

Investigation of seal and dogfish depredation in gill nets

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ABSTRACT

Impacts of predation by seals and dogfish on fish caught in gillnets has been largely neglected. This is important in Cape Cod's Fixed Gear Sector because all discarding associated with predation is counted against the sector's Total Allowable Catch (TAC). This results in a loss of profits for fishermen within the sector.

Between June 3rd and July 3rd 2007, sixty-one gillnet hauls were observed during regular commercial fishing activities in order to investigate predation rates of both species. Allometric regression was used in tandem with weight conversion factors to determine the estimated total weight of eaten and discarded fish in each haul. Spatial relationships and predation rates relative to certain environmental variables were also investigated.

Results showed that approximately 2,500 lbs of fish was discarded from a total catch weight of nearly 130,000 lbs because of predation by both seals and dogfish. This represented an estimated \$2,500 loss from a total catch value of \$64,000, signifying a 3.53% loss of the fishermen's gross profits. The biggest monetary loss was associated with the monkfish catch. With regard to environmental variable significance, there was a correlation between increased net soak duration and increased predation by both species. The water depth at which nets were set was also significant; however, this was only in relation to seal predation with predation events generally occurring between 25 and 31 fathoms. Seal events occurred mainly over clay and, dogfish over a sandy substrate, however, bias may exist in these latter findings based on the predominance of nets being set on sand. Furthermore, spatial investigations highlighted that fishing practices were taking place in closed and restricted areas. Overall, results suggest that amendments need

to be made to the NEFMP to ensure a reduction in discarding associated with predation by seals and dogfish. Also, although the gross profit loss appeared low, further investigations involving net profit loss would place these findings in greater context.

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1. INTRODUCTION

In 2003 The New England Fishery Management Council (NEFMC) developed and implemented the final rule to Amendment 13 of the Northeast Multispecies Fishery Management Plan (NEFMP) (Northeast Fisheries Management Council, 2003). This was done so that the existing NEFMP would be brought into compliance with the Magnuson-Stevens Fishery Conservation and Management Act established in 1976 (16 U.S.C. 1801-1882). The Final Supplemental Environmental Impact Statement (FSEIS) and Initial Regulatory Flexibility Analysis (IRFA) that was presented by the NEFMC detailed the proposed mechanisms to be used to end overfishing and also set forth the criteria to identify and rebuild damaged stocks (Northeast Fisheries Management Council, 2003). The Council projected that the stocks in need of formal rebuilding programs would be rebuilt by 2014, except in the case of Georges Bank (GB) cod, which was projected at 2026 (Northeast Fisheries Management Council, 2003).

Amendment 13 to the NEFMP was essentially over 40 years in the making. It involved not just fishermen and policy makers, but also scientists and environmentalists. Amendment 13 had major implications for fishing activities in the New England area. As a direct result of its actions, the GB trip limit for cod was reduced from 2,000 lbs per trip to 1,000 lbs per trip unless the fisherman was part of a sector with a hard Total Allowable Catch (TAC) (Northeast Fisheries Management Council, 2003). This drastic reduction greatly affected fishermen that were not members of sectors. Amendment 13 also set forth sector guidelines and stipulated requirements for sector formation. In addition, it certified the implementation of the first New England GB cod hard TAC which was

associated with the GB Cod Hook Sector (Northeast Fisheries Management Council, 2003).

The GB Cod Hook Sector was in operation for over two years before the second GB cod sector TAC was realized. This sector was called the GB Cod Fixed Gear Sector and came about through framework 42 to the NEFMP in November 2006 (Northeast Fisheries Management Council, 2005). It took effect on May 1st 2007. The main principle behind developing sectors with hard TAC's was to "allow fishing activity and resource conditions in a particular area, encourage a greater sense of stewardship, and ensure that fishing activity in one sector does not adversely affect fishing activity in another sector" (Northeast Fisheries Management Council, 2003). The Cape Cod Commercial Hook Fishermen's Association (CCCHFA), who manages fishermen that reside within both aforementioned sectors, devised the respective operations plans.

The CCCHFA is a non-profit organization of traditional day-boat fishermen. They play a pivotal role in Chatham's fishing community on Cape Cod. They take on a community-based fisheries management approach in an attempt to preserve not just the ocean's resources but also the local fishing traditions and way of life. By developing and managing the first two New England sectors with hard TACs they are attempting to reform currently futile and inefficient management initiatives that are failing to protect the fish and the fishing communities. In doing so, they have not just provided support for the local fishermen; they have also helped the Chatham fish processors and the local restaurants and fishmongers that sell the fish, thus promoting sustainable local seafood. Chatham is renowned for its small fishing village practices and tourists are drawn from all around the world to watch the fishermen land their daily catch at the fish pier. This has

generated a substantial amount of revenue for the town and the CCCHFA relies heavily on local support and donations from interest groups who support their endeavors.

A vital component of the CCCHFA's success in promoting sustainable fishing practices is their attempt to curtail excessive discarding with the use of the hard TAC. In the case of the GB Cod Fixed Gear Sector, the TAC was based on the documented landings of sector members during the qualifying period between 1996 and 2001 (Northeast Fisheries Management Council, 2003). All participants were also required to possess a valid northeast multispecies permit and an allocation of days-at-sea (DAS) to use the TAC (Northeast Fisheries Management Council, 2003).

The GB cod Fixed Gear Sector consists of a fleet of 9 self-selecting gillnet boats that operate within a multispecies fishery. They primarily target cod, monkfish and skate (GB Fixed Gear Sector & Cape Cod Commercial Hook Fishermen's Association, 2007). Each fisherman in the sector gets a quota of the overall TAC and they must agree to avoid exceeding the quota and allocated TAC, thus preventing overfishing. This means that although they may be targeting monkfish or skate on a particular trip, they still have to account for all cod discarding. Cod discards are then counted against the overall cod TAC for the sector. Fishermen can either use their own quota of the cod TAC or if they've used up their individual quota they can lease quota from someone else within the sector. The NEFMC has put forth several options for dealing with discarding in systems availing of quotas. One such proposal was to designate a certain amount of the TAC towards bycatch and discarding and just remove it, however, this may pose certain problems that will be discussed later in the paper (Eric Brazer, pers. comm.).

Fishermen in the sector fish with monofilament bottom-set gillnets. Gillnets are a fixed fishing gear that trap and entangle fish, usually by their gills, in the net mesh. This mesh can vary in size based on target species, therefore allowing for a level of size-selectivity of the target fish. This helps to reduce the likelihood that fish under the legal minimum size limit will get caught. Those operating within the sector use two different types of gillnet in order to catch different fish species. When they wish to target monkfish/skate they use nets with a mesh that is greater than 10”, usually 12-13”. These nets are also constricted in various locations in order to create protuberances in the mesh. Cod nets on the other hand usually have a mesh between 6.5 and 10” and do not elicit any bulges, therefore standing upright in the water column. A different number of DAS is associated with each mesh size.

The variations in gillnet type enables fishermen to target different fish species that typically inhabit different depths in the water column. This is made possible because net orientation is different for each net type and ensures maximum retention of trapped fish once caught. There have however, been problems associated with high gillnet retention rates. Some predators such as dolphins (Read et al 2003) and manatees (Powell 1978) have been known to specifically target gillnets to predate on the large quantities of trapped fish. It was these findings that spurred the generation of this research project in alliance with the CCCHFA. The association was interested to know whether seals and migratory dogfish, which was once the most abundant shark in the western North Atlantic (Bigelow and Schroeder 1953), were interacting with their sectors gillnets and subsequently having a negative impact on local commercial fishing activities.

In the early 1990's it was documented that the dogfish had surpassed the dominant silver hake to become the primary predator of fish in the GB (Sissenwine & Cohen, 1991). Fishermen also claim that seals are having a devastating impact on groundfish stocks in the region. Both species are protected by conservation initiatives such as amendments to the Dogfish Management Plan (DMP) and the Marine Mammal Protection Act (MMPA). Fishermen believe that this accounts for the growing populations of dogfish and seals, thus resulting in higher levels of predation and a related reduction in groundfish catch rates.

From 1990 - 2000, there was a market for spiny dogfish (*Squalus acanthias*) and the fishery off Cape Cod was one of the most lucrative in operation. It was an important fishery to fishermen residing in the ports of Plymouth, Scituate, and Chatham, and the fish processors in New Bedford (Pierce, 2000). However, in 2000 concerns over the waning dogfish populations arose and were attributed to factors including their very long gestation period. These concerns caused the Division of Marine Fisheries (DMF) and the Massachusetts Marine Fisheries Commission (MMFC) to alter the already existing management guidelines for the fishery. A complete closure of the fishery was proposed but an alternate management plan was decided upon in order to help preserve the Commonwealth's dogfish processing infrastructure and markets that would have otherwise been lost completely.

Prior to 2000, dogfish landings exceeded 45 million pounds per annum. This changed with the implementation of new management strategies that reduced the landing limit to less than 7 million pounds per annum (Pierce, 2000). It was also concluded that this TAC would be reached by August 26th of each year so after this date the fishery

would be closed until April 30th of the following year. This former date marked the end of the management councils' fishing year (Pierce, 2000).

Although these changes to the DMP marked the beginning of considerable alterations in dogfish fishing on Cape Cod, further modifications to the plan have occurred yearly. The 2007 regional quota of dogfish was 6 million lbs and specifically, for those fishermen holding federal permits, which includes all boats in the sector, the daily trip limit for dogfish was 600 lbs (Diodati, 2007). Fishermen argue that the dramatic decrease in the amount of dogfish that are allowed to be landed coupled with the fact that dogfish are quite high on the food chain, has resulted in an increase in depredation of target fish trapped in their gillnets. However, these events have not just been attributed to the recovering dogfish populations but also the increasing seal numbers in the vicinity.

Seals are also a major predator of fish and since 1972 they are protected under the Marine Mammal Protection Act which placed a moratorium on the "taking" of marine mammals, thus making it illegal to "harass, hunt capture or kill any marine mammal" (Act 16 U.S.C. 1361-1407). This has resulted in a subsequent increase in seal population numbers and an expansion of their range (Waring, 1994). Amendments made to the act in 1994 do however, allow for a designated level of marine mammals to be incidentally injured or killed during commercial fishery operations (MMPA regulations, 2005). Numerous seal species are readily seen in the coastal waters off Cape Cod and include the western Atlantic harbor seal (*Phoca vitulina*), the grey seal (*Halichoerus grypus*), the harp seal (*Phoca groenlandica*) and less frequently, the hooded seal (*Cystophora cristata*).

Both the grey and harbor seal species occur in the largest numbers off the

Massachusetts coast. They feed on inshore cephalopods and crustaceans such as squid, mussels and crab, but prefer their primary prey fish species, which includes cod, flounder, whiting and sole (Prime and Hammond, 1988; Bonner, 1982). Grey seals are believed to consume an estimated 16.5 -27.5 lbs of food per day and the harbor seal is thought to consume a probable 11-18.5 lbs per day (Bonner, 1982). Specifically, the harbor seal tends to occur seasonally in the southern reaches of New England from September through late May (Schneider and Payne 1983). However, year-round resident populations are also present particularly in the coastal waters of Maine (Katona *et al.*, 1993) and Cape Cod. This species is also known to reside in areas as distant North as eastern Canada and as far south as the Carolinas (Boulva and McLaren 1979).

In 2003, the NMFS proposed that the grey seal populations residing in two locations in Massachusetts had experienced a 20.5% increase in population between 1994-1999 (NMFS 2003). In 1994, Kenney and Gilbert published a paper that estimated a minimum population abundance of harbor seals along the Maine Coast to consist of 28,810 individuals. They also suggested that the number of harbor seals along the New England coast had increased almost five-fold in the 21 years following the implementation of the MMPA. Furthermore, they had conducted a series of surveys in 1981, 1982, 1986, and 1993 from which they concluded there was an estimated 8.7% annual increase in the harbor seal population within Maine coastal waters. Irrespective of the reduction in groundfish populations and mortality associated with fishing practices, if this estimate is accurate, the harbor seal population in Maine coastal waters in 2007 consisted of a projected 85,200 individuals which, collectively, ate a minimum of approximately 935,000 lbs of food a day.

Evidently dogfish and seal populations are on the rise and interactions of both species with sector gillnets is important to fully understand. This is because discarding associated with predation by either species is not just a waste of living resources; it also results in an economic loss for the fishermen. This loss is a consequence of the depletion of the sectors allocated TAC limits and the loss of viable fish species that could have otherwise been landed.

It was for this reason that during June and July 2007, a research project was completed in alliance with the CCCHFA that investigated discarding in sector gillnets. Specifically, discarding associated with seal and dogfish depredation. Onboard observations of sector fishing trips took place in order to accomplish the following: (1) Identify areas within Georges Bank that appear to have a high occurrence of depredation. (2) Quantify the weight (in lbs) of discards associated with depredation events. (3) Investigate if variables such as wave height, substrate type, water depth and soak duration of nets are affecting depredation events. (4) Investigate whether fishermen are abiding to current closed area fishing restrictions within Georges Bank and, (5) make recommendations that may ameliorate discarding associated with seal and dogfish depredation.

2. METHODS

Gillnet interactions by seals and dogfish were examined off Chatham, Cape Cod, from June 3rd to July 3rd 2007. Sixty-one hauls consisting of 661 gillnets were observed during regular commercial fishing activities on four different fishing vessels. This was done in order to investigate depredation by both aforementioned species. All nets hauled were monofilament gillnets with either 6.5-7.5” or 12-13” mesh, depending on target species.

At the beginning of each haul the starting GPS location, wave height, water depth and soak duration of the nets were recorded. The interval of each haul was monitored and when it concluded the end GPS location was noted. During each haul, any fish that elicited signs of seal or dogfish depredation was measured and weighed. The fish species was also identified along with the likely predator and any pertinent comments. It was possible to identify the predator based on the predator’s characteristic bite signature and preferred bite location.

Seals tended to create ragged bite marks to the abdomen where they fed solely on the liver and stomach. Dogfish however, made smooth edged bite marks to the body and dorsal side of the fish (Figure 1).

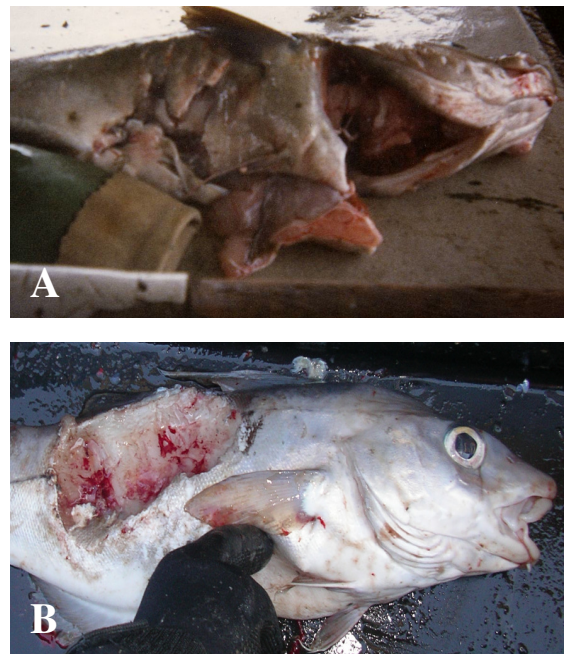


Figure 1. (A) Characteristic ragged seal bite mark (picture compliments of Amy Sierra Van Atten, NOAA). (B) Characteristic smooth edged dogfish bite mark (picture compliments of Erin Burke, Massachusetts Division on Marine Fisheries).

2.1. Identify areas within Georges Bank that appear to have a high occurrence of depredation.

Arc maps were created in tandem with interactive tools in Google map to highlight the number of depredation events that were caused by seals and dogfish during each haul. Lambert Conformal Conic was the projected coordinate system and GCS_WGS_1984 was the geographic coordinate system used for all data in Arc map. Python scripts were written in order to show the associated wave height, sediment type, water depth and net soak duration at each haul site on the map.

2.2. Quantify the weight (in lbs) of discards associated with depredation events.

All fish weights collected during the experimental period were post-depredation. In order to accurately quantify both the total weight of fish discarded (assuming that once attacked, the whole fish would be discarded) and the total weight of fish eaten during depredation, it was necessary to first calculate the estimated total weight of each fish prior to a depredation event. This was achieved using the following allometric length-weight equation given in NOAA's technical memorandum (2003):

$$\ln W = \ln a + b \ln L$$

This memorandum examined the length-weight relationships of 74 fish species collected during North East Fisheries Science Council (NEFSC) research vessel bottom trawls between 1992 and 1999. The research successfully calculated a and b coefficients for each fish species via linear regression using natural logarithmic transformation data. These coefficients were used in tandem with the above equation and the collected fish

lengths to estimate the full weight of depredated fish. All weights were added to yield a total weight (lbs) for each fish species subject to depredation. The coefficients used during this analysis were taken from autumn investigations that combined both males and females. This was done because such data did not exist for summer and also because sex had not been determined during depredation investigations (see Appendix A for table of coefficients used in this study).

Subsequently, it was possible to compute (1) the percentage of total catch that was discarded due to depredation, and (2) the percentage of total catch that was eaten by seals and dogfish. The total catch was obtained by adding the estimated total weight of the depredated fish to the total landed weight. Some of the landed weights however needed to be modified slightly before they could be used in the analysis. This was necessary because a few of the fish species were processed on the boat prior to landing at the dock, thus requiring conversion factors to calculate their estimated full body weights. The species in need of conversion factors included haddock, pollock (steak) and skate (wings) which were 1.14:1, 1.37:1 and 2.27:1 respectively (Eric Brazer pers. Comm.). Once completed, the total weight of fish discarded was divided by the total weight caught and multiplied by 100 in order to obtain (1) above, and the total weight of fish eaten was divided by the total weight caught and multiplied by 100 in order to obtain (2) above. These results were then further broken down to show lbs lost to seals and dogfish individually.

Market value prices were obtained for each fish species from the Gloucester / New Bedford fish auction for the dates that hauls were landed. The prices for each fish species varied by species, by boat and by day so an average market value was taken

across all of these variables. This yielded a single average value per pound for each fish species. Again, it is necessary to note that some fish species were processed prior to landing. As a result, landed weights were converted to whole weights in order for accurate comparison. To address this, the price per pound of haddock, pollock and skate needed to be divided by the aforementioned conversion factors to obtain viable price estimates. All prices were then multiplied by the total pounds caught for each species in question. This returned an estimated total market value price (\$) for all fish caught in the observed hauls. Using these dollar amounts, prices could then be determined for the amount of fish that were discarded and the weight of fish eaten by seals and dogfish.

2.3. Investigate if variables such as wave height, substrate type, water depth and soak duration of nets are affecting depredation events.

The significance of all variables collected during each haul was investigated with regard to depredation events. This was realized using a Generalized Linear Model (GLM) and Poisson distribution in 'R', the statistical package (see Appendix B for scripts run in R). Sediment type at the site of each haul was also a variable included in the analysis. This data was obtained from the U.S. Geological Survey East-Coast Sediment Analysis GIS Database.

2.4. Investigate whether fishermen are abiding to current closed area fishing restrictions within Georges Bank

Arc maps were generated which displayed haul locations, closed fishing areas and areas of rolling closure. All coordinates were in GPS so they were converted into lat/long using LoranGPS. All of the data was then projected as mentioned previously. The

'Intersect' tool was used on both the haul locations and the closed areas, and the haul locations and areas of rolling closure in order to detect if fishermen were hauling gear within these regions.

2.5. Make recommendations that might ameliorate discarding associated with seal and dogfish depredation

All of the results from this study were collectively assessed in order to provide recommendations to not just the fishermen, but also the NEFMC, in an effort to reduce the level of discarding associated with seal and dogfish depredation.

3. RESULTS

3.1. Identify areas within Georges Bank that appear to have a high occurrence of depredation.

During the investigation, a total of 57 seal and 306 dogfish depredation events were recorded. Nets in only 7 of the 61 hauls (11.48%) showed signs of seal depredation whereas nets in 36 of the 61 hauls (59.02%) elicited signs of dogfish depredation. Figures 2 and 3 show the locations at which all of these depredation events occurred. Each point location on the maps represents the site of a haul. Evidently, the majority of hauls occurred to the south east of Cape Cod, however, hauls did also occur to the north and to the south.

The interactive tools that were created in Google map in order to highlight the environmental variables associated with depredation events can be found at the following URL locations: seal depredation http://www.duke.edu/~arr18/Seal_Depred.html; dogfish depredation http://www.duke.edu/~arr18/Dogfish_Depred.html; and, locations where both seals and dogfish depredation occurred http://www.duke.edu/~arr18/Both_depred.html. This latter map identifies each haul based on whether there was (1) just seal depredation, (2) just dogfish depredation, (3) no depredation at all, or (4) depredation by both species. By clicking on each point you will display values for each environmental variable associated with that haul. The maps clearly depict the areas in Georges Bank that are greatly affected by both types of depredation. It appears that depredation ‘hot-spots’ reside to the south and southeast of Cape Cod.

3.2. Quantify the weight (in lbs) of discards associated with depredation events.

3.2.1. Percentage of total catch that was discarded due to depredation

Table 1 shows that a total weight of 3000.18 lbs of fish was discarded due to seal and dogfish depredation. This constituted 2.33% of the total 128,798.11 lbs of fish that was caught on the observed trips. Specifically, seals were responsible for 500.16 lbs of the discards, which represented an overall total of 0.39% of the total fish caught. Dogfish on the other hand were accountable for a slightly higher 2500.02 lbs, which was 1.94% of the total fish caught. Although skate were caught in the largest amounts, seals and dogfish did not appear to primarily predate on this species with only 0.20 lb and 1.42 lbs respectively, being discarded due to depredation by both species. Seals seemed to have the largest detrimental affects on monkfish and summer flounder landings with 4.81% and 8.24% respectively, of the total weight caught of the two species being discarded. The largest impacts that dogfish depredation had was seen on haddock and monkfish catches with an overall discard rate of 6.17% of the total haddock catch and 6.67% of the total monkfish catch.

3.2.2. Percentage of total catch that was eaten by seals and dogfish

Table 2 shows the weight of fish that got eaten by seals and dogfish. Seals ate 119.66 lbs and dogfish ate 1078.32 lbs of the overall 128,798.11 lbs of fish caught. Seals ate more monkfish (74.59 lbs) than any other fish species, followed by skate (41.84 lbs). Dogfish on the other hand ate more skate (460.72 lbs) and cod (371.03 lbs) than other fish species. Seals appeared to avoid feeding on dogfish or pollock and negligible

quantities of these two fish were eaten. Dogfish only ate small amounts of dogfish and Pollock, 2.15 lbs and 5.44 lbs respectively. Overall, both species ate 0.93% of the total fish caught on the observed hauls. It is necessary to note the -0.97 lbs weight value calculated for summer flounder eaten by seals. This highlights that all values are estimates and it may have arisen from using a small sample size and low post-depredation weight of flounder in the analysis. This value was not used when calculating total amount eaten by seals.

Table 1. Percentage of total fish caught (lbs) that was discarded due to both seal and dogfish depredation.

	Cod	Haddock	Skate	Flounder	Dogfish	Pollock	Monkfish	Total
Total weight caught (lbs)	22,493.68	1,891.02	92,191.34	477.17	5,885.50	449.58	5,409.82	128,798.11
Total weight landed (lbs)	21,100.00	1,654.14	89,388.06	413.00	5,877.00	437.71	4428	123,297.91
Total weight discarded due to seals	11.23	3.67	185.84	39.33	0.00	0.00	260.09	500.16
Total weight discarded due to dogfish	691.23	116.60	1,308.72	12.42	4.25	5.94	360.86	2,500.02
Percentage discarded due to seals	0.05	0.19	0.20	8.24	0.00	0.00	4.81	0.39
Percentage discarded due to dogfish	3.07	6.17	1.42	2.60	0.07	1.32	6.67	1.94
Percentage discarded due to both	3.12	6.36	1.62	10.84	0.07	1.32	11.48	2.33

Table 2. Percentage of total fish caught that was eaten by both seals and dogfish

	Cod	Haddock	Skate	Flounder	Dogfish	Pollock	Monkfish	Total
Total weight caught (lbs)	22,493.68	1,891.02	92,191.34	477.17	5,885.50	449.58	5,409.82	128,798.11
Total weight landed (lbs)	21,100.00	1,654.14	89,388.06	413.00	5,877.00	437.71	4428	123,297.91
Weight eaten by seals (lbs)	2.63	1.57	41.84	-0.97	0.00	0.00	74.59	119.66
Weight eaten by dogfish (lbs)	371.03	31.20	460.72	8.32	2.15	5.44	199.46	1,078.32
Total weight Eaten by both (lbs)	373.66	32.77	502.56	7.35	2.15	5.44	274.05	1,197.98
Percentage Eaten by both	1.66	1.73	0.55	1.54	0.04	1.21	5.07	0.93

3.2.3. Calculating a dollar value for fish discarded due to depredation

Table 3 shows that during the observed hauls an estimated total of \$63,712.77 worth of fish was caught. Cod and skate were the fish species that accounted for the

majority of this with total catch values estimating \$26,092.67 and \$25,702.18 respectively. In total, seals were responsible for an approximate monetary loss of \$436.11, a loss that was only one-third that of the monetary loss associated with dogfish, which was \$1,814.32. Collectively, both seals and dogfish accounted for a monetary loss of \$2,250.43 due to discarding. Seals appeared to have the largest negative impact on monkfish catches with an associated \$299.10 loss. Dogfish on the other hand, affected cod catches the most and accounted for a loss of \$801.82 of the cod catch. Collectively, discarding associated with seal and dogfish depredation represented a 3.53% loss in gross profits.

Table 3. Dollar values for fish discarded due to depredation by seals and dogfish

	Cod	Haddock	Skate	Flounder	Dogfish	Pollock	Monkfish	Total
Average Price/Pound	1.16	1.79	0.28	1.67	0.23	0.38	1.15	
Total weight caught (lbs)	22,493.68	1,891.02	92,191.34	477.17	5,885.50	449.58	5,409.82	128,798.11
Total value of caught (\$)	26,092.67	3,384.62	25,702.18	795.91	1,345.26	170.84	6,221.29	63,712.77
Total value lost to seals (\$)	13.03	6.57	51.81	65.60	0.00	0.00	299.10	436.11
Total value lost to dogfish (\$)	801.82	208.70	364.86	20.71	0.97	2.26	414.99	1814.32
Total value lost to both species (\$)	814.85	215.27	416.67	86.32	0.97	2.26	714.10	2250.43
Percentage value lost to both	3.12	6.36	1.62	10.84	0.07	1.32	11.48	3.53

3.2.4. Calculating a dollar value for fish eaten by seals and dogfish

Table 4 indicates that seals had the largest negative impact on monkfish catches by eating an estimated \$85.78 worth of the monkfish catch. Seals had no monetary impact on dogfish or Pollock catches due to the fact that they ate negligible amounts of these fish. Dogfish on the other hand affected cod catches the most by eating \$430.39 worth of cod, followed by monkfish (\$229.38). Seals ate an estimated total of \$103.30 worth of the total catch and dogfish ate an approximate \$963.80 worth of catch, thus

representing a 10 fold greater impact than seals. Collectively, the amount of fish eaten by both species accounted for an overall 1.51% loss in the gross profits.

Table 4. Dollar values for fish eaten by seals and dogfish

	Cod	Haddock	Skate	Flounder	Dogfish	Pollock	Monkfish	Total
Average price/lb	1.16	1.79	0.28	1.67	0.23	0.38	1.15	
Total weight caught (lbs)	22,493.68	1,891.02	92,191.34	477.17	5,885.50	449.58	5,409.82	128,798.11
Total value of caught (\$)	26,092.67	3,384.62	25,702.18	795.91	1,345.26	170.84	6,221.29	63,712.77
Total value eaten by seals (\$)	3.05	2.81	11.66	-1.62	0.00	0.00	85.78	103.30
Total value eaten by dogfish (\$)	430.39	55.85	128.45	13.87	0.49	2.07	229.38	860.50
Total value eaten by both species (\$)	433.44	58.66	140.11	12.26	0.49	2.07	315.16	963.80
Percentage value eaten by both	1.66	1.73	0.55	1.54	0.04	1.21	5.07	1.51

3.3. Investigate if variables such as wave height, substrate type, water depth and soak duration of nets are affecting depredation events.

Although a significant relationship exists with regard to the number of depredation events relative to net soak duration, the relatively low R^2 correlation coefficient values of 0.25 and 0.17 for seals and dogfish respectively, implies that the relationship is weak (tables 5 & 6 and figures 4 & 5). Seal depredation can also be predicted by variables including water depth and the sediment type ‘sand’ (table 5). Dogfish depredation on the other hand, can be predicted by variables including the sediment types ‘sand’ and ‘gravel (primarily composed of sand)’, and also to a lesser degree by wave height (this variable however, is only significant at a P value of 0.05 so will be disregarded for the duration of the analysis).

Figure 6 clearly shows the number of seal and dogfish depredation events in relation to water depth in which the nets were set. Water depth was only found to be significant with regard to seal depredation with depredation events readily occurring

between 25 and 30 fathoms. Once the depth increased beyond 30 fathoms, depredation by seals was very infrequent. Although water depth did not appear to have a hand in predicting dogfish depredation an interesting trend was noted. It seems that dogfish predated in nets between 25 and 34 fathoms and between 43 and 51 fathoms. Nets in depths between 34 and 43 fathoms elicited little to no depredation.

Table 5. Significance levels for variables involved in predicting seal depredation. Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	8.89625	3.44366	2.58	0.0098 **
Water Depth	-0.48780	0.08245	-5.92	3.3e-09 ***
Soak Duration	0.02992	0.00725	4.12	3.7e-05 ***
Sediment Type (gravel-sand)	1.53443	1.32792	1.16	0.2479
Sediment Type (sand)	2.35889	1.03758	2.27	0.0230 *

Table 6. Significance levels for variables involved in predicting dogfish depredation. Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	-3.42351	0.43032	-7.96	1.8e-15 ***
Wave Height	0.12236	0.04896	2.50	0.012 *
Soak Duration	0.02054	0.00136	15.06	< 2e-16 ***
Sediment Type (gravel-sand)	3.24054	0.34640	9.35	< 2e-16 ***
Sediment Type (sand)	3.65146	0.30845	11.84	< 2e-16 ***

Figure 7 shows the relationship between haul site and sediment type in Georges Bank. Georges Bank is composed of many different sediment types and the observed hauls primarily took place on sand (86% of the time), followed by gravel (primarily composed of sand) (7%) or clay (primarily composed of silt and sand) (7%). Both seal and dogfish depredation occurred on all three sediment types, however, the preponderance of depredation by seals was on clay (silt/sand) or sand, and by dogfish on sand. 250 dogfish depredation events took place on a sand substrate (Figure 8). This is

most likely a biased result however, because the majority of the hauls were actually set on sand. Such bias does not appear to be the case with regard to seal depredation. Although the majority of the sets were on sand, the highest occurrence of seal depredation was seen on clay with 30 events recorded to have taken place.

3.4. Investigate whether fishermen are abiding to current closed area fishing restrictions within Georges Bank

Fishing took place on two occasions in areas of Georges Bank that are designated regulated or closed. One fishing trip occurred to the north of Cape Cod in a zone which included a Gulf of Maine Regulated Mesh Area, rolling closure area 1 and rolling closure area 2 (Figure 9). Another trip occurred to the east of Cape Cod in a Groundfish Closed Area, in which fishing is strictly prohibited (Figure 10). It is possible to disregard the rolling closure areas 1 and 2 because the trip was observed in these regions outside the closure periods of both. However, fishing within a regulated mesh area without a special access permit and fishing within a closed area is still against the laws set out in the operations plan. It is necessary to point out however, that all GPS locations recorded onboard the vessels had to be converted to lat/long for this analysis. This conversion may have caused slight deviations in point locations and could perhaps account for the resulting points just within the closed area.

3.5. Make recommendations that might ameliorate discarding associated with seal and dogfish depredation

Based on all aforementioned results, recommendations that aim to ameliorate the impacts of seal and dogfish depredation on fishing activities, and propose to prevent increased future interactions, are outlined in the recommendations section of this paper.

Figure 2. Seal depredation in Georges Bank, Cape Cod.

Seal Depredation Occurrences in Georges Bank, Cape Cod

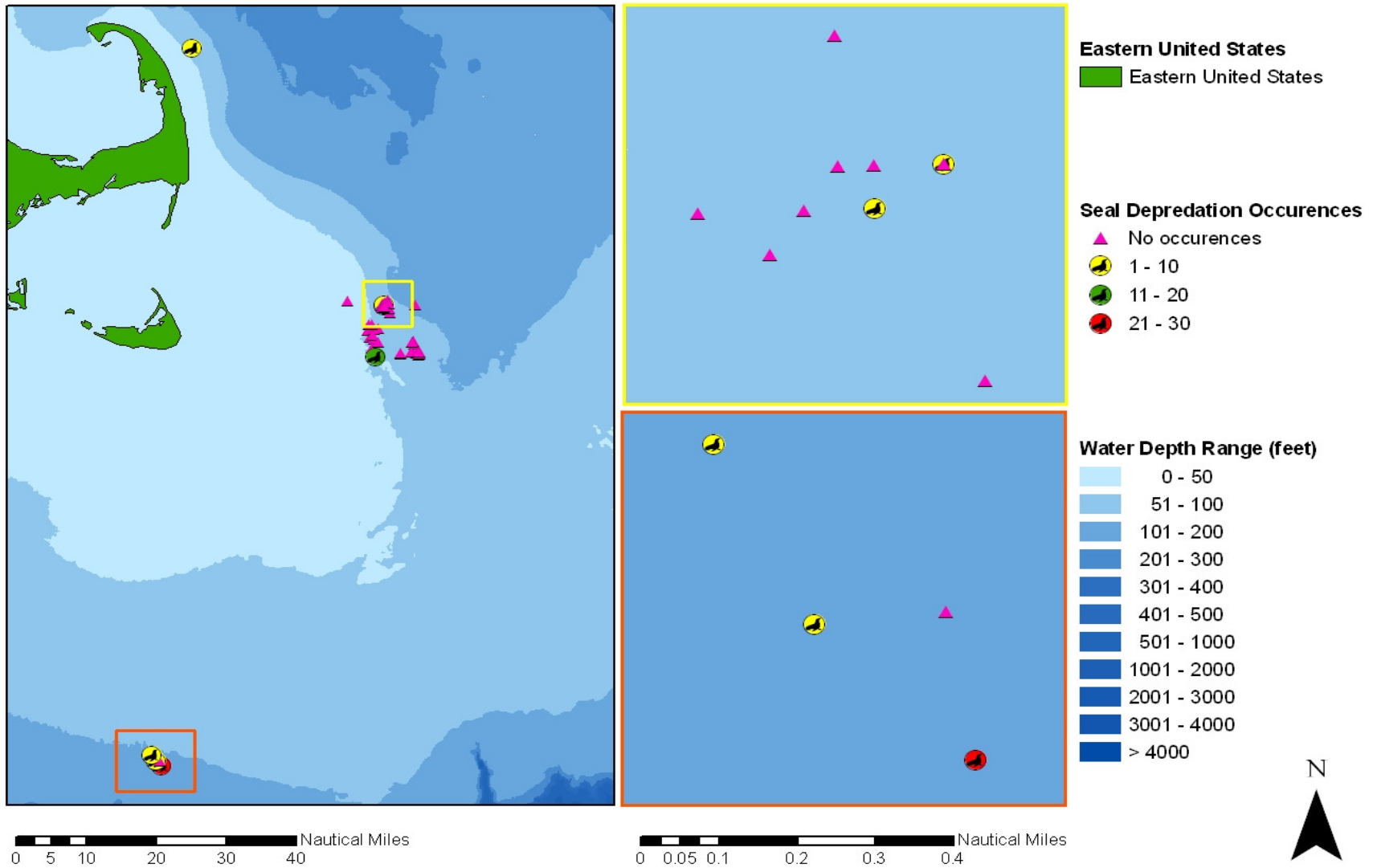


Figure 3. Dogfish depredation in Georges Bank, Cape Cod.

Dogfish Depredation Occurences in Georges Bank, Cape Cod

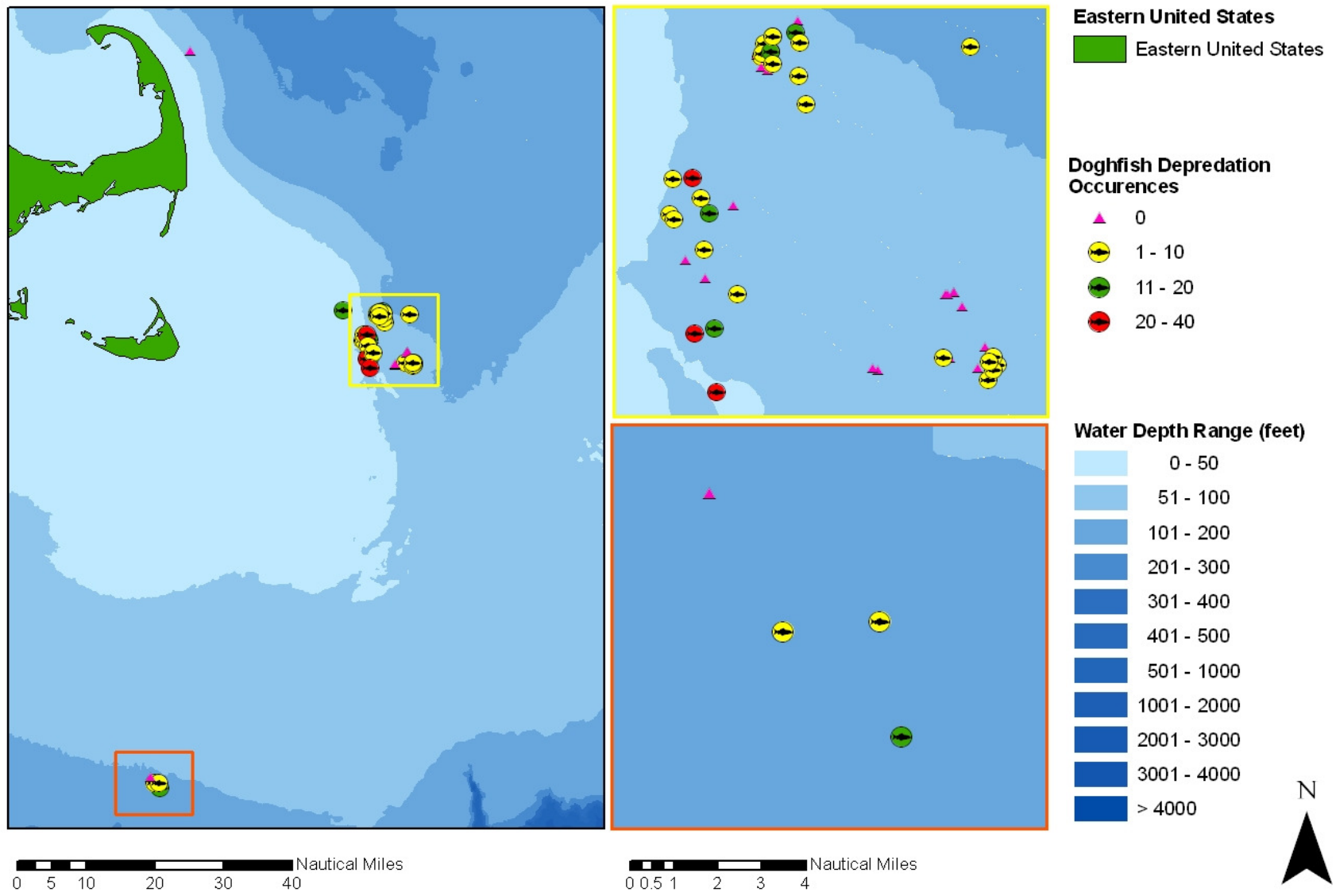


Figure 6. Number of depredation events by seals and dogfish in relation to water depth (fathoms).

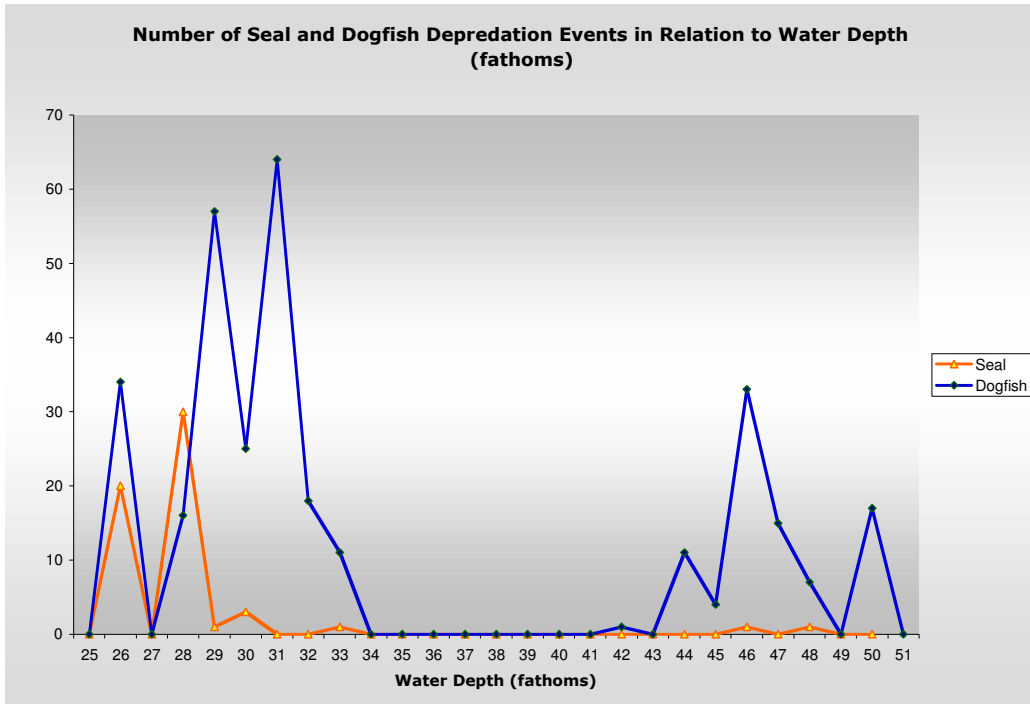


Figure 7. Sediment type and location of hauls in Georges Bank, Cape Cod.

Sediment Type Associated with Each Haul in Georges Bank, Cape Cod

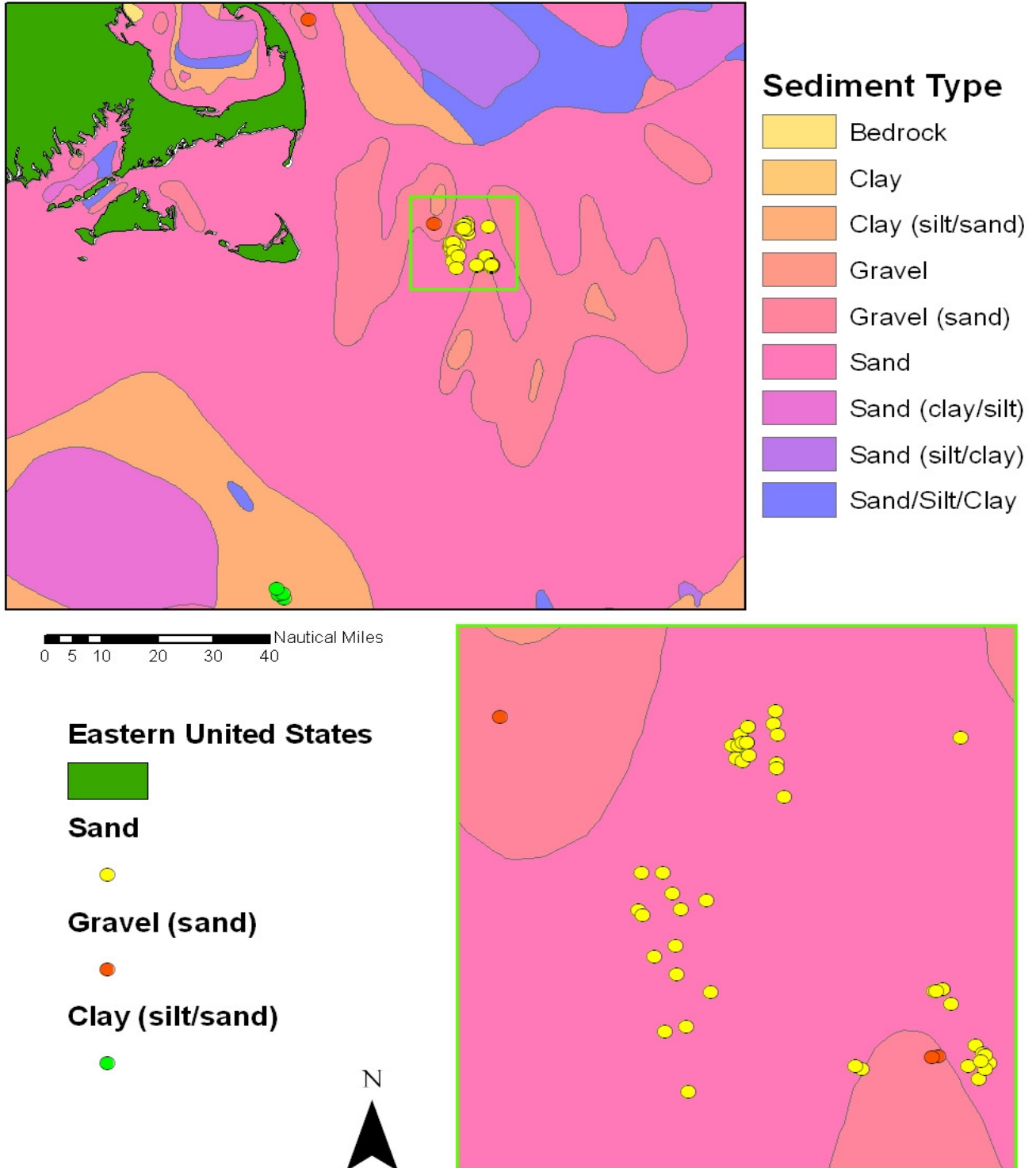


Figure 8. Number of seal and dogfish depredation events in relation to sediment type.

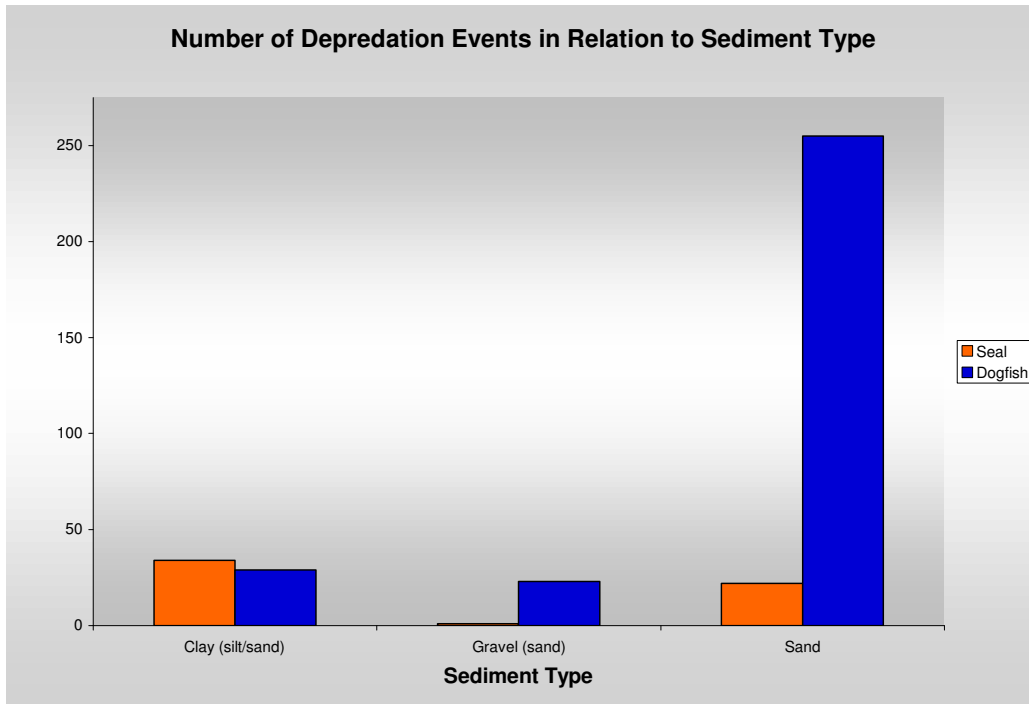


Figure 9. Haul sites and areas of rolling closure in Georges Bank, Cape Cod.

Fishing in Areas Eliciting Rolling Closure in Georges Bank, Cape Cod

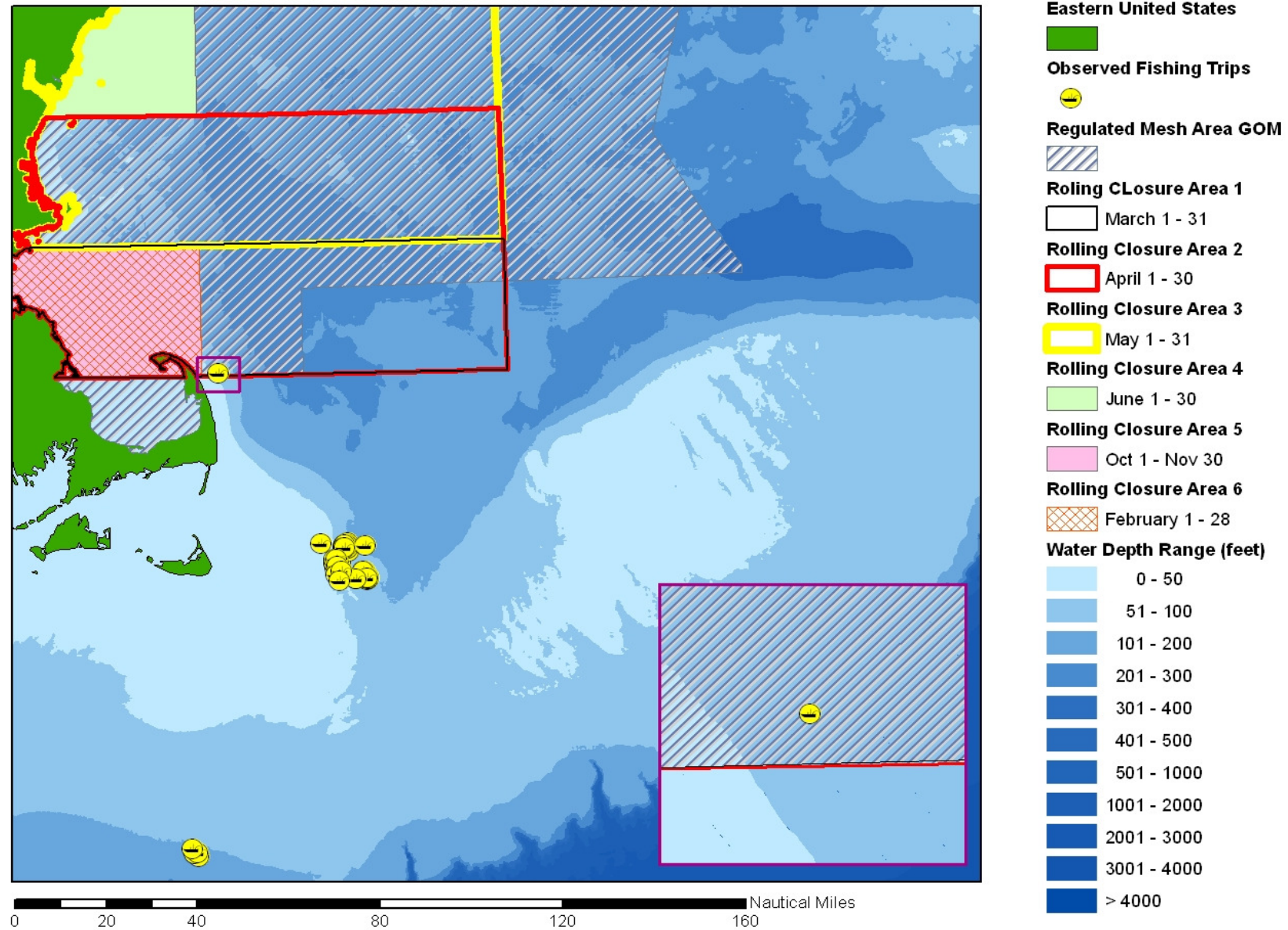
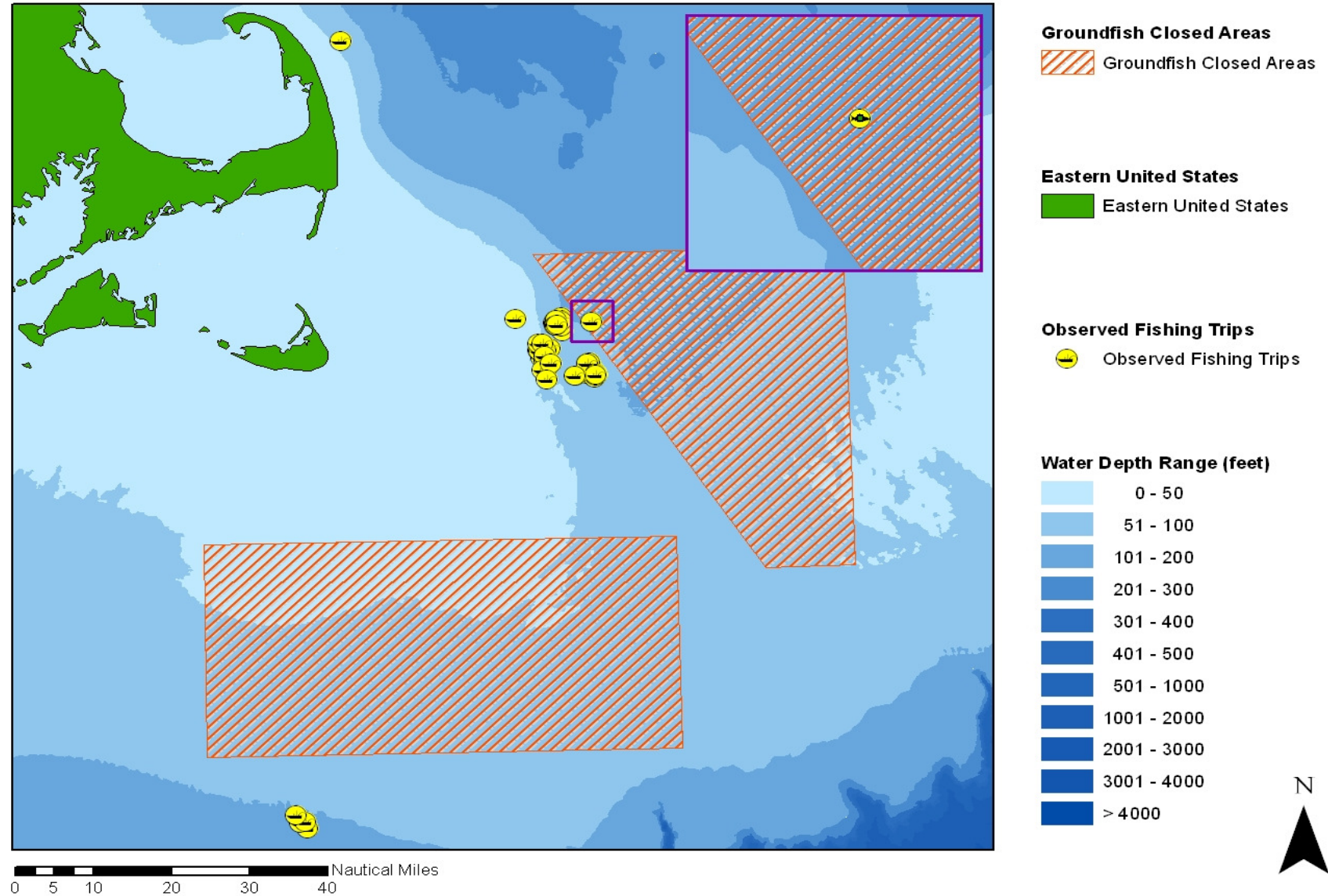


Figure 10. Haul sites and groundfish-closed areas in Georges Bank, Cape Cod.

Fishing in Groundfish Closed Areas in Georges Bank, Cape Cod



4. DISCUSSION

The Google maps found at the aforementioned URL locations, in tandem with figures 2 and 3, clearly show the regions in which seal and dogfish depredation was prominent. Depredation in gillnets by both aforementioned species readily occurred to the south and to the southeast of Cape Cod. These results highlight the areas that fishermen may choose to avoid during the month of June in order to reduce discarding associated with seal and dogfish depredation. Depredation events by dogfish occurred with an order of magnitude six times that of seals. Approximately 12% of the observed hauls showed signs of seal depredation whereas nets in nearly 60% of the hauls elicited signs of dogfish depredation. The common harbor seal was reported by fishermen to be the seal species most often seen interacting with Fixed Gear Sector gillnets. On two of the observed hauls harbor seals had become entangled in the nets while feeding and perished. The seal bite signatures of all fish attacked in both nets were standard throughout the entire observation period. It was for this reason that it was presumed the harbor seal was most likely responsible for the seal depredation that occurred during the experimental period.

Approximately 2,500 lbs of fish was discarded from a total catch weight of nearly 130,000 lbs due to depredation by both species. This represented slightly more than 2% of the total catch, which in monetary terms, was an estimated \$ 2500 worth of fish. About \$64,000 of fish was caught in total during all observed hauls. Collectively, discarding associated with seal and dogfish depredation represented a 3.53% loss in gross profits. Dogfish had the largest impact on total catch and discarding associated with dogfish exceeded seal discarding almost 5 fold. Fishermen lost approximately \$800 of cod and \$400 of monkfish to dogfish from total catch values of around \$26,000 and \$6,200

respectively. Seals on the other hand had the greatest impact on monkfish stocks. Seals accounted for losses of about \$300 of monkfish from a total catch value of \$6,200.

Collectively, both seals and dogfish had the largest negative impact on the monkfish catch with an 11.5% loss due to discarding, which translates to an excess of \$700. The largest monetary loss suffered in response to both species was seen in the cod catch with over \$800 being lost, however, this represented about only 3% of the total \$26,000 of cod caught. Almost 700 lbs of cod will be removed from the TAC as a result of seal and dogfish depredation during this short research period. If this best estimate held true for all months throughout the year, an annual loss of approximately 8,000 lbs of cod from the cod TAC alone would ensue as a result of depredation. This means a projected \$9,280 of just cod would be lost in a year. It is also worth noting here that the estimated losses associated with seal depredation could in fact be lower than reported above. Due to the fact that seals in this study primarily targeted livers and stomachs, it meant that in most cases fishermen could still use the fish caught even though they had been predated upon. In cases such as the skate, in which only the wings are retained for landing, it means that fishermen can still land the damaged fish.

With regard to the amount of fish that got eaten by seals and dogfish, it appears that dogfish ate almost 10 times more than seals. This can probably be explained by the fact that seals tended to feed on only the stomach and livers of fish, whereas dogfish ate substantial amounts of flesh. Skates were the fish species that got eaten the most by both predators, however, the largest monetary impacts were seen on the cod catch. Collectively, both seals and dogfish ate about \$430 of cod, followed by just over \$300 of

monkfish. Overall, seals and dogfish ate <1% of the total fish caught during the observed hauls.

The results associated with the investigation into whether different variables could be used to predict depredation events suggest that an increase in net soak duration would result in an increase in both seal and dogfish depredation events. One trip in particular involved hauling nets that had been soaking for 264 hours. The fish in these nets elicited high levels of seal depredation and for the most part, many of the remaining fish had to be discarded due to high levels of decomposition.

The water depth at which nets were set was also a significant variable in relation to seal depredation, with events generally occurring between 25 and 31 fathoms. Water depth was not found to be significant with regard to dogfish depredation but an interesting trend was observed. Dogfish appeared to depredate in nets between 25 and 33 fathoms and 43 and 51 fathoms. No depredation was seen between 33 and 43 fathoms. Morrissey and Gruber (1993) believed that the intraspecific competition in the lemon shark was a leading factor in determining the distribution of lemon sharks in the water column. Perhaps this is a reason that accounts for the bi-modal relationship between dogfish depredation events and water depth. Conceivably, there is a possible separation into different size classes of the dogfish, each size class inhabiting different levels of the water column to avoid cannibalism, which has been documented in lemon sharks since as early as 1962 by Vorenberg. Van der Elst (1979) noted that cannibalistic practices occurred within different shark species and intrauterine cannibalism has been noted with specific reference to the dogfish (Hamlett, Eulitt, Jarrell and Kelly, 2005).

Seal and dogfish depredation events appeared to be predicted by sediment type in Georges Bank. Most depredation events by seals occurred primarily on clay whereas dogfish depredation occurred mainly on sand, or gravel composed mainly of sand. Morrissey and Gruber (1993) found that juvenile lemon sharks preferred to inhabit sandy or rocky substrates, thus suggesting that this is a characteristic of multiple species of elasmobranch. However, as pointed out in the results section, the preponderance of hauls was set on a sandy substrate, therefore creating a bias in the results. Perhaps further studies that investigate whether seals or dogfish have a preference for foraging on different sediment types may fortify these findings.

This research showed evidence that two of the 61 hauls were within a regulated mesh area and a groundfish closed area. Although fishing is permitted within a regulated mesh area with a special access permit, fishermen within the Fixed Gear Sector do not possess such permits. Also, the groundfish-closed areas are permanently closed to fishing practices year round. This has major implications because it suggests that illegal fishing operations are occurring within the sector. As pointed out in the results section of this paper, conversion of GPS point locations to lat/long may have had a slight degree of inaccuracy. This may have yielded inaccurately placed point locations within regulated or closed areas. If this was in fact the case, it does however highlight that fishermen were setting their nets extremely close to the limits set out in management plans and that monitoring of vessels within the sector should be increase and strongly regulated.

In addition, the aforementioned option that the council has put forth for dealing with discarding in a quota system by just removing a predetermined weight of fish from the TAC seems unjustifiable. Some problems with this suggestion involve: (1) deciding

on how much such be taken away, (2) what factors this weight will be based on, (3) what if the weight removed is too high (thus encouraging discarding) or too low (thus encouraging early fishery closures). Furthermore, (4) how do you monitor such a decision? It clearly does not solve the problem of accounting for bycatch. This method does not reflect the specific history of the fishery (Eric Brazer pers. comm.) and the Council should perhaps turn to the CCCHFA for further suggestions.

Finally, one of the fishermen, who's boats activities were observed during the study, has recently noted that seal depredation is now occurring on redfish catches in the deep water (600+ feet) east of Chatham for the first time ever. This implies that seals are in fact extending their range, which, inevitably translates into higher rates of seal depredation. If this is in fact the case, even higher monetary losses than reported in this paper may be incurred. However, in order to fully understand such impacts, the loss associated with net profits needs to be addressed. Due to time constraints, this task could not be undertaken in the scope of this project, but would prove beneficial in the future.

5. RECOMMENDATIONS

(1) Implement an amendment to the NEFMP that generates areas of rolling closure that prevent fishermen from fishing within depredation ‘hot spots’ during seasons when depredation events are prevalent. However, in order to do so further studies that monitor seal and dogfish predation year round will have to be completed.

(2) Implement an amendment to the NEFMP that places a cap on net soak duration. This may prevent excessive depredation events in tandem with reducing high levels of decomposition of caught fish in the water.

(3) Fishermen should avoid setting their nets on sandy substrates so that high levels of dogfish depredation may be avoided. However, further studies should first be completed in order to fortify the findings in this paper.

(4) Fishermen should try and set their nets in areas where the water depth is between 34 and 43 fathoms. Perhaps this might reduce both seal and dogfish depredation.

(5) There should be an increase in observer coverage onboard fishing vessels within the sector in order to monitor all fishing practices. This may prevent illegal fishing practices from taking place and, in cases when it does it is easily identified. Also, perhaps by mapping all trips using satellite monitoring and Arc map it may serve as a useful tool to ensure fishermen are abiding to current management regulations.

(6) Perhaps the use of acoustic deterrence devices on gillnets may reduce depredation events. Acoustic harassment devices have been used in the Baltic salmon-trap, net fishery and have yielded some beneficial results in reducing grey seal net interactions (Fjälling, Wahlberg, Westerberg, 2006).

6. CONCLUSION

This study looked at depredation on fish in gillnets by seals and dogfish in Fixed Gear Sector Gillnets. The monetary loss of gross profits associated with depredation by both species was successfully quantified. With regard to these losses, it appears that seal and dogfish-gillnet fisheries interactions are having a relatively small impact. This impact however, may be somewhat larger when net profits are taken into account and this is what needs to be done in future investigations in order to put the findings in better context. Furthermore, this research highlighted the pressing need for amendments to be made to the NEFMP, which promises to reduce discarding associated with depredation and increase monitoring of fishing activities.

7. REFERENCES

- Bigelow, H. and Schroeder, W. (1953). Fishes of the Gulf of Maine. *U. S. Fish and Wildlife Service, Fisheries Bulletin*, **53**: 577.
- Bonner, W. (1982). The status of seals in the United Kingdom. Mammals in the Seas, Volume IV: small cetaceans, seals, sirenians and otters. *FAO Fisheries Series*, **5(4)**: 253-265.
- Boulva, J. and McLaren, I. (1979). Biology of the harbor seal, *Phoca vitulina*, in eastern Canada. *Bulletin - Fisheries Research Board of Canada*. **200**: 1-24.
- Department of Commerce, National Oceanic and Atmospheric Administration, 50 CFR Parts 648 (2003). Magnuson-Stevens Fishery Conservation and Management Act Provisions; Fisheries of the Northeastern United States; Northeast (NE) Multispecies Fishery; Amendment 13; Final Rule. *Federal Register*, **68**: 248.
- Diodati, P. Marine Fisheries Advisory: Modified Commercial Spiny Dogfish Trip Limits 2007-2008. (2007). www.mass.gov/marinefisheries.
- Eric Brazer. Personal Communication. Manager of the GB Cod Fixed Gear Sector, 2007.
- Fjälling, A., Wahlberg, M. and Westerberg, H. Acoustic harassment devices reduce seal interaction in the Baltic salmon-trap, net fishery. *ICES Journal of Marine Science*, **63(9)**: 1751 – 1758, 2006.
- Georges Bank Fixed Gear Sector & Cape Cod Commercial Hook Fishermen's Association. (2007). *Draft Environmental Assessment: Approval of the Georges Bank Cod Fixed Gear Sector & Operations Plan, 2007*.
- Hamlett, W., Eulitt, A., Jarrell, R. and Kelly, M. (2005). Uterogestation and placentation in elasmobranchs. *Journal of Experimental Zoology*, **226(5)**: 347 – 367.
- Katona, S., Rough, V. and Richardson, D. (1993). A field guide to whales, porpoises, and seals from Cape Cod to Newfoundland. *Smithsonian Institution Press: Washington, DC*, 316.
- Kenney, M. and Gilbert, J. (1994). Increase in harbor and gray seal populations in Maine. *Department of Commerce, NOAA-NMFS*, Page 19.
- Morrissey, J. and Gruber, S. Habitat selection by juvenile lemon sharks, *Negaprion brevirostris*. *Earth and Environmental Science*, **38**: 4, 1993.

National Marine Fisheries Service, NOAA & Commerce. (2005). MMPA regulations. <http://www.nmfs.noaa.gov/pr/laws/mmpa/>.

National Marine Fisheries Service. (2003). US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments. NOAA Technical Memorandum NMFS-NE-162. US Department of Commerce. National Oceanic and Atmospheric Administration. Northeast Fisheries Science Center. Woods Hole, MA.

North East Fisheries Management Council. (2003). Final Amendment 13 to the Northeast Multispecies Fishery Management Plan Including a Final Supplemental Environmental Impact Statement and an Initial Regulatory Flexibility Analysis.

North East Fisheries Management Council (2005). Framework Adjustment 42 to the Northeast Multispecies Fishery Management Plan and Framework Adjustment 3 to the Monkfish Fishery Management Plan Including a Final Supplemental Environmental Impact Statement and an Initial Regulatory Flexibility Analysis.

North East Fisheries Management Council. (2007). <http://www.nefmc.org/index.html>.

Pierce, D. (2003). DMF Studies Scaled-back Dogfish Fishery. *DMF News (third and fourth quarters)*, **20**: 1-2.

Powell, J. (1978). Evidence of Carnivory in Manatees (*Trichechus manatus*). *Journal of Mammology*, **59(2)**: 442.

Prime, J. and Hammond, P. (1988). Quantitative assessment of gray seal diet from fecal analysis. in: Huntley, A., Costa, D., Worthy, G., and Castellini, M. (eds.): Approaches to marine mammal energetics, 165-181, *Society of Marine Mammalogy Special Publication Number 1*, Lawrence, Kansas.

Read, A., Waples, D., Urian, K. & Swanner, D. (2003). Fine-scale behavior of bottlenose dolphins around gillnets. *Proceedings from the Royal Society of London*, **270**: 90-92.

Sissenwine, M.P. and E.B. Cohen. (1991). Resource productivity and fisheries management of the northeast shelf ecosystem. In: K. Sherman, L.M. Alexander, and B.D. Gold (eds.), "Food chains, yields, models, and management of large marine ecosystems". *AAAS Selected Symposium 99 Westian Press*, Boulder, CO, 107-123.

Schneider, D. and Payne, P. (1983). Factors affecting haul-out of harbor seals at a site in southeastern Massachusetts. *Journal of Mammology*, **64(3)**: 518-520.

Vorenberg, M. (1962). Cannibalistic tendencies of lemon and bull sharks. *Copeia*, 455 – 458.

Van der Elst, R. (1979). A proliferation of small sharks in the shore-based Natal sport fishery. *Environmental Biology of Fishes*, **4**: 349-362.

Waring, G. (1994). Spatial and Temporal Patterns in Harbor Seal Entanglements in the Gulf of Maine Sink Gillnet Fishery. *ICES CM*.

8. ENVIRONMENTALS LAW CITED

Magnuson-Stevens Fishery Conservation And Management Act 16 U.S.C. 1801-1882

Marine Mammal Protection Act 16 U.S.C. 1361-1407

National Environmental Policy Act 42 U.S.C. 4321-4347

9. APPENDIX A

Coefficients given in NOAA's Technical Memorandum (2003), that were used during the allometric regression in this study.

Species	Seasonal Group	Gender	N	(cm)	Ln a	sa	b	sb	sW	r2
Atlantic cod <i>Gadus morhua</i>	Autumn	Combined	3078	4-120	-11.9920	0.0180	3.1262	0.0047	0.1087	0.9931
Haddock <i>Melanogrammus aeglefinus</i>	Autumn	Combined	3959	7-88	-11.8111	0.0127	3.0888	0.0036	0.1183	0.9947
Winter skate <i>Leucoraja ocellata</i>	Autumn	Combined	2754	14-111	-13.1531	0.0302	3.3199	0.0075	0.1177	0.9861
Atlantic herring <i>Clupea harengus</i>	Autumn	Combined	3779	4-34	-11.5760	0.0391	2.9794	0.0123	0.1314	0.9400
Summer flounder <i>Paralichthys dentatus</i>	Autumn	Combined	3082	12-74	-12.2841	0.0271	3.2156	0.0075	0.0965	0.9834
Spiny dogfish <i>Squalus acanthias</i>	Autumn	Combined	6986	22-106	-12.6733	0.0256	3.0596	0.0061	0.1220	0.9728
Pollock <i>Pollachius virens</i>	Autumn	Combined	1097	13-112	-11.8353	0.0316	3.1151	0.0086	0.1099	0.9917
Goosefish <i>Lophius americanus</i>	Autumn	Combined	961	5-98	-10.7106	0.0404	2.9227	0.0118	0.2007	0.9845

10. APPENDIX B

R scripts used during statistical analysis of depredation events by seals and dogfish in relation to environmental variables:

Seal:

```
wd <- "U:\MP"
setwd(wd)
sp.pa <- read.csv(file="Samplefile.csv",header=T)
sp.pa[1:10,]
colnames(sp.pa)
summary(sp.pa)
mdlall <- glm(formula = sealobsNum ~ WATER_DEPTH + WAVE_HEIGHT +
SOAK_TIME + SED_TYPE, family = poisson(link = "log"), data = sp.pa)
summary(mdlall)
library(MASS)
mdl <- stepAIC(mdlall, trace=F)
summary(mdl)
```

Dogfish:

```
wd <- "U:\MP"
setwd(wd)
sp.pa <- read.csv(file="Samplefile.csv",header=T)
sp.pa[1:10,]
colnames(sp.pa)
summary(sp.pa)
mdlall <- glm(formula = sealobsNum ~ WATER_DEPTH + WAVE_HEIGHT +
SOAK_TIME + SED_TYPE, family = poisson(link = "log"), data = sp.pa)
summary(mdlall)
library(MASS)
mdl <- stepAIC(mdlall, trace=F)
summary(mdl)
```