ESTIMATES OF HUMAN-CAUSED REMOVALS OF GRAY SEALS IN THE NORTHEAST U.S. ATLANTIC AND ADJACENT CANADIAN WATERS: PRELIMINARY IMPLICATIONS FOR PBR-BASED MANAGEMENT

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Contents

Acronyms and Abbreviations

A

ASM	At Sea Monitoring Program
ARF	Annual Removals due to fisheries interactions

C

CV	Coefficient of variation

D

DFO	Fisheries and Oceans Canada

E

EEZ	Exclusive Economic Zone

I

IAB	Industry Advisory Board
IAT	Independent Advisory Team
IUCRC	Industry and University Cooperative Research program

L

LOESS	Locally estimated scatterplot smoothing

M

ME	Management Efficiency
MM	Marine Mammal(s)
MMPA	Marine Mammal Protection Act

N

NAFO	Northwest Atlantic Fisheries Organization
NEBT	Northeast Bottom Trawl
NEFOP	Northeast Fisheries Observer Program
NEFSC	Northeast Fisheries Science Center

NESG	Northeast Sink Gillnet
NMFS	National Marine Fisheries Service
Nmin	Minimum estimate of abundance
NSF	National Science Foundation

P

PBR	Potential Biological Removal

R

Rmax	Maximum net productivity rate

S

SAR	Stock Assessment Report
SCeMFiS	Science Center for Marine Fisheries
SW NS	Southwest Nova Scotia

V

VTRs	Vessel Trip Reports

Executive Summary

Under the U.S. Marine Mammal Protection Act (MMPA), the NMFS has adopted what is referred to as the Potential Biological Removal (PBR) regime for managing mortality or serious injury of marine mammals caused by human activities, including marine mammal-fishery interactions in U.S. waters. The PBR is a removal level above which a given population of marine mammals has an unacceptably high likelihood of becoming depleted or if depleted, of not recovering. Once PBR is exceeded, the stock becomes "strategic" elevating conservation and management requirements. The PBR is the product of a minimum estimate of abundance, one half of the maximum rate of net productivity (Rmax), and a Recovery Factor. More details on PBR-based management can be found in Wade (1998) and Moore & Merrick (2011). Key to the management of marine mammal bycatch in commercial fisheries is the ratio of bycatch to the PBR. The NMFS has created threshold values for this ratio that are used to prioritize observer placement on commercial vessels.

The following recommendations were derived from the analyses associated with this research.

1. First, using available data on trends in pup counts from Sable Island, Canada to estimate Rmax (i.e., scenario 2, Rmax was set at 0.141 rather than the default value of 0.12 - see Punt et al. 2020[1]) would cause the PBR to be increased by approximately 18% relative to base case (scenario 1). This alone results in a change in the ratio of bycatch in a given fishery to PBR from 0.591 to 0.503 and 0.014 to 0.012 for the sink gill net and bottom trawl fisheries.
2. Making the assumption that gray seals in waters off southwestern Nova Scotia mix uniformly with gray seals in U.S. waters, would change the ratio of bycatch in the sink gill net fishery to PBR from 0.591 to 0.415. This would change the fishery-specific classification from a Category I fishery to a Category II fishery. This has implications regarding observer placement prioritization by the NMFS. Perhaps more significantly, this approach is consistent with Moore and Merrick (2011) for transboundary stocks and could prevent triggering unwarranted management measures as the gray seal stock continues to increase along with an expected increase in bycatch
3. Making the assumption that gray seals in the waters south and east of Novia Scotia are panmictic, would change the bottom trawl fishery from a Category II fishery to a Category III fishery. It should be noted that the movement and tagging data available for gray seals indicates that this assumption is likely not met.

[1] Punt, A, J. Brandon, D. DeMaster, and P. Moreno. 2020. Estimating the Maximum Net Productivity Rate for Gray Seals in US waters of the western North Atlantic. (in review).

Photo Credit: NOAA/NEFSC/Kimberly Murray (Images collected under MMPA Research permit number 17670).

Purpose

The objective of this Task is to produce and summarize average estimates of annual fishery and non-fishery removals of gray seals from U.S and adjacent Canadian waters to be used as inputs into gray seal population dynamics and forecasting models (hereafter referred to as "gray seal models") currently under development by the IAT. The estimates of removals are a key input for the gray seal models; they are a necessary component for the quantitative evaluation of alternative management and monitoring approaches, i.e., in terms of meeting management objectives under the Potential Biological Removal (PBR), and fisheries classification regime used by the National Marine Fisheries Service (NMFS) to manage fishery interactions with marine mammals in U.S. waters under the Marine Mammal Protection Act (MMPA).

In this evaluation we will investigate different assumptions regarding the magnitude of mixing between seal stocks in U.S. and Canadian waters. The boundary between the U.S. and Canada is established by the Exclusive Economic Zones (EEZs). The "no-mixing" model configuration will consider removals only from U.S waters relative to the abundance of gray seals in U.S. waters, while estimates of removals in both U.S. and Canadian waters will be incorporated into the models with "mixing", as will estimates of abundance. Maximum rate of net productivity (Rmax) will be set at 0.12 or 0.141. Our analysis addresses four scenarios:

(1) No mixing across U.S./Canadian EEZs, where Rmax is set at 0.120 (considered the base case);
(2) No mixing across U.S./Canadian EEZs, where Rmax is set at 0.141 (Punt, Brandon, DeMaster and Moreno, 2020);
(3) Mixing of animals from the U.S. with animals from southwest Nova Scotia, where Rmax is set at 0.141; and
(4) Mixing of animals in western North Atlantic, excluding animals in the Gulf of St. Lawrence, where Rmax is set at 0.141.

Methods

Abundance estimates were based on the most recent survey year, where pups were counted at all rookeries (i.e., 2016), as reported in Hayes et al. (2019), Wood et al. (2020), and den Heyer et al. (2017). The 5-year mean of annual removals was considered representative of the level of human-caused removals for the purpose of this analysis. We selected the most recent available data (2012-2016) to estimate removals incidental to commercial fishing (i.e., bycatch), the main source of known human-caused removals in the U.S. For the U.S. data, we used annual fishery removals estimated by the NMFS based on Observer Programs for the fisheries identified as the main sources of gray seal bycatch: the northeast sink gillnet fishery—classified as Category I driven by gray seal stock levels of mortality and serious injury—and the northeast groundfish bottom trawl fishery, a Category II fishery (Hayes et al. 2020, List of Fisheries 2020). Details about these fisheries are included in Appendix A.

Because official estimates for incidental mortality of marine mammals based on Observer Programs of commercial fisheries are not available for Canadian fisheries, we assumed the same bycatch rates (i.e., number of gray seals incidentally killed per unit of fishing effort) as in analogous fisheries in the U.S. following the same approach used by the NMFS when classifying fisheries for which there is no Observer Program (List of Fisheries 2020).

We estimated bycatch in two Canadian fisheries based on the bycatch rates estimated for two U.S. fisheries, the northeast sink gillnet fishery and the northeast groundfish bottom trawl fishery, which are the main reported sources of bycatch operating in the waters surrounding the primary U.S. gray seal pupping colonies (Figure 1) (Hayes et al. 2020). The two fisheries considered in this analysis operate in waters adjacent to U.S. waters (see Northwest Atlantic Fisheries Organization – NAFO zones in Figure 1). It should be noted that groundfish fisheries operating in the U.S. northeast and adjacent Canadian waters may differ in the primary species targeted and fishing methods. Although further analysis is needed regarding the comparability of mesh sizes in the Canadian and U.S. gillnet fisheries, applying mesh-specific bycatch rates to estimate bycatch removals in Canadian fisheries would require additional analysis of U.S. observer and fisheries data because these estimates are not yet available for gray seal bycatch (Orphanides, C. pers comm[2]). For each fishery, we estimated average annual Canadian removals (mean, median) by multiplying the average annual bycatch rates (mean or median computed from all NMFS strata by year) by the annual fishing effort associated with Canadian regions (Maritimes, Nova Scotia, Fundy) in the NAFO zones of interest (4X, 5Ze, 5Y which were expanded to 4W, 4Vs for a broader range that would contain removals from the largest colony of seals, Sable Island). Fishing effort was measured in landing weight (metric tons) for the gillnet fishery and fished days for bottom trawl fisheries, obtained by querying the NAFO Annual Fisheries Statistics Databases (database 21B, NAFO 2018). We necessarily assumed that fishing effort in terms of landing weight for gillnet

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fisheries and fished days for bottom trawl fisheries was an adequate measure of effort because these are the fishery effort measures used by the NMFS when estimating marine mammal bycatch rates and removals from Observer Programs. The estimate of total bycatch in Canadian waters consists of the sum of removals from both fisheries. It is possible that additional bycatch of gray seals may occur in other Canadian fisheries in waters off Nova Scotia; however, our review of the available literature indicates this bycatch level is insignificant relative to the purpose of this analysis (DFO 2017).

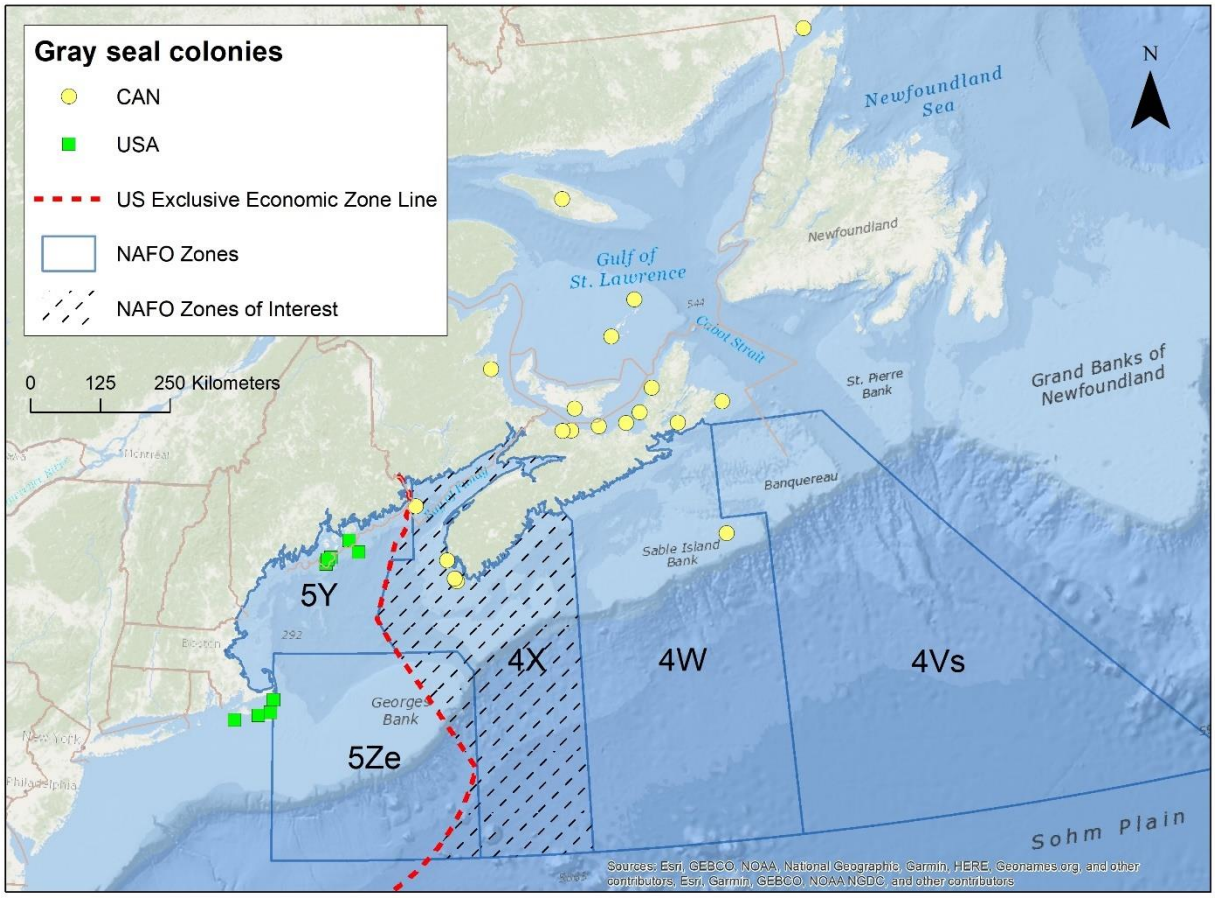

Figure 1. Location of gray seal pupping colonies identified in the U.S. (9 colonies, green squares) and in Canada (21 colonies, yellow circles). The NAFO zones of interest (dashed lines) were used to estimate bycatch of gray seals in Canadian waters adjacent to the Exclusive Economic Zone (EEZ) boundary line. For comparison, the area of interest was also expanded to include zones 4W and 4Vs, where seals from the largest colony (Sable Island) were likely to interact with fisheries.

In addition to bycatch removals, we also considered the impact of 5-year mean estimates of other types of human-related removals reported for the same period in the U.S and Canada. Non-fishery U.S. removals consisted of stranding mortalities with evidence of human-interaction. Canadian removals consisted of direct kills (harvest, nuisance and scientific kills). However, based on a review of the literature and discussions with Canada Department of Fisheries and Oceans staff

(Hammill, M. pers comm[3]), it appears all of the removals that can be documented (i.e., harvested animals and animals taken for scientific purposes) were from the Gulf of St Lawrence region; while nuisance animals were primarily taken from Sable Island. Therefore, while numbers of animals removed are included in Table 1, none of these removals were considered in the four scenarios analyzed in this paper, as they were not fishery related and would not influence the fishery classification protocol used by the NMFS for US fisheries.

Results

I. Other removals (non-bycatch)

1. U.S. Northeast Atlantic

In the Atlantic waters of the U.S., non-bycatch removals, including seal shootings, averaged 4.8 seals from 2012 to 2016 and represent minimum counts (Hayes et al. 2019). In addition, an average 0.8 seals during the same period were reported as U.S. research mortalities.

2. Atlantic Canadian waters

In the Canadian Atlantic region, direct removals (i.e., non-bycaught animals) consisting of commercial harvest, scientific takes and nuisance kills, averaged 4,826 and 5,167 seals (mean and median, respectively) from 2012 to 2016 (Table 1). The geographic range of commercial and scientific takes, which can be documented, occur primarily in the Gulf of St Lawrence (DFO, Mike Hammill, pers. comm.), while nuisance kills were primarily from Sable Island area. Therefore, it is unlikely that removals from these regions will influence the dynamics of gray seals in the region of interest (Gulf of Maine). Further, non-fisheries removals are not used by the NMFS in the classification of fisheries in US waters. Therefore, these data were not used in any of the four scenarios analyzed in this paper, but are included for completeness.

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Table 1. Canadian removals of gray seals from harvesting, scientific and nuisance kills from 2012 to 2016 (Source: DFO pers. comm., 2020; DFO 2017, Hammill et al. 2017). Note: these data are presented for completeness, but were not used in the analysis, as noted in the text above.

Year	Harvest	Scientific	Nuisance	**Total**
2012	0	159	5,428	**5,587**
2013	243	58	3,757	**4,058**
2014	82	83	3,732	**3,897**
2015	1,381	54	3,732	**5,167**
2016	1,612	75	3,732	**5,419**
5-yr Mean	**664**	**86**	**4,076**	**4,826**
5-yr Median	**243**	**75**	**3,732**	**5,167**

II. Fishery incidental removals (Bycatch)

The U.S. annual bycatch removals in this report are from the NMFS Stock Assessment Reports (SARs) for 2018 (Hayes et al. 2019) (See Appendix B). These data were used rather than those reported in SARs for 2019 (Hayes et al. 2020) to allow for a consistency in data reporting periods for the gillnet fisheries and bottom trawl fisheries in U.S. and Canadian waters (i.e., availability of NAFO landings data from 2012-2016). The bycatch rate estimates were obtained from the Northeast Fisheries Science Center (NEFSC) reports (Chavez-Rosales et al. 2018; Hatch and Orphanides 2014, 2015, 2016; Orphanides and Hatch 2017; Orphanides 2019).

To estimate annual bycatch removals for each marine mammal stock, the NMFS/NEFSC first estimates bycatch rates (defined as the number of dead or seriously injured animals per fishing effort unit) from two observer programs, the Northeast Fisheries Observer Program (NEFOP) and the Northeast Fisheries At-Sea Monitoring Program (ASM). Secondly, bycatch is extrapolated to a fishery fleet by multiplying estimated bycatch rates by the commercial fishing effort (defined as the weight of commercial landings in metric tons or fished days depending on the fishery), which for the NE bottom trawl (NEBT) fishery is obtained only from vessel trip reports (VTRs) and for the NE sink gillnet (NESG) fishery is also obtained from dealer weigh out slips and State ticket programs. Effort for the NESG fishery is measured in metric ton of landed catch and for the NEBT fishery is measured in number of days fished, i.e., gear tow duration in hours/24. Estimation of bycatch rates is performed using stratified ratio estimators with strata in the case of the NESG fishery consisting of season, management area, groundfish/non groundfish landings (to avoid overrepresentation of the fleet sampled by the ASM) and pinger presence (see Appendix C), and for the NEBT fishery consisting of season and ecoregion (Georges Bank and Gulf of Maine) (see Appendix D). Annual bycatch removals are obtained by summing removals across all strata and

standard errors estimated using a non-parametric stratified bootstrap technique[4]. See Orphanides and Hatch (2017) for further details on methodologies of bycatch estimation for the NESG fishery and Chavez-Rosales et al. (2018) for the NEBT fishery.

1. U.S. Atlantic

i. Northeast Sink Gillnet Fishery

The annual average bycatch estimated removals of gray seals in the sink gillnet fishery operating in the western North Atlantic in U.S. waters is summarized in Table 2. The 5-year mean bycatch level was 821 animals (CV=0.1) (See Appendix B).

Table 2. Estimates of annual removals of gray seals in the northeast sink gillnet fishery (Source: Hayes et al. 2019. See Appendix B).

Year	Observer Coverage	Est. Removals	Est. CVs
2012	0.15	542	0.19
2013	0.11	1127	0.2
2014	0.18	917	0.14
2015	0.14	1021	0.25
2016	0.1	498	0.33
5-yr mean	**-**	**821**	**0.1**

From 2012 to 2016, the gray seal summary statistics used to estimate bycatch by stratum for the NESG fishery ranged from a minimum of 0.007 seals/mt catch in 2014 to a maximum of 3.6 in 2013 (Table 3, Figure 2). However, as shown in Figure 2, the maximum bycatch rate in 2013 is an outlier. The summary statistics are presented in Table 3. The annual mean and median bycatch rates were used to estimate Canadian bycatch removals from the Canadian sink gillnet fishery. The mean and median bycatch rates, excluding the outlier, ranged from approximately 0.06-0.08 and 0.03-0.07, respectively. The 2013 bycatch rate outlier had no impact on the estimation of Canadian gray seal fishery removals because Canadian fisheries data were not available for this year. Note that the gray seal summary statistics used to estimate bycatch for the NESG fishery are based on the best available data (Hatch & Orphanides 2014, 2015, 2016; Orphanides & Hatch 2017; Orphanides 2019 – See Appendix C).

[4] Based on resampling of entire fishing trips to account for dependence among hauls nested within trips, and using the bias-corrected and accelerated method to determine confidence intervals. The finite population correction factor was applied to the bootstrapped estimate of the standard error when calculating the CV for strata with high observer coverage (i.e., ≥10%).

Table 3. Summary statistics used to estimate bycatch of gray seals in the northeast sink gillnet fishery from 2012 to 2016. (Data sources: Hatch & Orphanides 2014, 2015, 2016; Orphanides & Hatch 2017; Orphanides 2019 – See Appendix C).

Year	Minimum	Median	Mean	Maximum
2012	0.026	0.054	0.080	0.257
2013	0.012	0.044	0.421	3.579
2014	0.007	0.034	0.082	0.269
2015	0.012	0.037	0.067	0.235
2016	0.019	0.067	0.059	0.094

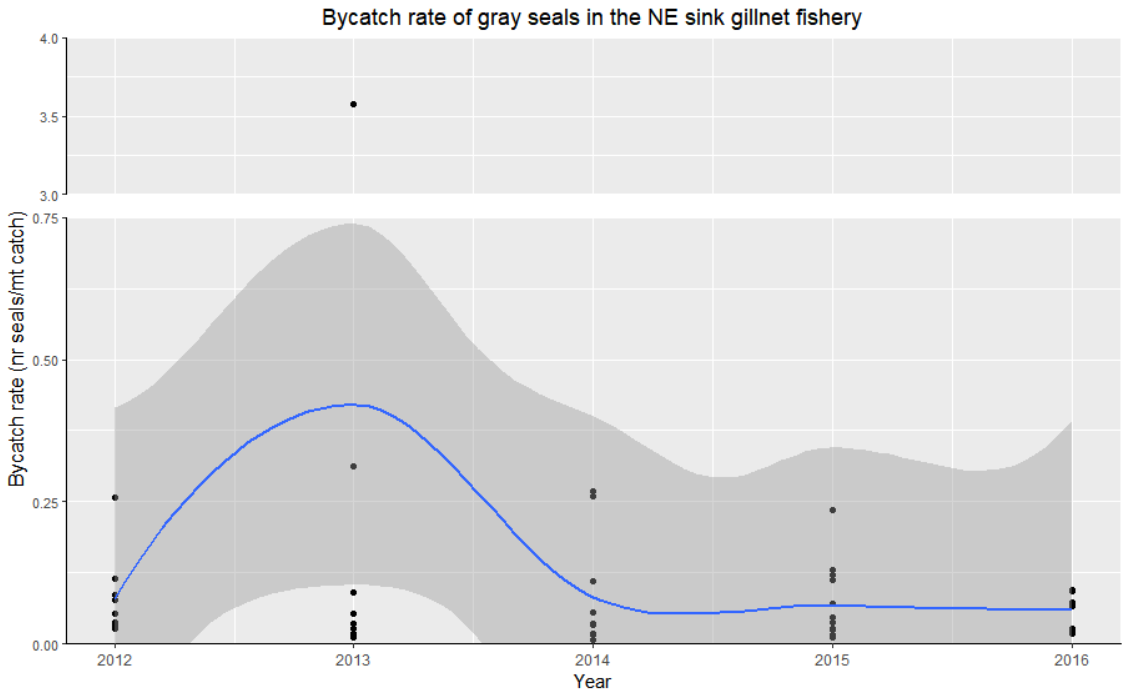

Figure 2. Summary statistics used to estimate bycatch of gray seals in the NE gillnet fishery from 2012 to 2016. Dots represent bycatch rate estimates for a given season-area stratum. The top panel shows the influential outlier (3.6) in 2013. A LOESS (locally estimated scatterplot smoothing) smoother (blue line) was fit to data. 95% Confidence intervals shown in gray. (Data sources: Hatch & Orphanides 2014, 2015, 2016; Orphanides & Hatch, 2017; Orphanides 2019 – See Appendix C).

ii. Northeast Bottom Trawl Fishery

The annual average bycatch of gray seals in the bottom trawl fishery operated in the western North Atlantic in U.S. waters is summarized in Table 4. The 5-year mean bycatch level was 20 animals (CV=0.23).

Table 4. Estimates of annual removals of gray seals in the northeast bottom trawl fishery. CV – Coefficient of variation. (Source: Hayes et al. 2019. See Appendix B).

Year	Observer Coverage	Estimated Removals	Est. CV
2012	0.17	37	0.19
2013	0.15	20	0.37
2014	0.17	19	0.45
2015	0.19	23	0.46
2016	0.12	0	0
5-yr mean		**20**	**0.23**

From 2012 to 2016, the gray seal bycatch rates for the NEBT fishery ranged from 0 seals/mt catch in 2016 to a maximum of 0.023 in 2012 (Figure 3, Table 5). The summary statistics used to estimate bycatch by stratum are presented in Table 5. The annual mean and median bycatch rates were used to estimate Canadian bycatch removals from the Canadian bottom trawl fishery. The mean and median bycatch rates ranged from approximately 0-0.01. Thus, the mean bycatch rate in the NESG fishery is more than six times higher than the bycatch rate in the NEBT fishery. Similar to the NESG fishery case (section *i* above), note that the gray seal summary statistics used to estimate bycatch for the NEBT fishery are based on the best available data (Chavez-Rosales et al. 2018 – See Appendix D).

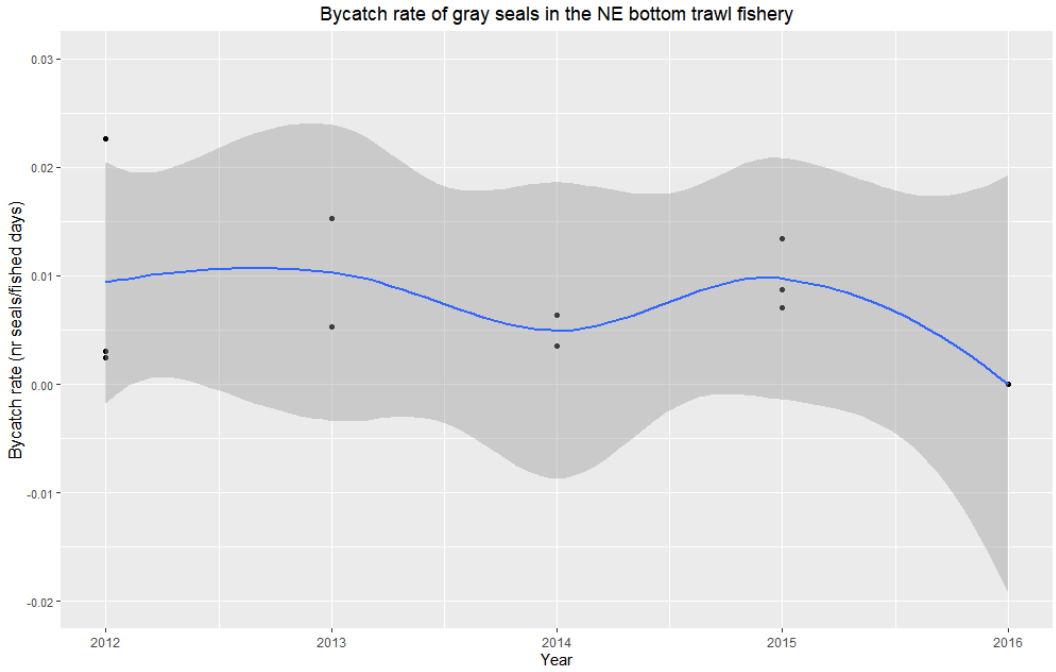

Figure 3. Summary statistics used to estimate bycatch of gray seals in the NE bottom trawl fishery from 2012 to 2016. Dots represent bycatch rate estimates for a given season-area stratum. A LOESS smoother (blue line) was fit to data. 95% Confidence intervals shown in gray. (Data source: Chavez-Rosales et al. 2018 – See Appendix D).

Table 5. Summary statistics used to estimate bycatch of gray seals in the northeast bottom trawl fishery from 2012 to 2016. (Data source: Chavez-Rosales et al. 2018. – See Appendix D).

Year	Minimum	Median	Mean	Maximum
2012	0.002	0.003	0.009	0.023
2013	0.005	0.010	0.010	0.015
2014	0.003	0.005	0.005	0.006
2015	0.007	0.009	0.010	0.013
2016	0	0	0	0

2. Atlantic Canadian waters adjacent to the U.S.

To provide an overall magnitude of gray seal bycatch in Canadian waters, we first included five NAFO zones (see Fig. 1) where seals from Sable Island (the Canadian rookery with the highest number of seals) and rookeries to the west might interact with fisheries. Estimates of bycatch removals used to inform the gray seal models (i.e., the "mixing" configuration) included data from all five of the NAFO zones in Fig 1. Next, we parsed bycatch in zones 4X, 5Y, and 5ZE from bycatch in 4W and 4VS. Given the relatively small number of gray seals estimated to have been killed incidental to commercial fisheries in Canada, our results from the parsed analysis did not change for scenario 3 or scenario 4 (i.e., limited mixing between U.S. and Canadian waters).

Note that we were unable to estimate Canadian bycatch removals for 2013 because there were no fisheries data in the NAFO database for this year. As a result, we present the 4-year average for the Canadian bycatch removals.

Appendix E provides estimates of distances of rookeries in the Gulf of Maine to the U.S.-Canadian boundary (i.e., EEZ). For U.S. rookeries, distances ranged from 81-121 km; while for Canadian rookeries in southwest Nova Scotia (SW NS), distances ranged from 10-124 km. Based on published reports from telemetry and tagging studies, gray seals are likely to move at least this far seasonally (DFO 2017, O'Boyle and Sinclair 2012). However, estimates of actual mixing rates for animals from Gulf of Maine rookeries are not currently available.

i. Sink Gillnet Fishery

The mean and median estimated removals of gray seals in the expanded NAFO region (5Ze and 5Y, 4X, 4W and 4Vs) for the groundfish gillnet fishery ranged between 82-224 seals and 34-232 seals, respectively (Table 6a). The 4-year average was 117 seals (median) and 164 seals (mean).

Table 6.a. Annual landings from gillnet fishery in Canadian waters adjacent to the U.S. (five NAFO zones: Canadian portions of 5Ze and 5Y, 4X, 4W and 4Vs – see Figure 1). Bycatch rates of gray seals in the U.S. northeast sink gillnet fishery from 2012 to 2016 (for details see Table 3) were used to estimate bycatch removals in the Canadian sink gillnet fishery. mt – metric tons (Source of fisheries data: NAFO 2018. Source of bycatch rates: Hatch & Orphanides 2014, 2015, 2016; Orphanides & Hatch 2017; Orphanides 2019 – See Appendix C). NA= Not Available (NAFO landings not available for 2013 precluded computation of removals for this year).

Year	Landings (mt)	Mean Bycatch rate	Median Bycatch rate	Mean Removals	Median Removals
2012	2,813	0.07978	0.0540	224.42	151.90
2013	NA	0.42100	0.0445	NA	NA
2014	996	0.08190	0.0340	81.57	33.86
2015	2,192	0.06708	0.0370	147.04	81.10
2016	3,456	0.05922	0.0670	204.66	231.55
4-year mean/median				**164.42**	**116.50**

In the NAFO region adjacent to the U.S. (5Ze and 5Y, 4X), the mean and median removals of gray seals in the groundfish gillnet fishery ranged between 79-156 seals and 34-106 seals, respectively (Table 6b). The 4-year average was 74 seals (median) and 102 seals (mean). The reduction in number of seal removals in this region compared to the expanded NAFO region is expected due to the reduction in fishing effort.

Table 6.b. Annual landings from gillnet fishery in Canadian waters adjacent to the U.S. (three NAFO zones: Canadian portions of 5Ze and 5Y, 4X – see Figure 1). Bycatch rates of gray seals in the U.S. northeast sink gillnet fishery from 2012 to 2016 (for details see Table 3) were used to estimate bycatch removals in the Canadian sink gillnet fishery. mt – metric tons (Source of fisheries data: NAFO 2018. Source of bycatch rates: Hatch & Orphanides 2014, 2015, 2016; Orphanides & Hatch 2017; Orphanides 2019 – See Appendix C). NA= Not Available (NAFO landings not available for 2013 precluded computation of removals for this year).

Year	Landings (mt)	Mean Bycatch rate	Median Bycatch rate	Mean Removals	Median Removals
2012	1,957	0.07978	0.0540	156.13	105.68
2013	NA	0.42100	0.0445	NA	NA
2014	994	0.08190	0.0340	81.41	33.80
2015	1,175	0.06708	0.0370	78.82	43.48
2016	1,571	0.05922	0.0670	93.03	105.26
4-year mean/median				**102.35**	**74.37**

ii. Bottom Trawl Fishery

The mean and median removals of gray seals in the expanded NAFO region (5Ze and 5Y, 4X, 4W and 4Vs) for the bottom trawl fishery ranged between 0-58 seals and 0-26 seals, respectively (Table 7a). No seal removals occurred in 2016 despite the high fishing effort. This is attributed to the zero bycatch rate estimated from the analogous U.S. fishery. The 4-year average was 20 seals (median) and 27 seals (mean), which corresponds to approximately 17% of the 4-year average removals in the gillnet fishery.

Table 7.a. Annual number of fished days for the bottom trawl fishery in Canadian waters adjacent to the U.S. (five NAFO zones: Canadian portions of 5Ze and 5Y, 4X, 4W and 4Vs – see Figure 1). Bycatch rates of gray seals in the U.S. groundfish bottom trawl fishery data from 2012 to 2016 (for details see Table 4) were used to estimate bycatch removals in the Canadian bottom trawl fishery (Data source for fisheries data: NAFO 2018. Source for bycatch rates: Chavez-Rosales et al. 2018. – See Appendix D). NA= Not Available (NAFO landings not available for 2013 precluded computation of removals for this year).

Year	Fished Days	Mean Bycatch rate	Median Bycatch rate	Mean Removals	Median Removals
2012	6,163	0.0094	0.0030	57.73	18.49
2013	NA	0.0103	0.0103	NA	NA
2014	4,461	0.0050	0.0050	22.08	22.08
2015	3,017	0.0097	0.0087	29.37	26.25
2016	5,091	0	0	0	0
4-year mean/median				**27.29**	**20.29**

In the NAFO region adjacent to the U.S. (5Ze and 5Y, 4X), the mean and median removals of gray seals for the bottom trawl fishery ranged between 0-17 seals and 0-26 seals, respectively (Table 7b). The 4-year average was 16 seals (median) and 21 seals (mean). As expected, the reduction in number of seal removals in this region compared to the expanded NAFO region is not as drastic as for the gillnet fishery due to much lower bycatch rates in the bottom trawl fishery.

Table 7.b. Annual number of fished days for the bottom trawl fishery in Canadian waters adjacent to the U.S. (three NAFO zones: Canadian portions of 5Ze and 5Y, 4X - see Figure 1). Bycatch rates of gray seals in the U.S. groundfish bottom trawl fishery data from 2012 to 2016 (for details see Table 4) were used to estimate bycatch removals in the Canadian bottom trawl fishery (Data source for fisheries data: NAFO 2018. Source for bycatch rates: Chavez-Rosales et al. 2018. – See Appendix D). NA= Not Available (NAFO landings not available for 2013 precluded computation of removals for this year).

Year	Fished Days	Mean Bycatch rate	Median Bycatch rate	Mean Removals	Median Removals
2012	5,005	0.0094	46.88	15.02	18.49
2013	NA	0.0103	NA	NA	NA
2014	3,351	0.0050	16.59	16.59	22.08
2015	1,963	0.0097	19.11	17.08	26.25
2016	4,225	0	0	0	0
4-year mean/median				**20.64**	**15.80**

III. Total incidental fishery removals (bycatch)

In the U.S. Atlantic waters, bycatch was the main source of seal removals, while in Canadian waters direct removals far exceeded the estimated bycatch removals (Tables 1, 8a, 8b). However, as noted earlier, several factors may contribute to the low bycatch estimates in Canadian waters relative to US waters. First, the estimates were based on U.S. bycatch rates and Canadian fishing effort data. Bycatch rates in analogous Canadian fisheries (i.e., sink gillnet and bottom trawl fisheries) could be higher because a higher density of seals is likely to occur, as one moves closer to the Sable Island area. Secondly, analogous fisheries in Canada may fish differently (e.g., may target different species or operate gear differently) and therefore may have bycatch per unit of fishing effort different from that observed in U.S. fisheries. However, without additional information from Canadian fishers, it is not possible to evaluate such possible biases.

In summary, from 2012 to 2016 the total U.S. bycatch removals for the NESG and NEBT fisheries were on average 841 seals, while the total Canadian removals averaged 192 seals and 123 seals in the five (Table 8a) and three NAFO zones (Table 8b), respectively. In total therefore, there is a combined U.S.-CA average for bycatch of 1,033 seals for the period between 2012 and 2016 in the five NAFO zones and an average of 964 seals in the three NAFO zones. The range of removals from 2012 to 2016 was 708 to 1,225 (five NAFO zones) (Table 8a) and 596 to 1,147 (three NAFO zones) (Table 8b).

Table 8.a. Summary of U.S. and Canadian (CA) removals of gray seals caused by bycatch 2012 to 2016. For the U.S., 5-year means are shown (in bold); for Canada and U.S.-CA combined, 4-year means are presented (in bold, missing data for 2013). Bycatch in Canadian waters includes five NAFO zones. NA= Not Available (NAFO landings not available for 2013 precluded computation of removals for this year).

Year	U.S. Bycatch	Mean CA Bycatch	Median CA Bycatch (*)	Total U.S.+CA
2012	579	282.15	170.39	866
2013	1,147	NA	NA	NA
2014	936	103.65	55.95	1,045
2015	1,044	176.40	107.35	1,225
2016	498	204.66	231.55	708
Mean	**841**	**191.72**	**-**	
Median	**936**	**-**	**138.87**	

(*) Median CA bycatch removals were estimated using median bycatch rates from the U.S. fisheries and were included solely for comparison to mean CA bycatch removals.

Table 8.b. Summary of U.S. and Canadian (CA) removals of gray seals caused by bycatch from 2012 to 2016. For the U.S., 5-year means are shown (in bold); for Canada and U.S.CA combined, 4-year means are presented (in bold, missing data for 2013). Bycatch in Canadian waters includes three NAFO zones. NA= Not Available (NAFO landings not available for 2013 precluded computation of removals for this year).

Year	U.S. Bycatch	Mean CA Bycatch	Median CA Bycatch (*)	Total U.S.+CA
2012	579	203.01	120.69	787
2013	1,147	NA	NA	NA
2014	936	98.00	50.38	1,039
2015	1,044	97.92	60.55	1,147
2016	498	93.03	105.26	596
Mean	**841**	**122.99**	**-**	
Median	**936**	**-**	**82.91**	

(*) Median CA bycatch removals were estimated using median bycatch rates from the U.S. fisheries and were included solely for comparison to mean CA bycatch removals.

IV. Preliminary calculation of impacts of bycatch removals under four scenarios

Under the U.S. Marine Mammal Protection Act (MMPA), the NMFS has adopted what is referred to as the PBR regime for managing marine mammal-fishery interactions in U.S. waters. The PBR is a removal level above which a given population of marine mammals has an unacceptably high likelihood of becoming depleted or if depleted, of not recovering. The PBR is the product of a minimum estimate of abundance, one half of the maximum rate of net productivity, and a Recovery Factor. More details on PBR-based management can be found in Wade (1998) and Moore and Merrick (2011). Typically, when the average of annual removals (i.e., bycatch plus other anthropogenic removals) exceeds the PBR threshold, the MMPA mandates that the NMFS undertake efforts to reduce removals to a level less than the PBR. This is often accomplished through the creation of a Take Reduction Team (https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-take-reduction-plans-and-teams). Herein, we have referred to the ratio of Annual Removals due to fishery interactions (ARF) to PBR as a measure of management efficiency (ME). We have used in this paper an ME of 0.5, as a threshold for a stock where bycatch levels are a concern (Table 9). The NMFS also uses the estimated PBR in its annual classifications of fisheries (List of Fisheries 2020), which is used inter alia to prioritize placement of marine mammal observers on commercial fishing vessels (e.g., under Tier 2, fisheries classified as Category I or II may be asked to carry an observer). In this case (Tier 2), only removals caused by individual commercial fisheries are considered in the analysis (Table 10). Unless the first step (Tier 1, when total bycatch from all fisheries interacting with a stock is compared against PBR) indicates that ME is below 0.1, each fishery is evaluated individually and classified accordingly by the NMFS.

In this analysis we have considered four scenarios, which the NMFS could adopt in implementing PBR-based management of commercial fisheries that interact with gray seals in U.S. waters. In the first scenario (base case), it is assumed that there is no mixing of gray seals between U.S. and Canadian waters. The minimum estimate of abundance (Nmin), the maximum net productivity rate (Rmax), and 5-year mean bycatch levels, are as reported in the 2018 Stock Assessment Report (Hayes et al. 2019). In the second scenario, the only change is that the value for Rmax is increased to 0.141, based on Punt et al. (2020). In the third scenario, it is assumed that the gray seal subpopulation that breeds and pups at rookeries in southwest Nova Scotia (SW NS) mixes freely with gray seals found in U.S. waters. Therefore, the estimates of abundance and bycatch under this scenario include animals found in SW NS (i.e., three dashed NAFO zones in Fig.1). It is also assumed the Rmax is 0.141. In the fourth scenario, it is assumed that gray seals in U.S. waters and all waters off Canada, except for the Gulf of St. Lawrence mix freely. Therefore, the estimates of abundance and bycatch under this scenario include animals found in all of the NAFO zones in Fig. 1 (i.e. three dashed NAFO zones plus 4W and 4Vs). While this assumption appears unlikely based on tagging data (O'Boyle and Sinclair 2012, DFO 2017), we included this scenario based on interest from the commercial fishing industry. Rmax was assumed to be 0.141 in this scenario as well. This information is summarized in Table 9.

Table 9. Preliminary estimates of parameters needed to evaluate the relationship between total annual removals in fisheries and PBRs based on various population scenarios. All abundance estimates are from 2016. Annual Removals due to fisheries interactions (ARF) are from Table 8a and b, based on data from 2012-2016; scenarios 3 and 4 combine removals from US and Canada (964 only accounts for the adjacent 3 NAFO zones; 1,033 accounts for the expanded 5 NAFO zones). Abundance estimates for U.S. gray seals are from Hayes et al. 2019. Abundance estimates for SW NS gray seals are based on pup count information from den Heyer et al. 2017, and a ratio of total population/pup counts of 4.3 (DFO 2017, Hayes et al. 2020). Abundance estimate for gray seals in western North Atlantic is from DFO 2017, but exclude animals from the Gulf of St. Lawrence region. CV- Coefficient of variation, shown in parenthesis, ME – Management efficiency.

Scenario	U.S. Abundance (CV)	Canada Abundance (CV)	Rmax	Annual Removals (ARF)	PBR*	ARF/PBR = ME
1	27,131 (0.19)	0	0.120	841	1,389	0.61
2	27,131 (0.19)	0	0.141	841	1,633	0.52
3	27,131 (0.19)	8,966 (0.075)	0.141	964	2,226	0.43
4	27,131 (0.19)	380,300 (0.1)	0.141	1,033	26,283	0.04

*based on a recovery factor of 1. Nmin for U.S. gray seal population was 23,158. Nmin for SW NS rookeries was 8,418. Nmin for Canadian gray seal population was 349,663.

The information in Table 9 is instructive for the following reasons:

1. As noted in Hayes et al. (2020) and den Heyer et al. (2017), the number of gray seals in U.S. waters and waters off SW Nova Scotia is increasing. Nevertheless, PBR-based management is based on an estimate of abundance at a single point in time and does not incorporate current trend data. Given the available data, the annual removal rate of gray seals under any of the scenarios in Table 9 is such that the stock is not strategic. This concurs with the finding in Hayes et al. (2020). The IAT will address the implications of population trends in Punt et al. (in prep)[5], such as how the robustness of PBR-based management in the Northeast region will be affected by increasing numbers of gray seals and possible increases in the bycatch level.

2. Using a more realistic estimate for Rmax (i.e., 0.141 rather than 0.12; scenario 2) causes the PBR to be increased by approximately 18% relative to base case (scenario 1). Given the way that the NMFS estimates the thresholds for fishery bycatch to classify fisheries for the purpose of observer placement, this difference could become important as the population of gray seals in U.S. waters and waters of SW NS continue to increase, which is likely to be associated with an increase in bycatch. We recommend its use in the calculation of PBR thresholds in the future.

3. Including gray seal abundance and bycatch from waters off southwestern Nova Scotia in the PBR-based management approach (scenario 3) causes the PBR to be increased by 60% relative to

[5] Punt, A., J. Brandon, D. DeMaster and P. Moreno. (in prep). Performance metrics for alternative management strategies for gray seal-commercial fishery interactions in the Northwest Atlantic.

scenario 1, while the estimated bycatch increases by approximately 15%. It is this combination of change in abundance levels and bycatch levels that causes the management efficiency ratio (i.e., ARF/PBR) to decrease from 0.61 to 0.43 (Table 9).

Further, under scenario 3 and using the catch data from 2012-2016, there is sufficient change in the ratio of bycatch to PBR for the NE sink gillnet fishery, that its fishery management classification would change from Category I to Category II (Table 10), if adopted by the NMFS. This would have the likely effect of lowering the priority of this fishery for carrying marine mammal observers under the NMFS marine mammal observer program.

4. When one considers gray seals in the western North Atlantic to be panmictic (scenario 4), excluding animals from the Gulf of St. Lawrence, PBR-based management would conclude that the NE bottom trawl fishery would change from Category II to Category III, while the fishery categorization for the NE sink gill net fishery would change from Category I to II (Table 10). As noted above, based on telemetry data, scenario 4 seems unlikely.

Table 10. Summary of the NMFS fishery classification assignments by scenario. Only removals caused by commercial fisheries are considered in this analysis. The fishery interaction category (i.e., I, II, III) is bolded in parenthesis as defined in: https://www.federalregister.gov/documents/2020/04/16/2020-06908/list-of-fisheries-for-2020 (See also Appendix A for details). Bycatch/PBR for scenarios 3 and 4 include data from Tables 1, 3, 5a,b, and 6a,b. An asterisk in a cell indicates a change in classification from base.

	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
	Bycatch by Fishery Type			
NE sink gill net	821	821	923	985
NE bottom trawl	20	20	41	47
	Potential Biological Removal (PBR)			
	1,389	1,633	2,226	26,283
	Bycatch/PBR (Fishery Category)			
NE sink gill net	0.591 (**I**)	0.503 (**I**)	0.415 (**II**) *	0.037 (**II**) *
NE bottom trawl	0.014 (**II**)	0.012 (**II**)	0.018 (**II**)	0.002(**III**) *

Conclusions

From both an industry perspective and a NMFS management perspective, the key information derived from this study is presented in Table 10. That is:

1. An Rmax of 0.141 should be used in calculating PBR, based on the results reported in Punt et al. 2020. This alone results in a change in the ratio of bycatch in a given fishery and PBR from 0.591 to 0.503 and 0.014 to 0.012 for the sink gill net and bottom trawl fisheries.
2. Making the assumption that gray seals in waters off southwestern Nova Scotia mix uniformly with gray seals in U.S. waters, would change the ratio of bycatch in the sink gill net fishery to PBR from 0.591 to 0.415. If adopted by the NMFS, this would change the

fishery specific classification from a Category I fishery to a Category II fishery. This has implications regarding marine mammal observer placement prioritization by the NMFS.

3. Making the assumption that gray seals in the waters south and east of Nova Scotia are panmictic, would change the bottom trawl fishery from a Category II fishery to a Category III fishery. It should be noted that the movement and tagging data available for gray seals indicates that this assumption is likely not met.

Future Work

The NEFSC is conducting important research to improve knowledge on movements and site-fidelity of gray seals in the main US rookeries. The stratified bycatch rates for the NE gillnet and bottom trawl fisheries are currently based on strata (area, season, etc.) that were primarily established for management of fishery interactions with the harbor porpoise stock. Hence, estimation of bycatch rates by strata better suited to the distribution and biology of gray seals, as well as in the case of the NE gillnet fishery stratification by mesh size (as large mesh size nets, e.g. monkfish fishery, are believed to pose greater risk of entanglement to gray seals) would be a logical next step to address the increasingly challenging management of interactions of commercial fisheries with gray seals. Development of a stratification approach for analyses of gray seal bycatch data is a promising research topic for future collaboration between the IAT and the NMFS/NEFSC scientists.

The NEFSC is also conducting important research on population monitoring of marine mammals in the NE US, including surveys to enumerate pup production. Given the increasing number of gray seals in NE over the past 15 years, it is critically important that estimates of abundance be available for this stock at least every 5-8 years. This is because as gray seal numbers increase, it is reasonable to expect increases in bycatch levels in US fisheries. Unless, abundance estimates are updated to reflect current status, the ratio of bycatch to PBR may indicate a conservation problem that in actuality does not exist. As noted above, the results reported in Punt et al. (in prep). should provide guidance as to what an optimal survey interval is, and what tradeoffs exist between funding marine mammal observer programs and additional population surveys.

The authors of this paper are hopeful that these results will prove useful to the NMFS and the industry in managing gray seal- commercial fishery interactions in US waters. Further, this report, along with the report on Rmax calculations and the modelling report will be made available to the Atlantic Scientific Review Group and the US Marine Mammal Commission. If requested, the authors will be available to provide a summary of the research to either party.

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APPENDIX

Appendix A.
Classification of the NE sink gillnet (A.1) and NE bottom trawl (A.2) fisheries based on interactions with marine mammals and associated fisheries' characteristics as per NMFS List of Fisheries 2020.

A.1 NE sink gillnet

Fisheries classification: Category I (i.e. mortality and serious injury equal to or greater than 50% of the stock's PBR). This fishery is currently classified based on mortalities and serious injuries of the Gray seal Western North Atlantic stock [1]

Marine Mammal Species and Stocks Incidentally Killed or Injured:

A. Seals (Pinnipeds)
- Gray seal, Western North Atlantic (WNA) [1]
- Harbor seal, WNA
- Harp seal, WNA

B. Large cetaceans (Mysticetes)
- Fin whale, WNA
- Humpback whale, Gulf of Maine
- Minke whale, Canadian east coast
- North Atlantic right whale, WNA

C. Small cetaceans (Odontocetes)
- Bottlenose dolphin, WNA offshore
- Common dolphin, WNA
- Harbor porpoise, Gulf of Maine/Bay of Fundy
- Risso's dolphin, WNA
- White-sided dolphin, WNA

Estimated number of participants (Vessels/Persons): 3,163[2]

[2] *Number of participants estimates are based on state and federal fisheries permit data. The estimated number of participants is expressed in terms of the number of active participants in the fishery, when possible. If this information is not available, the estimated number of vessels or persons licensed for a particular fishery is provided. If no recent information is available on the number of participants, then the number from the most recent LOF is used. NOAA Fisheries acknowledges that, in some cases, these estimations may be inflating actual effort.*

Total Effort: Total metric tons of fish landed from 1998 to 2012 were 22,933, 18,681, 14,487, 14, 634, 15,201, 17,680, 19,080, 15.390, 14,950, 15,808, 18,808, 17,207, 18,170, 19,279 and 17,490 respectively (NMFS). Includes descriptions of Northeast anchored float and Northeast drift gillnets. Data on total quantity of gear fished (i.e., number of sets) have not been reported consistently among commercial gillnet fishermen on vessel logbooks, and therefore will not be reported here.

Estimated observer coverage (as a percentage, number of trips observed/total commercial trips reported): From 1990 to 2013 was 1%, 6%, 7%, 5%, 7%, 5%, 4%, 6%, 5%, 6%, 6%, 4%, 2%,

3%, 6%, 7%, 4%, 7%, 5%, 4%, 17%,19%, 15%, and 11%. Includes descriptions of Northeast anchored float and Northeast drift gillnets.

Target Species: Atlantic cod, haddock, pollock, yellowtail flounder, winter flounder, witch flounder, American plaice, windowpane flounder, spiny dogfish, monkfish, silver hake, red hake, white hake, ocean pout, skate spp, mackerel, redfish, and shad.

Fishing area and seasonality: The fishery operates from the U.S.-Canada border to Long Island, New York, at 72° 30'W. long. south to 36° 33.03'N. lat. (corresponding with the Virginia-North Carolina border) and east to the eastern edge of the Exclusive Economic Zone (EEZ), including the Gulf of Maine, Georges Bank, and Southern New England. Fishing effort occurs year-round, peaking from May-July primarily on continental shelf regions in depths from 30-750 ft (9-228.6 m), with some nets deeper than 800 ft (244 m).

Gear Description: Sink gillnet gear, i.e. anchored gillnet fished in the lower one-third of the water column. The dominant material is monofilament twine with stretched mesh sizes from 6-12 in (15-30.5 cm) and string lengths from 600-10,500 ft (183-3,200 m), depending on the target species. The mesh size and string length vary by the primary fish species targeted for catch.

A.2 NE bottom trawl

Fisheries classification: Category II (i.e. mortality and serious injury greater than 1% and less than 50% of the stock's PBR). This fishery is currently classified based on mortalities and serious injuries of the White-sided dolphin Western North Atlantic stock [1]

Marine Mammal Species and Stocks Incidentally Killed or Injured:

A. *Seals (Pinnipeds)*
   - *Gray seal, Western North Atlantic (WNA)*
   - *Harbor seal, WNA*
   - *Harp seal, WNA*

B. *Small cetaceans (Odontocetes)*
   - *Bottlenose dolphin, WNA offshore*
   - *Common dolphin, WNA*
   - *Harbor porpoise, Gulf of Maine/Bay of Fundy*
   - *Risso's dolphin, WNA*
   - *White-sided dolphin, WNA* [1]
   - *Long-finned pilot whale, WNA*

Estimated number of participants (Vessels/Persons): 2,238[2]

[2] *Number of participants estimates are based on state and federal fisheries permit data. The estimated number of participants is expressed in terms of the number of active participants in the fishery, when possible. If this information is not available, the estimated number of vessels or persons licensed for a particular fishery is provided. If no recent information is available on the number of participants, then the number from the most recent LOF is used. NOAA Fisheries acknowledges that, in some cases, these estimations may be inflating actual effort.*

Total Effort: Total number of trips from 1998 to 2013 were 13,263, 10,795, 12,625, 12,384, 12,711, 11,577, 10,354, 10,803, 8,603, 8,950, 8,900, 6,791, 5,747, 8,219 and 6,440

Estimated observer coverage (as a percentage, number of trips observed/total commercial trips reported): From 1994 to 2016 estimated percent observer coverage (measured in trips) was 0.4%, 1.1%, 0.2%, 0.2%, 0.1%, 0.3%, 1.0%, 1.0%, 3%, 4%, 5%, 12%, 6%, 6%, 8%, 9%, 16%, 26%, 17%, 15%, 17%, 19% and 12%. Observer coverage for 2010- 2016 includes both observers and at-sea monitors.

Target Species: Atlantic cod, haddock, pollock, yellowtail flounder, winter flounder, witch flounder, American plaice, Atlantic halibut, redfish, windowpane flounder, summer flounder, spiny dogfish, monkfish, silver hake, red hake, white hake, ocean pout, and skate species.

Fishing area and seasonality: The Northeast bottom trawl fishery includes all U.S. waters south of Cape Cod, MA that are east of 70° W and extending south to the intersection of the Exclusive Economic Zone (EEZ) and 70° W (approximately 37° 54' N), as well as all U.S. waters north of Cape Cod to the Maine-Canada border. The fishery operates year-round, with a peak from May-July.

Sources: List of Fisheries 2020. Federal Register 85 FR 21079. 50 CFR 229, Vol. 85, No. 74, April 16, 2020, p21079-21103, 25p. and online (accessed on September 28, 2020) at:

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Appendix B.

Annual and 5-year mean bycatch removals for gray seals from 2012 to 2016 by fishery.

Fishery	Years	Data Type [a]	Observer Coverage [b]	Observed Serious Injury[c]	Observed Mortality	Est. Serious Injury	Est. Mortality	Est. Comb. Mortality	Est. CVs	Mean Annual Combined Mortality
Northeast Sink Gillnet	2012	Obs. Data,Weighout, Trip Logbook	0.15	0	91	0	542	542	0.19	821 (0.10)
	2013		0.11	0	69	0	1127	1127	0.20	
	2014		0.18	0	159	0	917	917	0.14	
	2015		0.14	0	131	0	1021	1021	0.25	
	2016		0.10	0	43	0	498	498	0.33	
Mid-Atlantic Gillnet	2012	Obs. Data, Trip Logbook, Allocated Dealer Data	0.11	0	1	0	14	14	0.98	12 (0.56)
	2013		0.03	0	0	0	0	0	0	
	2014		0.05	0	1	0	22	22	1.09	
	2015		0.06	0	1	0	15	15	1.04	
	2016		0.08	0	1	0	7	7	0.93	
Northeast Bottom Trawl	2012	Obs. Data,Trip Logbook	0.17	0	8	0	37	37	0.49	20 (0.23)
	2013		0.15	0	5	0	20	20	0.37	
	2014		0.17	0	4	0	19	19	0.45	
	2015		0.19	0	4	0	23	23	0.46	
	2016		0.12	0	0	0	0	0	0	
Mid-Atlantic Bottom Trawl	2012	Obs. Data,Trip Logbook	0.05	0	1	0	4	4	0.96	20 (0.47)
	2013		0.06	0	2	0	25	25	0.67	
	2014		0.08	0	1	0	7	7	0.96	
	2015		0.09	0	0	0	0	0	0	
	2016		0.097	0	3	0	26	26	0.57	
Northeast Mid-water Trawl – Incl.Pair Trawl	2012	Obs. Data,Trip Logbook	0.45	0	1	0	na	na	na	0.4 (na) [d]
	2013		0.37	0	1	0	na	na	na	
	2014		0.42	0	0	0	0	0	0	
	2015		0.08	0	0	0	0	0	0	
	2016		0.27	0	0	0	0	0	0	
TOTAL	-	-	-	-	-	-	-	-	-	873 (0.10)

a. Observer data (Obs. Data) are used to measure bycatch rates, and the data are collected within the Northeast Fisheries Observer Program. The Northeast Fisheries Observer Program collects landings data (Weighout), and total landings are used as a measure of total effort for the sink gillnet fishery. Mandatory logbook (Logbook) data are used to determine the spatial distribution of fishing effort in the Northeast multispecies sink gillnet fishery.

b. The observer coverages for the northeast sink gillnet fishery and the mid-Atlantic gillnet fisheries are ratios based on tons of fish landed. North Atlantic bottom trawl mid-Atlantic bottom trawl, and mid-Atlantic mid-water trawl fishery coverages are ratios based on trips. Total observer coverage reported for bottom trawl gear and gillnet gear includes traditional fisheries observers in addition to fishery monitors through the Northeast Fisheries Observer Program (NEFOP).

c. Serious injuries were evaluated for the 2012–2016 period (Josephson *et al.* 2019)

Source: NOAA Technical Memorandum NMFS-NE-258. US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments - 2018 (Hayes et al., 2019)

Appendix C.

Bycatch rate estimates by strata for gray seals from 2012 to 2016 in the northeast sink gillnet (NESG) fishery.

Table 5. Observed number of takes, estimated bycatch rates, estimated takes, coefficient of variation (CV), and lower (L) and upper (U) bounds on 95% confidence intervals (CI) of Atlantic gray seal (*Halichoerus grypus grypus*) bycatch in the New England sink gillnet fishery for 2012, by season and portgroup/management area. Seasons were defined as "W" winter (January to May), "S" summer (June to August), and "F" fall (September to December).

Season	Portgroup/ Management Area (MA)	Observed Takes	Bycatch Rate	Estimated Takes	CV	95% CI L	95% CI U
F	East of Cape Cod	5	0.026	33.89	0.62	7	116
F	Subtotal	5	-	33.89	0.62	7	116
S	East of Cape Cod	37	0.077	181.12	0.24	108	317
S	North of Boston	3	0.032	26.72	0.52	8	72
S	Offshore Port	1	0.054	7.31	1.29	1	51
S	Subtotal	41	-	215.15	0.24	139	361
W	East of Cape Cod	2	0.257	27.42	1.74	2	196
W	Mass Bay MA	1	0.039	2.53	0.78	1	14
W	South Cape MA	12	0.032	50.91	0.47	14	118
W	Southern New England MA	18	0.086	183.13	0.34	83	362
W	Stellwagen Bank MA	12	0.115	29.30	0.22	16	49
W	Subtotal	45	-	293.29	0.29	165	510
All	Total	91	-	542.33	0.19	376	789

Source: Hatch JM and Orphanides. 2014. Estimates of cetacean and pinniped bycatch in the 2012 New England sink and mid-Atlantic gillnet fisheries. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 14-02, Woods Hole, MA, 20 p.

Table 9. Observed number of bycatch, estimated bycatch rates, estimated bycatch, coefficient of variation (CV), and lower (L) and upper (U) bounds on 95% confidence intervals (CI) of Atlantic gray seal (*Halichoerus grypus grypus*) bycatch in the New England sink gillnet fishery for 2013, by season and portgroup/management area. Seasons were defined as "W" (winter; January - May), "S" (summer; June - August), and "F" (fall; September - December).

Season	Portgroup/ Management Area (MA)	Observed Takes	Bycatch Rate	Estimated Takes	CV	95% CI L	95% CI U
F	East of Cape Cod	1	0.008	9.71	0.97	1	38
F	Mass Bay MA	3	3.579	146.27	0.75	3	731
F	Stellwagen Bank MA	1	0.091	8.42	0.88	1	39
F	Subtotal	5	-	164.40	0.83	10	770
S	East of Cape Cod	25	0.054	128.10	0.20	76	190
S	North of Boston	1	0.018	5.42	0.95	1	27
S	New Hampshire	1	0.012	5.74	0.92	1	32
S	Offshore	1	0.027	5.02	0.97	1	25
S	South of Cape Cod	2	0.027	47.91	0.70	2	166
S	Subtotal	30	-	192.19	0.21	122	305
W	Offshore MA	2	0.054	10.36	0.69	2	37
W	Southern New England MA	31	0.313	754.97	0.23	451	1172
W	Stellwagen Bank MA	1	0.035	4.93	0.86	1	23
W	Subtotal	34	-	770.26	0.22	468	1190
	Total	69	-	1126.85	0.20	745	1686

Source: Hatch J. and Orphanides C. 2015. Estimates of cetacean and pinniped bycatch in the 2013 New England sink and mid-Atlantic gillnet fisheries. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 15-15, Woods Hole, MA, 26 p.

Table 5. Observed number of bycatch, estimated bycatch rates, estimated bycatch, coefficient of variation (CV), and lower (L) and upper (U) limits on 95% confidence intervals (CI) of gray seal (*Halichoerus grypus*) bycatch in the New England sink gillnet fishery for 2014, by season and port group (P)/management area (MA) (Figure 1a). Seasons were defined as "W" (winter: January - May), "S" (summer: June - August), and "F" (fall: September - December).

Season	Port group (P)/ Management Area (MA)	Observed Bycatch	Bycatch Rate	Estimated Bycatch	CV	95% CI L	95% CI U
W	Mid-Coast (MA)	2	0.033	4.96	0.88	2	31
W	Cape Cod South (MA)	4	0.055	48.25	0.55	11	125
W	Southern New England (MA)	63	0.269	467.20	0.24	271	774
W	Stellwagen Bank	7	0.260	25.09	0.44	8	68
W	Subtotal	76	-	545.50	0.21	344	858
S	East of Cape Cod (P)	66	0.111	295.50	0.16	205	413
S	New Hampshire (P)	1	0.007	5.76	0.99	1	21
S	Subtotal	67	-	301.26	0.16	211	423
F	East of Cape Cod (P)	10	0.018	38.46	0.34	15	79
F	Mid-Coast (MA)	4	0.016	12.74	0.41	4	29
F	Offshore (P)	1	0.015	3.87	0.80	1	26
F	Cape Cod South (MA)	1	0.035	15.29	0.93	1	56
F	Subtotal	16	-	70.36	0.28	37	131
	Total	159	-	917.12	0.14	687	1234

Source: Hatch J. and Orphanides C. 2016. Estimates of cetacean and pinniped bycatch in the 2014 New England sink and mid-Atlantic gillnet fisheries. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 16-05, Woods Hole, MA, 22 p.

Table 4. Observed number of bycatch, estimated bycatch rates, estimated bycatch, coefficient of variation (CV), and lower (L) and upper (U) limits on 95% confidence intervals (CI) of gray seal (*Halichoerus grypus grypus*) bycatch in the New England sink gillnet fishery for 2015, by season and port group (P)/management area (MA). Seasons were defined as "W" (winter: January - May), "S" (summer: June - August), and "F" (fall: September - December).

Season	Port Group (P)/ Management Area (MA)	Observed Bycatch	Bycatch Rate	Estimated Bycatch	CV	95% CI L	95% CI U
W	Cape Cod South (MA)	7	0.112	86.62	0.47	31	208
W	Southern New England (MA)	65	0.235	623.84	0.41	295	1544
W	Stellwagen Bank	1	0.130	5.50	0.93	1	27
W	Subtotal	73	-	715.96	0.34	383	1610
S	East of Cape Cod (P)	22	0.037	111.55	0.48	39	360
S	North of Boston (P)	4	0.071	24.18	0.50	6	64
S	New Hampshire (P)	1	0.012	5.55	0.95	1	24
S	Southern Maine (P)	1	0.025	1.70	0.67	1	10
S	South of Cape Cod (P)	1	0.012	22.69	0.98	1	117
S	Subtotal	29	-	165.67	0.36	84	422
F	East of Cape Cod (P)	11	0.047	53.22	0.31	25	103
F	Mid-Coast (MA)	13	0.121	51.61	0.32	24	106
F	North of Boston (P)	1	0.028	2.00	0.90	1	14
F	South of Cape Cod (P)	2	0.026	27.66	2.05	2	287
F	Cape Cod South (MA)	2	0.016	5.19	1.35	2	40
F	Subtotal	29	-	139.68	0.41	74	322
	Total	131	-	1021.31	0.25	644	1852

Source: Orphanides CD and Hatch JM. 2017. Estimates of cetacean and pinniped bycatch in the 2015 New England sink and mid-Atlantic gillnet fisheries. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 17-18, Woods Hole, MA, 21 p.

Table 4. Gray seal (*Halichoerus grypus atlantica*) bycatch in the New England sink gillnet fishery during 2016. Provided are the observed number of bycatch, estimated bycatch rates, estimated bycatch, coefficient of variation (CV), and lower (L) and upper (U) limits on 95% confidence intervals (CI) by season and port group (PG)/management area (MA). Seasons were defined as "W" (winter: January - May), "S" (summer: June - August), and "F" (fall: September - December).

Season	Port Group (PG)/ Management Area (MA)	Observed Bycatch	Bycatch Rate	Estimated Bycatch	CV	95% CI	
						L	U
W	Cape Cod South (MA)	5	0.071	59.29	0.46	21	139
W	Southern New England (MA)	11	0.074	177.20	0.41	72	388
W	Subtotal	16	-	236.49	0.33	122	451
S	East of Cape Cod (PG)	5	0.019	70.99	0.45	15	146
S	North of Boston (PG)	2	0.023	12.73	0.65	2	40
S	Subtotal	7	-	83.72	0.40	33	171
F	East of Cape Cod (PG)	12	0.067	137.30	0.94	55	791
F	Mid-Coast (MA)	1	0.027	6.33	1.00	1	35
F	North of Boston (PG)	1	0.066	3.23	0.84	1	18
F	Cape Cod South (MA)	5	0.092	24.93	0.62	5	85
F	Stellwagen Bank	1	0.094	6.08	0.94	1	26
F	Subtotal	20	-	177.87	0.72	89	814
	Total	43	-	498.08	0.33	317	983

Source: Orphanides CD. 2019. Estimates of cetacean and pinniped bycatch in the 2016 New England sink and Mid-Atlantic gillnet fisheries. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 19-04; 12 p.

Appendix D.

Bycatch rate estimates by strata for gray seals from 2012 to 2016 in the northeast bottom trawl (NEBT) fishery.

Table 3 (Cont'd) Stratified observed bycatch (OBS Byc), bycatch rates (Byc Rate), total (VTR DF) and observed days fished (OBS DF), percent coverage (Cov %), total bycatch mortality (M), and coefficient of variation (CV) by species, region (NE = Northeast, MA = Mid-Atlantic; shaded rows), year (2012-2016), season (w = January-April, s = May-August, f = September-December), and ecoregion (ECO; GOM = Gulf of Maine, GB = Georges Bank, MA = Mid-Atlantic) in Northeast and Mid-Atlantic commercial bottom trawl trips. Years and seasons absent from the 5-year time series means no bycatch events were observed; thus, the estimated total bycatch for that year is defined as zero.

Species	Region	Year	Season	ECO	VTR DF	OBS DF	Cov %	OBS Byc	Byc Rate	M	CV
Gray seal (*Halichoerus grypus atlantica*)	NE	2012	s	GB	1076	177	16.41	4	0.0226	24.37	0.64
	NE	2012	s	GOM	1831	405	22.11	1	0.0025	4.52	0.86
	NE	2012	w	GOM	2860	1011	35.36	3	0.003	8.49	0.46
	NE	2013	f	GB	858	188	21.86	1	0.0053	4.58	0.86
	NE	2013	s	GB	1009	262	25.99	4	0.0153	15.39	0.4
	NE	2014	s	GB	1299	310	23.86	2	0.0064	8.31	0.63
	NE	2014	w	GOM	3058	570	18.64	2	0.0035	10.70	0.63
	NE	2015	f	GB	881	141	16.00	1	0.0071	6.26	0.93
	NE	2015	s	GB	1183	229	19.36	2	0.0087	10.29	0.65
	NE	2015	w	GB	458	74	16.16	1	0.0134	6.14	0.90

Source: NOAA Technical Memorandum NMFS-NE-250. Estimates of Cetacean and Pinniped Bycatch in Northeast and Mid-Atlantic Bottom Trawl Fisheries, 2012-2016 (Samuel Chavez-Rosales et al., 2018)

Appendix E.

Pup counts from U.S. rookeries and six eastern Canadian rookeries relevant for this study. All counts were from 2016. * indicates site not surveyed in 2016. Distance from the rookeries to the U.S.-Canadian EEZ (dashed line in Fig.1) calculated by Moreno using ArcGIS tools.

Rookery	Country	Region	Lat	Lon	Pup Count	Distance rookery to EEZ (km)
Muskeget	USA	Massachusetts	41.3375	-70.305	3787	269.3
Monomoy	USA	Massachusetts	41.59	-69.9903	935	232.5
Green	USA	Maine	44.15944	-68.3342	34	81.0
Seal	USA	Maine	43.8875	-68.7403	1043	105.4
Mount Desert Rock	USA	Maine	43.96861	-68.1283	*	59.8
Nomans	USA	Massachusetts	41.25556	-70.8161	32	310.8
Matinicus Rock	USA	Maine	43.78556	-68.8531	193	111.5
Wooden Ball	USA	Maine	43.85444	-68.8183	284	110.6
Great Point	USA	Massachusetts	41.38861	-70.0458	*	247.8
Mud	CAN	Gulf of Maine	43.481	-65.9884	858	120.7
Round	CAN	Gulf of Maine	43.5074	-65.9846	538	120.2
Noddy	CAN	Gulf of Maine	43.4655	-65.9861	382	121.3
Flat	CAN	Gulf of Maine	43.5087	-66.004	71	118.6
Grand Manan	CAN	Gulf of Maine	44.69	-66.82	*	10.1
Yarmouth Lighthouse	CAN	Gulf of Maine	43.80694	-66.1583	*	92.2

Source: den Heyer et al. 2017; Wood et al. 2020