles, and seabirds in Greater Atlantic fisheries for the NBR.

Fishery Group	Taxon Groups	Method Shorthand	Years Applied	Reference(s)
All	Fish	Combined ratio estimator with broad fleet stratification	2005, 2010-2015	Wigley et al., 2008; Blaylock et al., 2013; Blaylock et al., 2015; Tholke et al., 2017
All	Fish	Separate ratio estimator with fine fleet stratification (estimates rolled up to broad fleets)	2017-2023	Hocking et al., 2024
Mid-Atlantic and New England Bottom Otter Trawl, Mid-Atlantic and New England Gillnet (sink and drift)	Protected resource (PR) fish	Generalized linear model framework (with quasi-poisson assumption)	2000-2021	Miller and Shepherd, 2011; Miller, 2015; Curti, 2016; Boucher and Curti, 2023
Mid-Atlantic Gillnet	Marine mammals	Stratified annual and pooled ratio estimators (five-year weighted average; estimates generated for gillnets aggregated over mesh sizes)	2007-2018	Lyssikatos and Garrison, 2018; Lyssikatos, 2022
Mid-Atlantic Gillnet	Marine mammals	Stratified annual ratio estimator (estimates generated for gillnets aggregated over mesh sizes)	2005-2019	Precoda and Orphanides, 2022; Orphanides and Hatch, 2017
Mid-Atlantic and Northeast Bottom Otter Trawl (includes twin trawl)	Marine mammals	Stratified annual ratio estimator (five-year average)	2008-2022	Precoda and Lyssikatos, 2024; Lyssikatos and Chavez-Rosales, 2022; Lyssikatos, 2015; Chavez-Rosales et al., 2017
Mid-Atlantic and Northeast Single and Paired Midwater Trawl	Marine mammals	Ratio estimator or Poisson logistic regression model	2003-2010	Hayes et al., 2023; Waring et al., 2010

Fishery Group	Taxon Groups	Method Shorthand	Years Applied	Reference(s)
Mid-Atlantic and New England Gillnet	Marine mammals	Stratified annual ratio estimator (estimates generated for gillnets aggregated over mesh sizes)	2006-2022	Precoda, 2024; Precoda and Orphanides, 2022; Orphanides and Hatch, 2017
Mid-Atlantic Gillnet	Sea turtles	Generalized additive model (GAM) with a Poisson distribution	1995-2006, 2007-2011	Murray, 2009; Murray, 2013
Mid-Atlantic and Georges Bank Sink Gillnet	Sea turtles	Stratified ratio estimator	2012-2023	Murray, 2018; Murray, 2023
Mid-Atlantic Scallop Dredge	Sea turtles	GAM with a Poisson distribution	2001-2008, 2009-2014	Murray, 2011; Murray, 2015a
Mid-Atlantic Scallop Dredge	Sea turtles	Ratio estimator	2015-2019	Murray, 2021
Mid-Atlantic Bottom Trawl	Sea turtles	GAM	2005-2008, 2009-2013	Warden, 2011; Murray, 2015b
Mid-Atlantic and Georges Bank Bottom Trawl	Sea turtles	Stratified ratio estimator	2014-2018	Murray, 2020
Mid-Atlantic and/or New England Gillnets, Purse Seine, Bottom Otter Trawl, Paired Midwater Trawl, and Sea Scallop Dredge	Seabirds	Bayesian hierarchical model	1996-2016	Hatch, 2017; Sigourney et al., 2019

Fish and Invertebrate Bycatch Estimation Methods for All Fisheries

For 2005 and 2010-2013, the Greater Atlantic Region provided annual bycatch estimates of federally managed fish and invertebrate species using a combined ratio estimator and broad fleet stratification (Wigley et al., 2008; Blaylock et al., 2013, 2015; NOAA Fisheries, 2011). For 2014-2015, the analyses were expanded to include 165 individual species and species groups (Tholke et al., 2017; Benaka et al., 2019).

The approach for 2005 and 2010-2015 NBR estimates used a combined discard-to-kept ratio estimator (Cochran, 1963) and a broad fleet stratification (gear type, mesh size, access area, trip category, area fished, and calendar quarter) to produce bycatch estimates. This analysis defined “discard” as discarded pounds of a given species or species group and “kept” as the kept pounds of all species. The sampling frame was defined as federally permitted vessels with VTRs (including logbooks from the surf clam and ocean quahog fisheries) because all federally permitted vessels are required to file a VTR for each fishing trip, except for vessels holding only a federal lobster permit (Blaylock et al., 2015; Tholke et al., 2017). Analysts multiplied the estimated discard rate for that particular species in that fleet by the corresponding fleet landings from VTRs to derive estimated total annual discards (in weight) of a species by a fleet (Wigley et al., 2008; Blaylock et al., 2013; Blaylock et al., 2015; Tholke et al., 2017). Bycatch of fish and invertebrates were estimated at the level of individual fisheries, rather than at the fishery group level, as was done for Greater Atlantic protected species bycatch estimates (as described in the following section). This is because the sample sizes of observed fish bycatch events were much higher than the sample sizes for bycatch of protected species due to differences in gear selectivities and population densities.

The approach for generating bycatch estimates for the NBR from 2017 to 2023 generally followed the SBRM originally described by Wigley et al. (2007) and modified by Nitschke (2010) to support quota monitoring. The process involves using a ratio estimator (Cochran, 1977) for trips carrying a human at-sea observer (i.e., "observed" subtrips) to estimate the rate (or ratio) of discarded weight for a given species per total kept weight of all species (i.e., a proxy for effort) for each subtrip of a trip. A subtrip is defined as a change in federal statistical area, gear, or mesh, which follows the VTR reporting requirements. Unobserved subtrips are assumed to discard a given species at rates similar to those of observed subtrips, depending on a collection of stratification variables describing subtrip attributes (e.g., gear type, mesh, and statistical area fished) and potentially other relevant attributes such as regulation and fishing year. Discard estimation within a fishing year includes additional methods to accommodate sparse data in the early part of a fishing year for species with quota management needs where rates are joined with previous years or aggregated to broader stratifications when there are fewer than five observed subtrips (Linden et al., 2016). Observed subtrips are assigned the observer-reported discards rather than the estimated rate. Groundfish trips monitored with EM are assigned the recorded discards when reviewed. Unreviewed EM trips are assigned a model-based estimate that is a function of the vessel's past history of self-reported discards on their VTR relative to the reviewed EM discards (Linden, 2021). This approach is designed to accommodate data gaps created by monitoring waivers issued by NOAA Fisheries during the COVID-19 pandemic, although lower sample sizes (number of observed trips) contribute to greater uncertainty or higher coefficients of variation in the corresponding bycatch estimates.

Atlantic Sturgeon Bycatch Estimation Methods

Bycatch of ESA-listed Atlantic sturgeon is estimated by modeling sturgeon takes using a generalized linear model framework with quasi-poisson assumption, with trip-specific species mix, year, and quarter as predictors (Miller and Shepherd, 2011; Miller, 2015; Curti, 2016; Boucher and Curti, 2023). This approach allows the variation to be greater than the variation of a Poisson distribution. The trip-level species composition of landings was used as a proxy variable for changes in gear and fishing practices that were not consistently recorded. Bycatch was not estimated in 2020 due to reduced observer coverage from the COVID-19 pandemic. The QAICc value was used to select the best model for each gear type (otter trawl and gillnet), and the selected models were then applied to vessel trip reports to yield estimated sturgeon bycatch for all trips (Boucher and Curti, 2023).

Marine Mammal Bycatch Estimation Methods for Mid-Atlantic Gillnet Fisheries and New England Gillnet Fisheries

The NEFSC estimates bycatch of coastal bottlenose dolphins (*Tursiops truncatus*) in Mid-Atlantic Gillnet fisheries using stratified annual ratio estimators and pooled ratio estimators where trips are pooled over multiple years (Cochran, 1977). Analysts multiply the resulting bycatch rate estimates by the total number of commercial gillnet fishing trips to produce total bycatch mortality estimates for the four coastal stocks of bottlenose dolphins (Lyssikatos and Garrison, 2018; Lyssikatos, 2022). Because the coastal bottlenose dolphin stocks overlap spatially and temporally, analysts assign some observed bycaught animals to more than one stock. For each stock, analysts produce minimum and maximum bycatch estimates, where the minimum estimates are based on observed bycaught animals that were genetically identified to stock or were bycaught in a specific stratum with known stock affiliation. Maximum bycatch estimates also include bycaught animals with unknown stock identification that were assigned to two or more stocks based on the timing and location of the bycatch event (Lyssikatos and Garrison, 2018). Analysts calculate final average estimates of both minimum and maximum bycatch as the average of the five-year mean mortality estimate from both the stratified annual and pooled ratio estimators. They then weight the five-year mean mortality estimate by the inverse of the coefficient of variance to give more weight to the more precise estimate (Lyssikatos and Garrison, 2018; Lyssikatos, 2022). Analysts also aggregate coastal bottlenose dolphin bycatch estimates for gillnet fisheries over mesh sizes.

The NEFSC uses different methods to estimate bycatch of Atlantic white-sided dolphins (*Lagenorhynchus acutus*), common dolphins (*Delphinus delphis delphis*), common bottlenose dolphins (offshore stock; *Tursiops truncatus truncatus*), Risso's dolphins (*Grampus griseus*), long-finned pilot whales (*Globicephala melas*), harbor porpoises (*Phocoena phocoena phocoena*), harbor seals (*Phoca vitulina vitulina*), harp seals (*Pagophilus groenlandicus*), and gray seals (*Halichoerus grypus atlantica*) in grouped Mid-Atlantic Gillnet and New England Gillnet fisheries. Analysts use stratified annual ratio estimators to estimate bycatch of these species aggregated over mesh sizes. They generally define strata to reflect the spatiotemporal distributions of marine mammals and commercial gillnetters. The strata for the New England sink gillnet fisheries are defined by seasonality and port group or management area. Analysts weight the estimated stratum-specific bycatch rates in New England by pinger use and NEFOP-observed groundfish or non-groundfish landings in order to explicitly account for observed fishing effort targeting groundfish versus non-groundfish and for the use of pingers on gillnets (Orphanides and Hatch, 2017). Strata for the Mid-Atlantic gillnet fisheries are based on area, season, mesh size, and soak duration. Analysts calculate estimates of bycatch in a gillnet fishery stratum by multiplying the stratum-specific bycatch rate by the total commercial fishing effort associated with that stratum (Orphanides and Hatch, 2017). They then sum these stratum-specific bycatch estimates to produce seasonal subtotal and total bycatch estimates.

The NEFSC modified bycatch estimation methods slightly for the 2019 and subsequent estimates of small cetacean and pinniped bycatch in the New England sink and Mid-Atlantic gillnet fisheries. Rather than calculating estimated bycatch as the product of the estimated bycatch rate and total landings, analysts calculated estimated bycatch by adding observed bycatch to the product of the estimated bycatch rate and the total unobserved landings (Precoda and Orphanides, 2022). This change improved the overall accuracy of the bycatch estimates since the observed bycatch is a known quantity (without uncertainty), and the confidence intervals should only reflect the uncertainty in the estimated bycatch from unobserved fishing activities. Precoda and Orphanides (2022) describe other minor changes to the bycatch estimation methods, such as changes to rounding and a change in the application of a finite population correction factor.

Because of low and potentially unrepresentative observer coverage due to the COVID-19 pandemic, the NEFSC altered the methodology for producing marine mammal bycatch estimates for the gillnet fisheries in some years affected by the pandemic (Precoda and Lyssikatos, 2023). For the New England Gillnet fishery in 2020-2021 and the Mid-Atlantic Gillnet fishery in 2020-2022, marine mammal bycatch rates were calculated from observer data pooled over 2017-2019 and then applied to the effort in the target year (2020, 2021, or 2022) to derive bycatch estimates (Precoda, 2023). For marine mammal bycatch in the New England and Mid-Atlantic bottom trawl fisheries, the average bycatch estimate from years 2017 to 2019 was used for 2020 only (Hayes et al., 2023).

Marine Mammal Bycatch Estimation Methods for Mid-Atlantic Otter Trawl Fisheries and New England Otter Trawl Fisheries

The NEFSC applied stratified annual ratio estimators with five-year averages to estimate bycatch of marine mammals in grouped Mid-Atlantic Otter Trawl Fisheries and grouped New England Otter Trawl Fisheries. Specifically, the NEFSC estimates bycatch of Atlantic white-sided dolphins, common dolphins, common bottlenose dolphins (offshore stock), Risso's dolphins, long-finned pilot whales, harbor porpoises, harbor seals, harp seals, and gray seals using this method. Analysts stratify data by geographic region, year, season, and ecoregion. They use a standard ratio estimator to produce stratified bycatch rates and estimates, where the sum of the observed bycatch mortality is divided by the sum of observed days fished, and then the quotient is multiplied by the total days fished for each marine mammal species (Lyssikatos, 2015; Chavez-Rosales et al., 2017; Lyssikatos and Chavez-Rosales, 2022). Analysts estimate uncertainty using a standard bootstrap procedure to calculate standard errors (Efron and Tibshirani, 1993). The sampling unit was an observed trip, and analysts applied a finite population correction factor to the bycatch rate standard error for all strata with 10% or greater observer coverage (Cochran, 1977). Beginning with the 2022 bycatch estimates, uncertainty was estimated using the adjusted bootstrap percentile (BCa) confidence interval (Davison and Hinkley, 1997), which was also used for marine mammal bycatch estimates in the gillnet fisheries.

Sea Turtle Bycatch Estimation Methods for Gillnet Fisheries

Murray (2009) estimated bycatch rates of loggerhead turtles (*Caretta caretta*) in the Mid-Atlantic Gillnet Fisheries for 1995 to 2006 using a generalized additive model (GAM) with a Poisson distribution that evaluated bycatch rates in relation to fishing practices and environmental variables. Murray (2013) used the same methodology to estimate loggerhead turtle bycatch for the Mid-Atlantic Gillnet Fisheries from 2007 to 2011.

Murray (2018) used stratified ratio estimators to estimate bycatch rates for loggerhead, Kemp's ridley (*Lepidochelys kempii*), and leatherback (*Dermochelys coriacea*) sea turtles in the Mid-Atlantic and Georges Bank Sink Gillnet Fisheries, where total estimated bycatch for each turtle species from 2012 to 2016 was the sum over all strata of the product of the bycatch rate and total adjusted VTR fishing effort within each stratum.

Murray (2023) used the same methods to estimate bycatch rates in these fisheries from 2017 to 2021 but also estimated bycatch of green sea turtles (*Chelonia mydas*). In addition, to evaluate the impact of reduced observer monitoring in 2020 and 2021 as a result of the COVID-19 pandemic, Murray (2023) evaluated percent observer coverage by month and ecological production unit within each year. Because sampling may not have been representative of commercial gillnet fishing effort in time and space in 2020 and 2021, Murray (2023) used a reduced time series spanning only years 2017 to 2019 to estimate interaction rates, confidence intervals, and the combined coefficients of variation. Murray (2023) then calculated stratified rates from the three-year time series, applied the rates to VTR data from 2017 to 2021, and compared results to the estimates and uncertainty generated from the 5-year time series.

Sea Turtle Bycatch Estimation Methods for Scallop Dredge Fisheries

Murray (2015a) estimated loggerhead sea turtle interactions in the Mid-Atlantic Scallop Dredge Fisheries from 2009 to 2014 using a GAM describing interaction rates as a function of sea surface temperature, chain mats, depth, and year. Murray (2015a) then applied the rates to commercial VTR data to estimate total loggerhead interactions. From 2015 to 2019, observers documented only four loggerhead interactions in Atlantic Sea Scallop Dredge gear when an observer was on watch. To estimate loggerhead interaction rates in this fishery, Murray (2021) pooled observer data from 2015 to 2019 with data from 2001 to 2014. Murray (2021) then applied interaction rates from the pooled time period to VTR fishing effort from 2015 to 2019 to estimate observable and unobservable (yet quantifiable) interactions. Murray (2021) estimated interaction rates with a ratio estimator, where rates were stratified by ecological production unit, season, and whether dredges were modified (having a chain mat and/or a turtle deflector dredges) or standard (no chain mat or turtle deflector dredge).

Sea Turtle Bycatch Estimation Methods for Mid-Atlantic and Georges Bank Bottom Trawl Fisheries

Warden (2011) estimated loggerhead sea turtle interactions for Mid-Atlantic Bottom Trawl gear by developing a GAM of interactions using 1994–2008 NEFOP data from trawl fisheries that were not required to deploy turtle excluder devices. Warden (2011) applied predicted loggerhead interaction rates to 2005–2008 commercial fishing data to estimate the number of interactions for the trawl fleet. For trawl fisheries in which TEDs were required, Warden (2011) applied an experimentally-determined TED exclusion rate (97%) to estimate the number of loggerheads that were excluded by TEDs. Murray (2015b) used a GAM to estimate loggerhead sea turtle interactions for 2009 to 2013, and like Warden (2011), Murray (2015b) modeled interaction rates as a function of latitude, depth, and sea surface temperature. Murray (2020) expanded her analysis to estimate loggerhead, Kemp's ridley, green, and leatherback sea turtle interactions for Mid-Atlantic Bottom Trawl gear, as well as loggerhead and leatherback sea turtle interactions for Georges Bank Bottom Trawl gear from 2014 to 2018. Murray (2020) estimated interaction rates for each turtle species using stratified ratio estimators, where rates were stratified by ecological production unit (Georges Bank and Mid-Atlantic), latitude zone, season, and depth.

Seabird Bycatch Estimation Methods for Fixed and Mobile Gear Fisheries

Building on the work of Hatch (2017), Sigourney et al. (2019) estimated bycatch for 10 species of seabirds in 6 Greater Atlantic gear types, including fixed (e.g., gillnets, purse seines, and common beach seines) and mobile (e.g., bottom otter trawls, paired midwater trawls, and sea scallop dredges) gear types. Sigourney et al. (2019) adopted the Bayesian hierarchical approach detailed in Hatch (2017) to estimate seabird bycatch. Sigourney et al. (2019) analyzed a total of 20 species–gear combinations for which there was observed bycatch, analyzing each species–gear combination separately. Within a species–gear combination, Sigourney et al. (2019) stratified data by year, statistical area, season, and FMP. In the few cases where the observed fishing effort for a stratum was greater than its measured total fishing effort, Sigourney et al. (2019) considered the observed bycatch to be a complete census for that stratum, which therefore required no estimation.

7. The Future of the National Bycatch Report

In an effort to make the NBR more timely and useful for stakeholders and the public, NOAA Fisheries will develop an enhanced NBR database, which will be incorporated into the NOAA Fisheries public portal Fisheries One Stop Shop (FOSS) database[12] as the main vehicle for sharing bycatch estimates and associated bycatch estimation methods for NBR fisheries. NOAA Fisheries staff are in the process of establishing links between NOAA Fisheries regional bycatch estimate databases and FOSS to increase the efficiency of the data input process. NOAA Fisheries staff are also exploring automated quality assurance and quality control procedures of data inputs.

NOAA Fisheries recognizes the need to actively share information about NBR bycatch estimates with the public. Therefore, at the end of each calendar year, beginning with calendar year 2024, NOAA Fisheries will review the status of all regional bycatch estimate data sets added to the FOSS database over the past 12 months. As resources allow, this review will identify:

- The regional fisheries for which bycatch estimates and related landings data have been added to the database.
- The taxonomic categories of the regional fishery bycatch estimates that have been added (i.e., fish, marine mammal, sea turtle, and/or seabird).
- Changes to bycatch monitoring and/or estimation procedures over the past 12 months.
- Remaining information gaps and general plans for filling those gaps.
- As appropriate, summaries of fishery-specific bycatch levels and trends, assuming the database is in a “production environment” (i.e., live for public users); due to the complexity of this project, the database may not be in a production environment before 2026.

By the end of March 2025, and annually thereafter, NOAA Fisheries will publish an online update summarizing the results of the annual review described above.

The contents of these updates will depend on available resources and the ability of bycatch data experts at NOAA Fisheries regional offices and science centers to prioritize the establishment of database links and procedures for transmitting regionally created bycatch estimates to the NBR/FOSS database on a regular (ideally, at least yearly) basis. The updated NBR database and public portal in FOSS will support timely communication of bycatch-reduction progress to Congress, stakeholders, and the public.

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[12] NOAA Fisheries Fisheries One Stop Shop (FOSS) database. Available at https://www.fisheries.noaa.gov/foss/f?p=215:200::::::

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Appendix 1. National Bycatch Report (NBR) Fisheries (from Benaka et al., 2019 and selected anticipated future NBR fisheries), Related Fisheries in the Marine Mammal Protection Act (MMPA) List of Fisheries (LOF), and Related Federal Fishery Management Plans (FMPs).

NBR Fishery Name[1]	2023 MMPA LOF Name	Related Federal FMP
Pacific Islands		
Hawai'i-Based Shallow-Set Pelagic Longline Fishery for Swordfish	Hawai'i Shallow-Set Longline	Fishery Ecosystem Plan for the Pelagic Resources of the Western Pacific Region
Hawai'i-Based Deep-Set Pelagic Longline Fishery for Tuna	Hawai'i Deep-Set Longline	
American Samoa Pelagic Longline	American Samoa Longline	
Alaska		
BSAI Pollock Trawl	AK Bering Sea, Aleutian Islands pollock trawl	Bering Sea and Aleutian Islands Groundfish FMP
Aleutian Islands/Eastern Bering Sea Atka Mackerel Trawl	AK Bering Sea, Aleutian Islands rockfish trawl	
BSAI Rockfish Trawl	AK Bering Sea, Aleutian Islands rockfish trawl	
BSAI Non-Pollock Trawl		
BSAI Flatfish Trawl Fisheries	AK Bering Sea, Aleutian Islands flatfish trawl	
BSAI Pacific Cod Trawl	AK Bering Sea, Aleutian Islands Pacific cod trawl	
BSAI Trawl Limited Access		
Aleutian Islands/Eastern Bering Sea Atka Mackerel Trawl (marine mammals)		
GOA Rockfish Nonpelagic Trawl	AK Gulf of Alaska rockfish trawl	Gulf of Alaska Groundfish FMP
GOA Rockfish Pelagic Trawl		
GOA Rockfish Trawl		
GOA Flatfish Trawl Fisheries	AK Gulf of Alaska flatfish trawl	
GOA Pacific Cod Trawl	AK Gulf of Alaska Pacific cod trawl	

NBR Fishery Name[1]	2023 MMPA LOF Name	Related Federal FMP
GOA Nonpelagic Trawl		
GOA Sablefish Trawl		
GOA Pollock Trawl	AK Gulf of Alaska pollock trawl	
BSAI Pacific Cod Longline	AK Bering Sea, Aleutian Islands Pacific cod longline	Bering Sea and Aleutian Islands Groundfish FMP
BSAI Catcher Processor Longline		
BSAI Catcher Vessel Longline		
BSAI Greenland Turbot Longline	AK Bering Sea, Aleutian Islands Greenland turbot longline	
BSAI Sablefish Longline	AK Bering Sea, Aleutian Islands sablefish longline	
BSAI Pacific Cod Pot	AK Bering Sea, Aleutian Islands Pacific cod pot	
BSAI Groundfish Pot		
BSAI Sablefish Pot	AK Bering Sea, Aleutian Islands sablefish pot	
GOA Sablefish Longline	AK Gulf of Alaska sablefish longline	Gulf of Alaska Groundfish FMP
GOA Pacific Cod Longline	AK Gulf of Alaska Pacific cod longline	
GOA Pot	AK Gulf of Alaska Pacific cod pot	
	AK Gulf of Alaska sablefish pot	
BSAI Halibut Longline	AK Bering Sea, Aleutian Islands halibut longline	Bering Sea and Aleutian Islands Groundfish FMP
GOA Halibut Longline	AK Gulf of Alaska halibut longline	
Alaska Statewide Salmon Fisheries	AK Bristol Bay salmon set gillnet	
	AK Bristol Bay salmon drift gillnet	
	AK Kodiak salmon set gillnet	

NBR Fishery Name[1]	2023 MMPA LOF Name	Related Federal FMP
	AK Cook Inlet salmon set gillnet	
	AK Cook Inlet salmon drift gillnet	
	AK Peninsula/Aleutian Islands salmon drift gillnet	
	AK Peninsula/Aleutian Islands salmon set gillnet	
	AK Prince William Sound salmon drift gillnet	
	AK Southeast salmon drift gillnet	
	AK Yakutat salmon drift gillnet	
	AK Kuskokwim, Yukon, Norton Sound, Kotzebue salmon gillnet	
	AK Prince William Sound salmon set gillnet	
Bering Sea Snow Crab Pot	AK Bering Sea, Aleutian Islands crab pot	Bering Sea/Aleutian Islands King and Tanner Crab FMP
Bering Sea Tanner Crab Pot		
Bristol Bay Red King Crab Pot		
St. Matthew Island Blue King Crab Pot		
West Coast		
California/Oregon Drift Gillnet (Mesh Size >14 in) for Swordfish and Thresher Shark	CA thresher shark/swordfish drift gillnet (>/=14 in mesh)	FMP for West Coast Fisheries for Highly Migratory Species
California Halibut/White Seabass and Other Species Set Gillnet (>3.5 in Mesh)	CA halibut/white seabass and other species set gillnet (>3.5 in mesh)	
West Coast Limited Entry Bottom Trawl; Groundfish Bottom Trawl	WA/OR/CA groundfish trawl	Pacific Coast Groundfish FMP
West Coast Mid-Water Trawl for Rockfish, Shoreside Processing	WA/OR/CA groundfish trawl	
California/Oregon Nearshore Rockfish	WA/OR/CA groundfish/finfish hook and line	
West Coast Mid-Water Trawl for Hake, Shoreside Processing	WA/OR/CA groundfish trawl	

NBR Fishery Name[1]	2023 MMPA LOF Name	Related Federal FMP
West Coast Mid-Water Trawl for Hake, At-Sea Processing	WA/OR/CA groundfish trawl	
West Coast Groundfish Non-Trawl Gear; Limited-Entry Sablefish-Endorsed Fixed Gear	WA/OR/CA groundfish, bottomfish longline/set line; WA/OR/CA sablefish pot	
West Coast Groundfish Non-Trawl Gear; Non-Endorsed Fixed Gear	WA/OR/CA groundfish/finfish hook and line; WA/OR/CA groundfish, bottomfish longline/set line	
West Coast Limited Entry Bottom Trawl; Fixed Gear	WA/OR/CA groundfish/finfish hook and line	
West Coast Salmon Troll, Non-Tribal Ocean	CA/OR/WA salmon troll	Pacific Coast Salmon FMP
West Coast Salmon Troll, Tribal Ocean		
California Halibut Trawl	CA halibut bottom trawl	
Washington, Oregon, California Pink Shrimp	WA/OR/CA shrimp trawl	
Ridgeback Prawn	WA/OR/CA shrimp trawl	
Sea Cucumber	CA sea cucumber trawl	
Southeast		
Gulf of Mexico Shrimp Trawl	Southeastern U.S. Atlantic, Gulf of Mexico shrimp trawl	FMP for the Shrimp Fishery of the Gulf of Mexico, U.S. Waters
Southeastern Atlantic Shrimp Trawl		FMP for the Shrimp Fishery of the South Atlantic Region
Gulf of Mexico Reef Fish Bottom Longline	Southeastern U.S. Atlantic, Gulf of Mexico, and Caribbean snapper-grouper and other reef fish bottom longline/hook-and-line	FMP for the Reef Fish Resources of the Gulf of Mexico
Gulf of Mexico Reef Fish Vertical Line		
Southeastern Atlantic Snapper-Grouper Bottom Longline		FMP for the Snapper Grouper Fishery of the South Atlantic Region
Southeastern Atlantic Snapper-Grouper Vertical Line		
Southeastern Atlantic Coastal Gillnet (Including North Carolina)	Gulf of Mexico gillnet	
	NC inshore gillnet	
	Southeast Atlantic gillnet	
	Southeastern U.S. Atlantic shark gillnet	

NBR Fishery Name[1]	2023 MMPA LOF Name	Related Federal FMP
Southeastern Atlantic and Gulf of Mexico Shark Bottom Longline	Southeastern U.S. Atlantic, Gulf of Mexico shark bottom longline/hook-and-line	Consolidated Atlantic Highly Migratory Species Management Plan
Southeastern Atlantic and Gulf of Mexico Shark Bottom Longline Research		
Atlantic and Gulf of Mexico HMS Pelagic Longline		
Gulf of Mexico Coastal Migratory Pelagic Troll		FMP for the Coastal Migratory Pelagic Resources in the Gulf of Mexico and Atlantic Region
Southeastern Atlantic Coastal Migratory Pelagic Troll		
Greater Atlantic		
New England Large-Mesh Haddock Separator Otter Trawl		Northeast Multispecies FMP; Atlantic Mackerel, Squid, and Butterfish FMP; Summer Flounder, Scup, and Black Sea Bass FMP; Northeast Skate Complex FMP; Monkfish FMP; Atlantic Spiny Dogfish FMP
New England Large-Mesh Otter Trawl		
New England Large-Mesh Ruhle Otter Trawl		
New England Otter Trawl Fisheries (marine mammals, seabirds)		
Mid-Atlantic Large-Mesh Otter Trawl		
New England Small-Mesh Otter Trawl	Northeast bottom trawl	
Mid-Atlantic Small-Mesh Otter Trawl	Mid-Atlantic bottom trawl	
Mid-Atlantic Otter Trawl Fisheries (marine mammals, seabirds)		
Mid-Atlantic and New England Otter Trawl Fisheries (seabirds)		
Mid-Atlantic Twin Trawl		Atlantic Mackerel, Squid, and Butterfish FMP
New England Twin Trawl		
New England Extra-Large-Mesh Gillnet	Northeast sink gillnet	Northeast Multispecies FMP, Northeast Skate Complex FMP, Spiny Dogfish FMP
New England Large-Mesh Gillnet		

NBR Fishery Name[1]	2023 MMPA LOF Name	Related Federal FMP
New England Small-Mesh Gillnet		
New England Gillnet Fisheries (marine mammals, seabirds)		
Mid-Atlantic Extra-Large-Mesh Gillnet	Mid-Atlantic gillnet	Monkfish FMP, Atlantic Spiny Dogfish FMP
Mid-Atlantic Large-Mesh Gillnet		
Mid-Atlantic Small-Mesh Gillnet		
Mid-Atlantic Gillnet Fisheries (marine mammals, seabirds)		
New England Bottom Longline	Northeast/Mid-Atlantic bottom longline/hook-and-line	Northeast Multispecies FMP, Monkfish FMP, Atlantic Spiny Dogfish FMP
New England Hand Line		Summer Flounder, Scup, Black Sea Bass FMP
Mid-Atlantic Hand Line		
New England Purse Seine	Gulf of Maine herring purse seine	Atlantic Herring FMP
	Gulf of Maine menhaden purse seine	
New England Fish Pots and Traps	Atlantic mixed species trap/pot	Summer Flounder, Scup, and Black Sea Bass FMP
New England Conch Pots and Traps		
Mid-Atlantic Fish Pots and Traps	U.S. Mid-Atlantic eel trap/pot	Summer Flounder, Scup, and Black Sea Bass FMP
Mid-Atlantic Conch Pots and Traps		
New England Lobster Pots	Northeast/Mid-Atlantic American lobster and Jonah crab trap/pot	
Mid-Atlantic Lobster Pots		
New England Clam/Quahog Dredge	New England and Mid-Atlantic offshore surf clam/ocean quahog dredge	FMP for Atlantic Surf Clam and Ocean Quahog Fisheries
Mid-Atlantic Clam/Quahog Dredge		
New England General Category Open Area Scallop Dredge	Gulf of Maine, U.S. Mid-Atlantic sea scallop dredge	Atlantic Sea Scallop FMP
New England Limited Access Closed Area Scallop Dredge		

NBR Fishery Name[1]	2023 MMPA LOF Name	Related Federal FMP
New England Limited Access Open Area Scallop Dredge		
Mid-Atlantic General Category Closed Area Scallop Dredge		
Mid-Atlantic General Category Open Area Scallop Dredge		
Mid-Atlantic Limited Access Closed Area Scallop Dredge		
Mid-Atlantic Limited Access Open Area Scallop Dredge		
Mid-Atlantic and New England Scallop Dredge (seabirds)		
Mid-Atlantic Scallop Dredge Fisheries (seabirds)		
New England Scallop Dredge Fisheries (seabirds)		
Mid-Atlantic General Category Open Area Scallop Trawl		Atlantic Sea Scallop FMP
Mid-Atlantic General Category Closed Area Scallop Trawl		
Mid-Atlantic Limited-Access Open Area Scallop Trawl		
Mid-Atlantic Limited-Access Closed Area Scallop Trawl		
New England Open Area Mid-Water Otter Trawl	Northeast mid water trawl (including pair trawl)	Atlantic Herring FMP
New England Closed Area Mid-Water Trawl		
New England Mid-Water Otter Trawl (marine mammals, seabirds)		
Mid-Atlantic Mid-Water Otter Trawl (marine mammals)		
New England Crab Pots	Atlantic mixed-species trap/pot	Atlantic Deep-Sea Red Crab FMP
Mid-Atlantic Crab Pots		

[1]Italicized fisheries in the NBR Fishery Name column indicate fisheries that are grouped for the purpose of protected species bycatch estimation.