EXPLORING BYCATCH REDUCTION IN THE HADDOCK FISHERY THROUGH THE USE OF THE ELIMINATOR TRAWL™ WITH FISHING VESSELS IN THE 250 TO 550 HP RANGE

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ABSTRACT

We investigated the performance of two large mesh faced (upper and lower wings, side panels, first bottom belly) bottom trawls designed to capture haddock (*Melanogrammus aeglefinus*) while reducing the bycatch of cod (*Gadus morhua*) and other species. These experimental nets (fishing circle: 184 x 40cm and 250 x 40 cm) are smaller versions of the previously tested Eliminator Trawl™ (315 x 40 cm). All species captured were weighed for total weight. The Eliminator Trawls™ significantly reduced the catch of stocks of concern including cod, yellowtail flounder (*Limanda ferruginea*), winter flounder (*Pseudopleuronectes americanus*), witch flounder (*Glyptocephalus cynoglossus*), and American plaice (*Hippoglossoides platessoides*). Other species such as monkfish (*Lophius americanus*) and skate also showed a significant decrease in catch in the Eliminator Trawl™. For the 250 x 40 cm Eliminator Trawl™, the catch of haddock, the target species, did not differ significantly between nets. The results of this study indicate that additional research is necessary for the 184 x 40 cm Eliminator Trawl™ before management recommendations can be made. However, results for the 250 x 40 cm suggest some important possibilities for the fishing industry when trying to exploit healthy stocks while avoiding stocks of concern. Specifically, the Eliminator Trawl™ would be an efficient tool in gaining access to closed areas and used in recovery programs to exploit more abundant fish species. Examples in the Northeast USA include a B Days-at-Sea Program (DAS) as well as a Special Access Program (SAP).

INTRODUCTION

Atlantic cod and haddock support important USA commercial fisheries. Both are managed under the New England Fishery Management Council's (NEFMC) Northeast (NE) Multispecies Fishery Management Plan (FMP) (NEFMC, 2003). Cod and haddock are included in a complex of 19 groundfish stocks which have been managed by area closures, gear restrictions, minimum size limits, trip limits, and since 1994, direct effort controls including a moratorium on permits and days-at-sea restrictions (Brodziak and Traver, 2006; Mayo and O'Brien, 2006). The overall goal of the management program is to reduce fishing mortality as to allow stocks to rebuild to target biomass levels (Brodziak and Traver, 2006; Mayo and O'Brien, 2006). The stocks found in US waters for both cod and haddock are assessed and managed as two stocks: Gulf of Maine (GOM) and Georges Bank (GB) and Southward. In the most recent assessment, GB cod were declared overfished and overfishing was determined to be occurring. However, GOM cod were not overfished but overfishing was occurring (NEFSC, 2008). For both stocks of haddock, they were not overfished and not experiencing overfishing (NEFSC, 2008).

This study focused on the reduction of cod, as well as other key bycatch species, in the directed haddock fishery. Haddock and cod are regularly caught together and due to the status of the stocks and the rebuilding objectives for cod, there are constraints on the harvest of haddock (TRAC, 2009). There is a zero bycatch tolerance for the cod fishery, and therefore once the quota of cod is attained, the haddock fishery is closed. In most years, this means that the total allowable catch (TAC) is not reached resulting in a loss of revenue to the fishermen (Table 1). The basic impact of the research described is to provide fishermen an alternative means of harvesting haddock without impacting the cod stock.

For decades, bycatch has been an issue in trawl fisheries and consequently much effort has been directed to improve the selective performance of trawls. Research focuses on reducing both the bycatch of undersized fish as well as non-target species (Engås, 1994). Reduction of undersized fish has been accomplished using mesh size regulations and more recently there has

been a trend towards the development of species-selective trawl gears (Isaksen and Valdermarsen, 1994). A trawl does not simply filter fish out of the sea passively; instead there is an interaction between the trawl and the fish (Main and Sangster, 1981; Thomsen, 1993). This interaction is complex, involving both the fishing gear performance and fish behavior. To improve the selectivity of trawls, it is necessary to identify those characteristics of the gear and fish behavior that affect the capture process (Main and Sangster, 1981).

Separation of species becomes difficult when dealing with fish that have virtually identical shape and size; therefore, the knowledge of fish behavior is a very important component in the development of more selective gear. Different species of fish show clear differences in their reaction behaviors in response to specific components of the gear (Glass and Wardle, 1996). For example, cod and haddock are bottom fish with similar shapes. However, it has become clear that the separation of cod and haddock is possible due to the different behaviors they exhibit when entering the net (Main and Sangster, 1981). Cod remain low near the seabed and enter the trawl close to the groundline, whereas haddock rise when entering a bottom trawl, high over the groundline into the top part of the net mouth, and enter the trawl in the upper half. In addition, flatfish also remain low when entering the net. By exploiting these behavior differences, more selective trawls can be developed to separate the catch by species which in turn may result in improved management of fish stocks (Chosid et al., 2008; He et al., 2008; Wardle, 1993; Main and Sangster, 1981).

Species-selective trawls are useful in multispecies fisheries regulated with quotas where it can be necessary to limit fishing effort when the quota of one species is met. In these cases, overfishing the stock of concern is avoided by stopping all fishing or permitting a certain amount of bycatch of that species (Isaksen and Valdermarsen, 1994). Fishermen need to become more precise in their fishing practices in quota managed fisheries (Glass and Wardle, 1996) and it is therefore beneficial for the fishermen to use a technology where the bycatch is minimal and within legal limits.

This study was developed based on the successful results of the CRPP Project: "Bycatch Reduction in the Directed Haddock Bottom Trawl Fishery" (Beutel et al., 2006). The impacts from that study were that it provided the fishermen the ability to harvest haddock without impacting the cod stock. It was the winner of the 2007 World Wildlife Fund International Smart Gear Competition, and it was implemented for use in the Regular B days-at-sea (DAS) program and Eastern US/Canada Haddock Special Access Program (SAP) effective on August 13, 2008. Additionally, it was tested in the North Sea and implemented in regulations based on the successful results of the sea sampling. These impacts combined with input from fishermen, showed a need to design and test scaled down versions of the Eliminator Trawl™.

The primary goal of this study was the reduction of cod bycatch in the mixed species fishery. The main objectives were:

(1) To test the effectiveness of the Eliminator Trawl™ on its ability to reduce the catches of cod, as well as other bycatch, in a targeted haddock fishery.
(2) To promote collaborative research directed by fishermen.

METHODS

Field Methods

A bottom trawl catch characterization study was conducted aboard commercial fishing vessels, targeting haddock using the "side-by-side" towing method comparing the control net (constructed to current legal specifications) to the scaled down versions of the large mesh Eliminator Trawl™. Side-by-side towing also referred to as parallel fishing, parallel tow technique, or parallel haul method, involves two vessels fishing on the same ground at the same time, the only difference being the design of the trawl being towed. The side-by-side method greatly reduces the effects of the many uncontrolled variables.

184 x 40 cm Eliminator Trawl™

Two fishing vessels based in New Hampshire USA were used to conduct the sea sampling; F/V *Lady Victoria* and F/V *Stormy Weather*. The two vessels were equivalent in length, horsepower, and fishing capacity. Each vessel had an identical control net and Eliminator Trawl™.

Sampling was performed in the Gulf of Maine (Figure 1). Depths ranged from 55 to 125 meters. The amount of wire out depended on the depth of water and ranged from 100 to 200 fathoms (~183 to 366 m). Six days of fishing were conducted, three in May 2008 and three in April 2009. A total of 40 tows were conducted, however, due to hangs and gear damage, only 33 were able to be used in the analysis.

On each day of sampling, the two vessels towed side-by-side with one vessel towing the control net and the other the Eliminator Trawl™. Tow duration was one hour and all tows began and ended simultaneously which was coordinated by the vessel's captains. All catch was sorted by species and when appropriate, subdivided into sublegal and legal, and total weights were recorded.

250 x 40 cm Eliminator Trawl™

Two fishing vessels based in Rhode Island USA were used to conduct the sea sampling; F/V *Conor and Michael* and F/V *Lena Pearl*. The two vessels were equivalent in length, horsepower, and fishing capacity. Each vessel had an identical control net and Eliminator Trawl™.

Sampling was performed on Georges Bank (Figure 2). Depths ranged from 55 to 181 meters. The amount of wire out depended on the depth of water and ranged from 125 to 300 fathoms (~229 to 549 m). Six days of fishing were conducted in June 2009. A total of 36 tows were conducted which were all included in the analysis.

On each day of sampling, the two vessels towed side-by-side with one vessel towing the control net and the other the Eliminator Trawl™. Tow duration was one hour and all tows began and

ended simultaneously which was coordinated by the vessel's captains. All catch was sorted by species and when appropriate, subdivided into sublegal and legal, and total weights were recorded.

Trawl Design

Control Net

The control nets were the standard groundfish nets used by each vessel. The nets were standardized between the vessels conducting the side-by-side towing for each design of the Eliminator Trawl™. The vessels testing the 184 x 40 cm Eliminator Trawl™ used a control net with a fishing circle of 282 x 6 inches. The vessels testing the 250 x 40 cm Eliminator Trawl™ used a control net with a fishing circle of 328 x 6 inches.

184 x 40 cm Eliminator Trawl™

The four seam mini Eliminator Trawl™ was constructed with large mesh (160 cm) jibs, wings, bunts, and first bottom belly; the square and second bottom belly of 80 cm webbing; each of those sections was followed by 20 cm webbing sections; and the last top and bottom bellies were 6 inch (15.2 cm) webbing (Figure 3). The side panels were the same mesh size configuration as the top sections. The fishing circle was 184 x 40 cm and the hanging line was 2216 cm. The rockhopper groundline was constructed of 14 inch rock hopper discs in the center approximately 1 foot apart and the wings have 12 inch rock hopper discs approximately 1 foot apart. Vertical lift was attained using a 1-panel kite. This trawl is appropriate for vessels with 300 horsepower (HP) plus or minus 50 HP.

250 x 40 cm Eliminator Trawl™

The four seam mid Eliminator Trawl™ was constructed with large mesh (240 cm) jibs, wings, bunts, and first bottom belly; the square and second bottom belly of 80 cm webbing; each of those sections was followed by 20 cm webbing sections; and the last top and bottom bellies were 6 inch (15.2 cm) webbing (Figure 4). The side panels were the same mesh size

configuration as the top sections. The fishing circle was 250 x 40 cm and the hanging line was 3313 cm. The rockhopper groundline was constructed of 14 inch rock hopper discs in the center approximately 1 foot apart and the wings have 12 inch rock hopper discs approximately 1 foot apart. Vertical lift was attained using a 2-panel kite. This trawl is appropriate for vessels with 500 HP plus or minus 50 HP.

Analysis

Weight data for all species was determined to be non-normal by the Shapiro-Wilk *W* statistic and therefore nonparametric paired comparison tests were conducted to test for differences between weight of fish in the control net and the Eliminator Trawl™. The sign test was calculated on the difference between the control net and the Eliminator Trawl™ catch weights for each tow for each species using PROC UNIVARIATE in SAS 9.2. The hypothesis tested was:

H_0: the mean weight in the control net and Eliminator Trawl™ is the same, $\mu_1 = \mu_2$.

H_A: the mean weight in the control net and Eliminator Trawl™ is not the same, $\mu_1 \neq \mu_2$.

The sign test counts the number of positive and negative signs among the differences and the hypothesis tested is that the *n* plus and minus signs are sampled from a population that has equal proportions of the two kinds of signs (Sokal and Rohlf, 1995). Only paired tows with at least one fish present in either net were included. The sign test was conducted on those species that were present in at least 10 tows.

Ratios of total weight of cod, yellowtail flounder, and total skate were calculated against haddock for the control net and the Eliminator Trawl™ individually.

RESULTS

<u>184 x 40 cm Eliminator Trawl™</u>

The total weight of all species captured was 14863 and 5776 kg in the control net and Eliminator Trawl™, respectively (Table 2). For both the control net and the Eliminator Trawl™,

haddock and cod were the dominant species comprising of 77 and 93% combined, respectively. Flounders were 10% of the control net total catch and less than 1.5% in the Eliminator Trawl™. Total catch weights for key species can be found in Figures 5 and 6.

The overall ratio of haddock to cod was 1.2:1 and 1.8:1 for the control net and Eliminator Trawl™, respectively (Table 3; Figure 6). The ratio of haddock to yellowtail flounder from the control net 14.5:1 which was improved in the Eliminator Trawl™ to 86.7:1 (Table 3; Figure 7). The haddock to skate ratio was 19:1 for the control net and 388:1 for the Eliminator Trawl™ (Table 3; Figure 8).

There were 15 species that were present in at least 10 paired tows and the sign test was conducted on those species. The results of the sign test (Table 4) shows that the two nets did not differ in the weights of haddock sublegal, windowpane flounder (*Scophthalmus aquosus*), redfish (*Sebastes fasciatus*) (legal and sublegal), monkfish sublegal, and sea raven (*Hemitripterus americanus*). The control net and Eliminator Trawl™ were not significantly different for these species, and therefore fail to reject the null hypothesis. For haddock legal, cod, yellowtail flounder, winter flounder, witch flounder, American plaice, and many other species, there was a significant difference in the catch weights between the control net and the Eliminator Trawl™ (Table 4). For all species that differed significantly between nets, the control net had the higher mean.

<u>250 x 40 cm Eliminator Trawl™</u>

The total weight of all species captured was 15109 and 6344 kg in the control net and Eliminator Trawl™, respectively (Table 5). For the control net, more than 92% of the total catch was comprised of skate, haddock, and cod which constituted 66.0%, 11.9%, and 14.4%, respectively (Figure 9). Haddock was the dominant species caught in the Eliminator Trawl™ which comprised 81.1% of the total catch (Figure 10). Total catch weights for key species can be found in Figures 11 and 12.

For the control net, the number of cod and skate were greater than the number of haddock with ratios of 0.82:1 and 0.18:1, respectively (Table 6; Figures 13 and 14). For the Eliminator Trawl™ the ratio of haddock to cod was 9.1:1 and for skate it was 24.5:1. The haddock to yellowtail flounder ratio was 7.7:1 and 165.5:1 for the control net and Eliminator Trawl™, respectively (Table 6; Figure 15).

There were 17 species that were present in at least 10 paired tows and the sign test was conducted on those species. The results of the sign test (Table 7) shows that the two nets did not differ in the weights of haddock legal, silver hake (*Merluccius bilinearis*), spiny dogfish (*Squalus acanthias*), and shortfin squid (*Illex illecebrosus*). The control net and Eliminator Trawl™ were not significantly different for these species, and therefore fail to reject the null hypothesis. For haddock sublegal, cod, yellowtail flounder, winter flounder, witch flounder, American plaice, monkfish, and many other species, there was a significant difference in the catch weights between the control net and the Eliminator Trawl™ (Table 7). For all species that differed significantly between nets, except haddock sublegal, the control net had the higher mean.

DISCUSSION

Two scaled down versions of the already approved Eliminator Trawl™ (also referred to as the Ruhle Trawl by the National Marine Fisheries Service (NMFS)) were tested. It is important to review the results of each net separately because the nets were developed for different HP vessels and fished in different waters.

For the smallest scaled-down version of the Eliminator Trawl™ (184 x 40 cm), sampling was conducted in the GOM. In addition to different stocks and status found in these waters versus GB, fishing practices in that area are also different and in general the GOM fishery does not target haddock and is directed mostly at flatfish. The 184 x 40 cm Eliminator Trawl™ successfully reduced the catch of cod, yellowtail flounder, winter flounder, witch flounder, and

American plaice. However, the catch of legal haddock was also significantly reduced in the Eliminator Trawl™ to slightly over half the catch of the control net. The reduction in catch may be attributed to the parallel tow sampling method. In the rolling closure area (Figure 16) where the sampling was conducted, the bottom was steeply sloped. One vessel was frequently towing at a different depth than the other. Haddock are not spread evenly over the bottom configuration and the difficulty in maintaining the same depth may have introduced discrepancy in the catches. Another possibility in the haddock capture difference is that the 184 x 40 cm Eliminator Trawl™ is not sufficiently big in circumference for the haddock to escape the large bottom belly meshes. Additional research is necessary before recommending this size Eliminator Trawl™ as an appropriate fishing gear for groundfish.

The results for the 250 x 40 cm Eliminator Trawl™ indicate that this net may have management potential. As with the original Eliminator Trawl™ study (Beutel et al. 2008), sampling was conducted on GB (although not in the closed area) and results followed a similar trend. The Eliminator Trawl™ successfully reduced the catch of the major stocks of concern on GB. These included cod, yellowtail flounder, winter flounder, witch flounder, and American plaice. A variety of other species were also reduced such as skate and monkfish. In addition, haddock catch, the target species, was the same between the Eliminator Trawl™ and the currently regulated net.

The importance of reducing the catch of GB cod relates to the status of the stock which is overfished and experiencing overfishing (GARM, 2008). Resource productivity is poor due to low recent recruitment and low weights at age (TRAC, 2009). Due to the low level of cod, there is a zero bycatch tolerance which means that the haddock fishery is closed once the cod quota is reached. The fishing industry lost an average of $11 million per year in haddock revenue from 2004 to 2008 due to the closing of the fishery (Table 1). For 2008, there was a significant increase in the landings compared to the previous years with a paralleled decrease in value lost. The reason for this may be related to management actions.

Modifications to fishing gear and practices may mitigate the concerns related to the high discarding of cod due to the higher haddock quota (TRAC, 2009). The substantial reduction of cod in the Eliminator Trawl™ suggests that this net could be used as a tool to prevent the closure of the haddock fishery resulting in the utilization of more of the allotted TAC of haddock.

In the USA, groundfish species are managed using a variety of methods including DAS. The number of days vessels can use to harvest groundfish are limited. Amendment 13 to the NE Multispecies FMP defined three categories of DAS. The 2 main types are A DAS that can be used to target any regulated groundfish stock and B DAS that are used to target healthy groundfish stocks ("stocks that do not need a reduction in fishing mortality" (NEFMC, 2003)). The usage of B DAS has been made possible through the Regular B DAS Program under Framework 42 of NE Multispecies FMP (50 CFR Part 648, 2006). Also under Framework 42 is the Eastern U.S./Canada Haddock SAP. SAPs are another management method used in the Northeast USA to provide fishermen access to healthier stocks. They allow limited entry into closed areas. Both the Regular B DAS Program and the SAP program require vessels to use an approved gear that reduces the catch of stocks of concern, notably cod, yellowtail flounder, and winter flounder. The haddock separator trawl as well as the 315 x 40 cm Eliminator Trawl™ are approved gears that meet the catch guidelines established under the FMP.

NMFS implemented specific gear standards that could be used to evaluate additional gear proposed for use in the Regular B DAS Program and the Eastern US/Canada Haddock SAP (50 CFR Part 648, 2008). New gear can be approved if it meets one of the two standards. The first states that the gear must result in a statistically significant reduction, compared to the control gear, of at least 50 percent in catch of each regulated species stock of concern. For the 250 x 40 cm Eliminator Trawl™, the mean weight of cod in 34 tows in the control net was 64.1 kg and in the Eliminator Trawl™ was 16.9 kg, a 73.6% reduction. When looking at the data in more detail, 22 of the 31 tows that contained cod provided a reduction of 50% or greater. For yellowtail flounder, there was an 86.4% reduction in the Eliminator Trawl™ and 24 of the 28

tows had a reduction of 50% or greater in the Eliminator Trawl™. These results suggest that the 250 x 40 cm Eliminator Trawl™ has the potential to be an appropriate gear to be used in the Regular B DAS Program as well as the Eastern US/Canada Haddock SAP.

Although the original concept behind the development of the Eliminator Trawl™ was the reduction of cod, the net also significantly reduces the yellowtail flounder catch. GB yellowtail flounder have recently been brought to the forefront by NMFS because catch and discard information indicates that 76% of the TAC for GB yellowtail flounder has been harvested as of November 12, 2009 and the current catch rate will result in the harvest of the TACs of these species before the end of the 2009 fishing year (April 30, 2010).

The situation currently occurring in the yellowtail flounder fishery suggests that the use of a bycatch reducing net could keep the fishermen fishing. It is necessary to slow the catch rate of GB yellowtail flounder to prevent a 2009 overharvest. The NMFS has prohibited the use of trawl net gear in the area south of 41°40' N latitude in the Western U.S./Canada Area (Area 4) (Figure 17) except for a haddock separator trawl or a Ruhle trawl (Small Entity Compliance Guide, November 17, 2009). In addition, those vessels that do fish with one of the approved trawls are still restricted in the possession limits of flounders (all species combined), monkfish, and skates to 500 lb (whole weight) each (227 kg), and possession of lobsters is prohibited. Vessels are currently prohibited from using trawl gear other than a haddock separator trawl or a Ruhle trawl in the entire Eastern U.S./Canada Area.

The catch results for the 250 x 40 cm Eliminator Trawl™ fall within these guidelines. The net caught a total of 35.9 kg of flounders in 36 hours of towing (36 tows at 1.0 hours each) for an average of approximately 1 kg per hour. For a 16 hour fishing day, that would amount to 16 kg per day. The total weight of skate and monkfish was 215.17 and 4.28 kg for 36 hours, respectively. This amounts to 95.6 kg of skate and less than 2 kg of monkfish for a 16 hour day. These results demonstrate the effectiveness of the 250 x 40 cm Eliminator Trawl™ to reduce the catch of the stocks of concern encountered.

CONCLUSION

The majority of fishing is conducted in a multispecies setting, therefore developing selective gear that can help protect stocks that need rebuilding is essential. Although the results for the 184 x 40 cm Eliminator Trawl indicate that additional research is necessary before any recommendations can be made, the results for the 250 x 40 cm Eliminator Trawl™ suggest some important possibilities for the fishing industry when trying to exploit healthy stocks while avoiding stocks of concern. The 250 x 40 cm Eliminator Trawl™ did not reduce the catch of the target species, haddock, but did significantly decrease the catch of cod, yellowtail flounder, and other stocks of concern. Overall, this study is a good example of scientists, industry, and managers working together to develop more selective fishing gear.

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Table 1. Fishing data for haddock for 5 years including TAC, landings for each year, and the value lost by the fishermen due to not reaching the TAC because the haddock fishery was closed.

Year	TAC (mt)	Landings (mt)	Total value ($)	$/mt	TAC not harvested (mt)	Value lost ($)
2004	14,955	8,237.3	18,159,927	2204.6	6717.7	14,809,821
2005	12,282	7,581.4	19,044,869	2512.1	4700.6	11,808,150
2006	7,480	3,265.0	11,424,900	3499.2	4215.0	14,749,143
2007	6,270	3,603.6	12,294,712	3411.8	2666.4	9,097,186
2008	8,050	6,206.5	16,028,714	2582.6	1843.5	4,760,966

Fishing data obtained from the Fisheries Statistics Division of NMFS online commercial fishery landing program. TAC info was obtained from the NMFS Office of Sustainable Fisheries and review of the Federal Registry.

Table 2. Total catch weights (in kilograms) and percentages for all trips combined for the 184 x 40 cm Eliminator Trawl™.

	Control Net		Eliminator Trawl™	
	Total Weight	%	Total Weight	%
Haddock legal	6279.15	42.25	3486.38	60.36
Haddock sublegal	41.73	0.28	35.30	0.61
Cod legal	5192.57	34.94	1894.05	32.79
Cod sublegal	248.55	1.67	77.50	1.34
Yellowtail flounder legal	302.96	2.04	29.04	0.50
Yellowtail flounder sublegal	132.18	0.89	11.60	0.20
Winter flounder legal	102.63	0.69	14.70	0.25
Winter flounder sublegal	15.12	0.10	0.20	0.00
Witch flounder legal	81.19	0.55	3.10	0.05
Witch flounder sublegal	7.51	0.05	0.00	0.00
American plaice legal	576.41	3.88	16.92	0.29
American plaice sublegal	300.89	2.02	5.40	0.09
Windowpane flounder	16.00	0.11	3.00	0.05
White hake	2.85	0.02	0.00	0.00
Pollock	167.40	1.13	6.14	0.11
Halibut	1.20	0.01	0.00	0.00
Ocean pout	1.20	0.01	1.70	0.03
Redfish legal	24.60	0.17	19.02	0.33
Redfish sublegal	11.85	0.08	2.34	0.04
Total regulated groundfish	13505.99	90.87	5606.39	97.07
Summer flounder legal	1.60	0.01	0.00	0.00
Fourspot flounder	2.70	0.02	0.80	0.01
Monkfish legal	80.34	0.54	1.28	0.02
Monkfish sublegal	3.60	0.02	1.20	0.02
Atlantic herring	0.15	0.00	0.40	0.01
Wolffish	248.60	1.67	34.84	0.60
Silver hake	4.64	0.03	1.60	0.03
Red hake	0.00	0.00	0.42	0.01
Lumpfish	2.20	0.01	2.76	0.05
Striped bass	5.30	0.04	0.00	0.00
Sculpin	166.72	1.12	2.30	0.04
Sea raven	54.16	0.36	16.70	0.29
Spiny dogfish	321.56	2.16	74.42	1.29
Skate unclassified	331.81	2.23	23.60	0.41
American lobster	132.25	0.89	9.08	0.16
Spider crab	1.30	0.01	0.00	0.00
Sea scallop	0.30	0.00	0.00	0.00
Total	14863.22	100.00	5775.79	100.00

Table 3. Ratio of total weight of three species versus haddock for the 184 x 40 cm Eliminator Trawl™.

Ratio of haddock to:	Control Net	Eliminator Trawl™
Cod	1.2 : 1	1.8 : 1
Yellowtail flounder	14.5 : 1	86.7 : 1
Skate	19 : 1	388 : 1

Table 4. Results from the nonparametric paired comparison of weights for the 184 x 40 cm Eliminator Trawl™.

Species	*P*-value	*n*
Haddock legal	0.0013	33
Haddock sublegal	0.4244	25
Cod legal	<.0001	33
Cod sublegal	0.0351	33
Yellowtail flounder legal	<.0001	32
Yellowtail flounder sublegal	<.0001	33
Winter flounder legal	0.0026	20
Winter flounder sublegal	<.0001	15
Witch flounder legal	0.0007	19
Witch flounder sublegal	0.0002	13
American plaice legal	<.0001	33
American plaice sublegal	<.0001	33
Windowpane flounder	0.1185	15
Redfish legal	1.0000	15
Redfish sublegal	0.0654	11
Monkfish legal	0.0002	13
Monkfish sublegal	1.0000	5
Wolffish	0.0127	17
Sculpin	0.0009	22
Sea raven	0.2101	16
Spiny dogfish	0.0002	13
Skate unclassified	<.0001	30
American lobster	<.0001	31

The P-value is from the sign test. Those species highlighted in grey resulted in no significant difference between the control net and the Eliminator Trawl™ when using a 5% significance level (0.05).

Table 5. Total catch weights (in kilograms) and percentages for all trips combined for the 250 x 40 cm Eliminator Trawl™.

	Control Net		Eliminator Trawl™	
	Total Weight	%	Total Weight	%
Haddock legal	1772.03	11.73	5142.50	81.06
Haddock sublegal	19.63	0.13	119.46	1.88
Cod legal	2137.42	14.15	557.32	8.78
Cod sublegal	41.99	0.28	18.70	0.29
Yellowtail flounder legal	228.48	1.51	31.56	0.50
Yellowtail flounder sublegal	5.23	0.03	0.23	0.00
Winter flounder legal	14.40	0.10	0.00	0.00
Witch flounder legal	19.49	0.13	0.32	0.01
Witch flounder sublegal	7.71	0.05	0.00	0.00
American plaice legal	81.25	0.54	0.90	0.01
American plaice sublegal	39.30	0.26	0.45	0.01
Windowpane flounder	3.10	0.02	2.46	0.04
White hake	18.22	0.12	5.86	0.09
Pollock legal	26.17	0.17	41.57	0.66
Pollock sublegal	0.59	0.00	0.00	0.00
Halibut	0.27	0.00	0.00	0.00
Ocean pout	3.16	0.02	0.00	0.00
Redfish legal	27.77	0.18	43.33	0.68
Redfish sublegal	1.46	0.01	2.95	0.05
Total regulated groundfish	4447.67	29.44	5967.61	94.07
Fourspot flounder	2.14	0.01	0.00	0.00
Monkfish legal	103.11	0.68	3.38	0.05
Monkfish sublegal	31.23	0.21	0.90	0.01
Blue black herring	0.23	0.00	0.00	0.00
Silver hake	4.93	0.03	2.56	0.04
Red hake	1.70	0.01	1.36	0.02
Alewife	0	0.00	0.23	0.00
Longhorn sculpin	35.53	0.24	3.08	0.05
Sea raven	48.73	0.32	5.07	0.08
Sea robin	28.51	0.19	1.58	0.02
Spiny dogfish	162.58	1.08	46.83	0.74
Barndoor skate	162.95	1.08	2.37	0.04
Little skate	481.08	3.18	8.39	0.13
Thorny skate	24.12	0.16	0	0.00
Winter skate	9307.69	61.60	204.41	3.22
Total skate	9975.84	66.02	215.17	3.39
American lobster	117.67	0.78	8.02	0.13
Jonah crab	11.20	0.07	0.00	0.00
Rock crab	0.47	0.00	0.00	0.00
Snow crab	0.68	0.00	0.00	0.00
Sea scallop	3.06	0.02	0.00	0.00
Longfin squid	5.28	0.03	0.11	0.00
Shortfin squid	126.03	0.83	88.20	1.39
Bird	1.70	0.01	0.00	0.00
Yellow sponge	0.56	0.00	0.00	0.00
Empty shell	0.46	0.00	0.00	0.00
Total	15109.31	100.00	6344.10	100.00

Table 6. Ratio of total weight of four species versus haddock for the 250 x 40 cm Eliminator Trawl™.

Ratio of haddock to:	Control Net	Eliminator Trawl™
Cod	0.82 : 1	9.1 : 1
Yellowtail flounder	7.7 : 1	165.5 : 1
Skate	0.18 : 1	24.5 : 1

Table 7. Results from the nonparametric paired comparison of weights for the 250 x 40 cm Eliminator Trawl™.

Species	*P*-value	*n*
Haddock legal	0.3771	32
Haddock sublegal	0.0002	21
Cod legal	0.0008	34
Cod sublegal	0.0309	18
Yellowtail flounder legal	<.0001	27
Yellowtail flounder sublegal	0.0313	6
Witch flounder legal	0.0002	13
Witch flounder sublegal	0.0039	9
American plaice legal	<.0001	26
American plaice sublegal	<.0001	21
Monkfish legal	0.0018	14
Monkfish sublegal	0.0003	17
Silver hake	0.3593	19
Longhorn sculpin	0.0003	17
Sea raven	<.0001	28
Sea robin	0.0309	18
Spiny dogfish	0.0636	19
Barndoor skate	<.0001	32
Little skate	0.0309	18
Thorny skate	0.0005	12
Winter skate	<.0001	49
American lobster	<.0001	31
Shortfin squid	0.2005	30

The P-value is from the sign test. Those species highlighted in grey resulted in no significant difference between the control net and the Eliminator Trawl™ when using a 5% significance level (0.05).

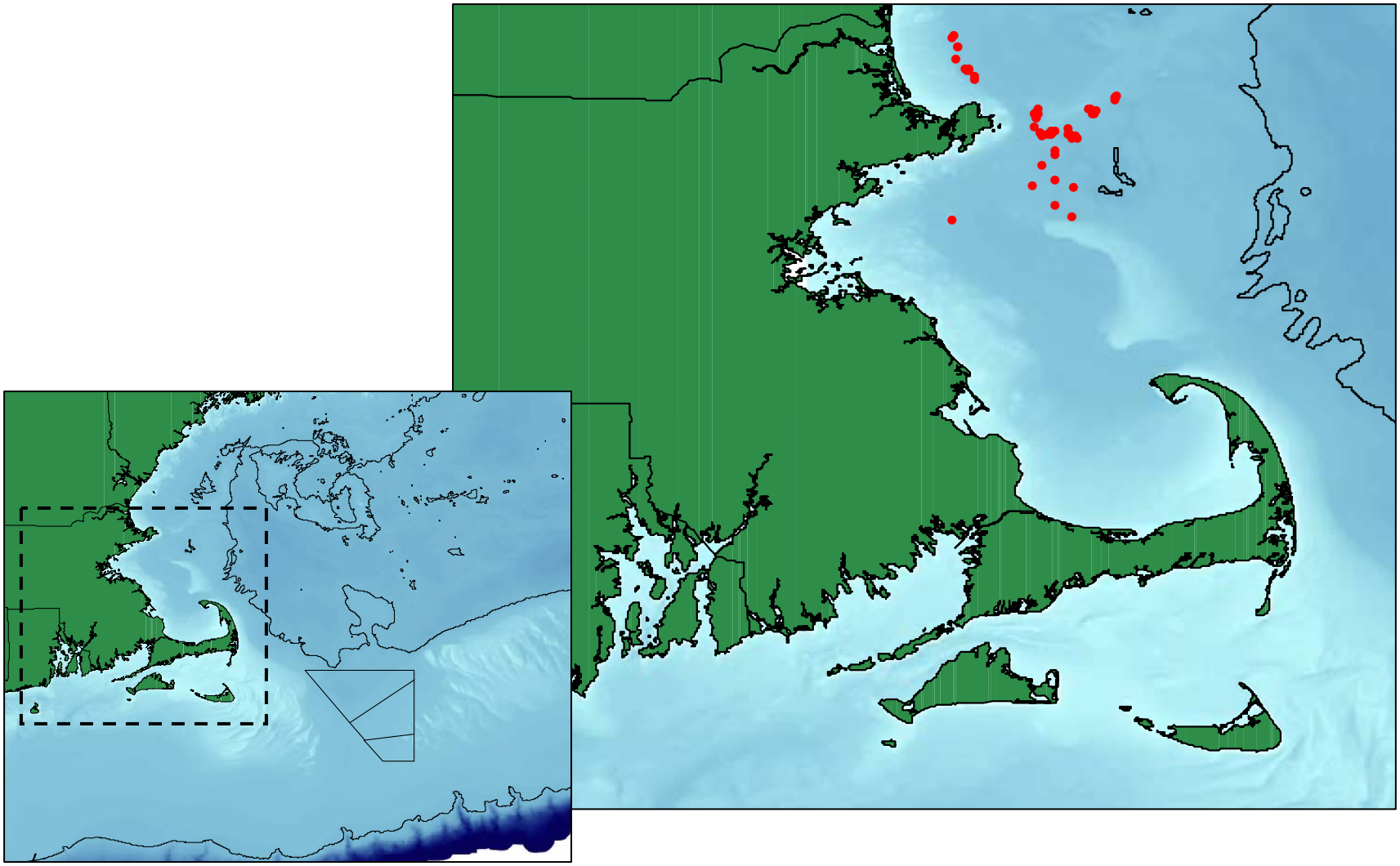

Figure 1. Trawling distribution map of tows (start coordinates shown in red) conducted using the 184 x 40 cm Eliminator Trawl™.

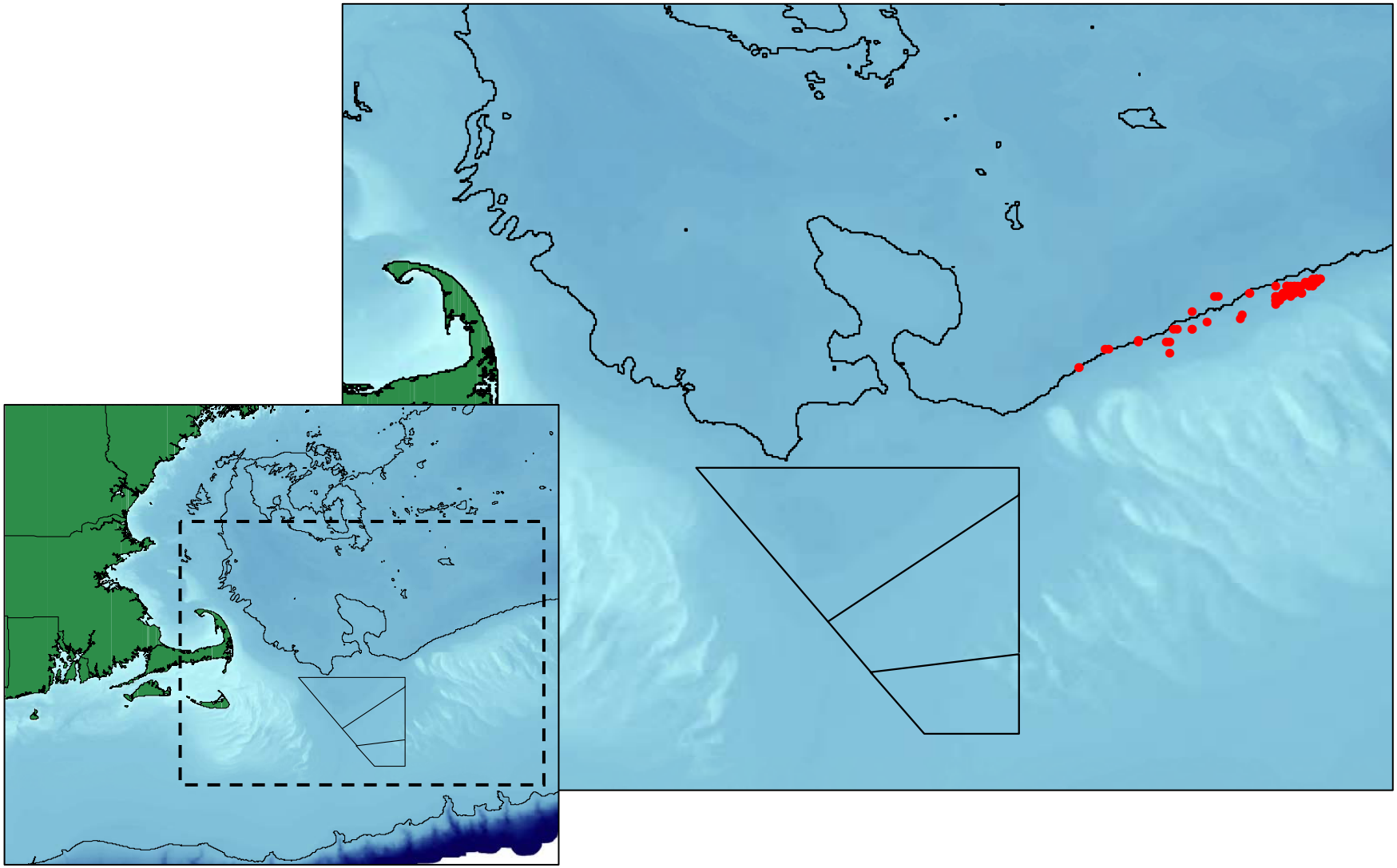

Figure 2. Trawling distribution map of tows (start coordinates shown in red) conducted using the 250 x 40 cm Eliminator Trawl™.

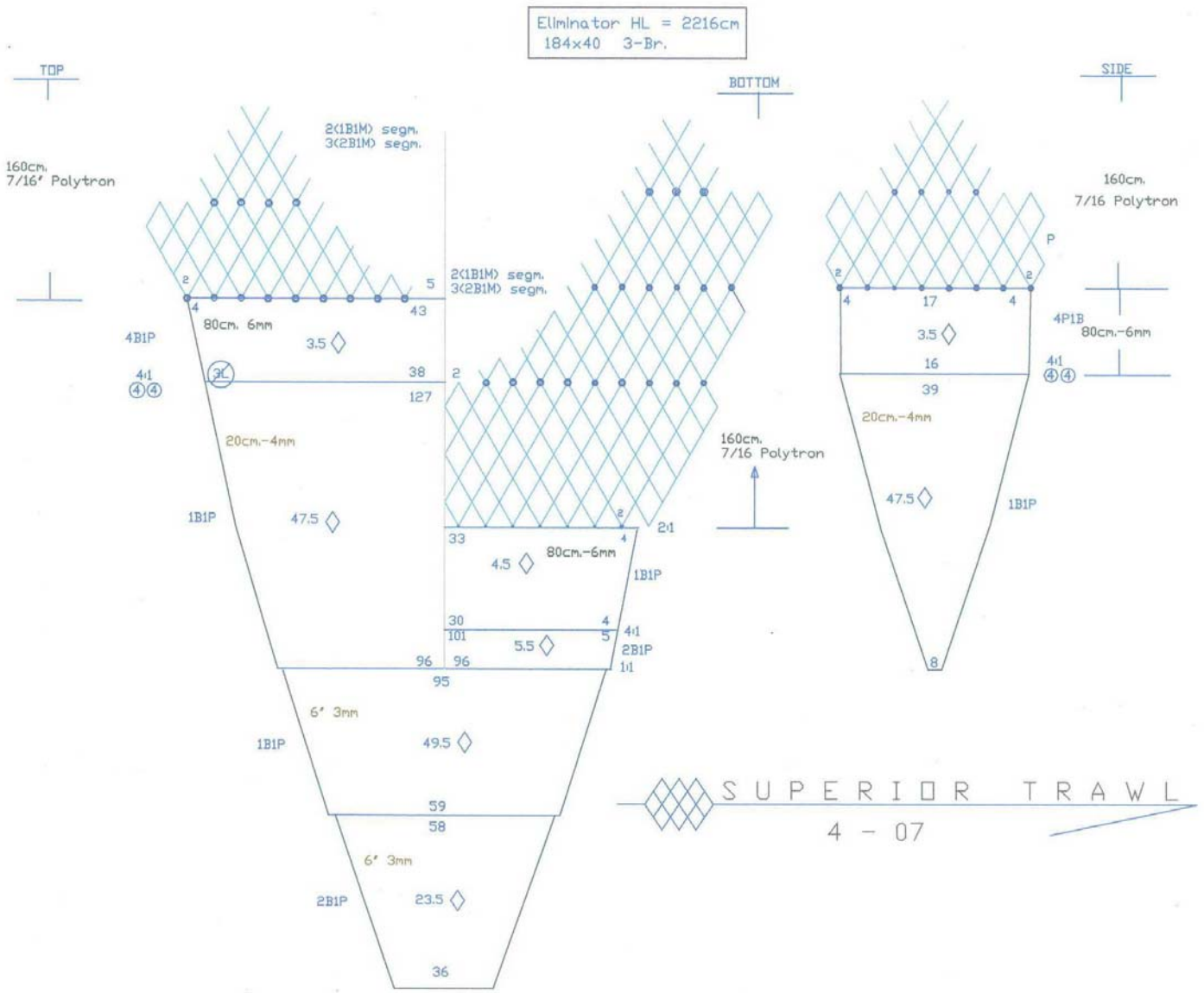

Figure 3. Net plan for the 184 x 40 cm Eliminator Trawl™.

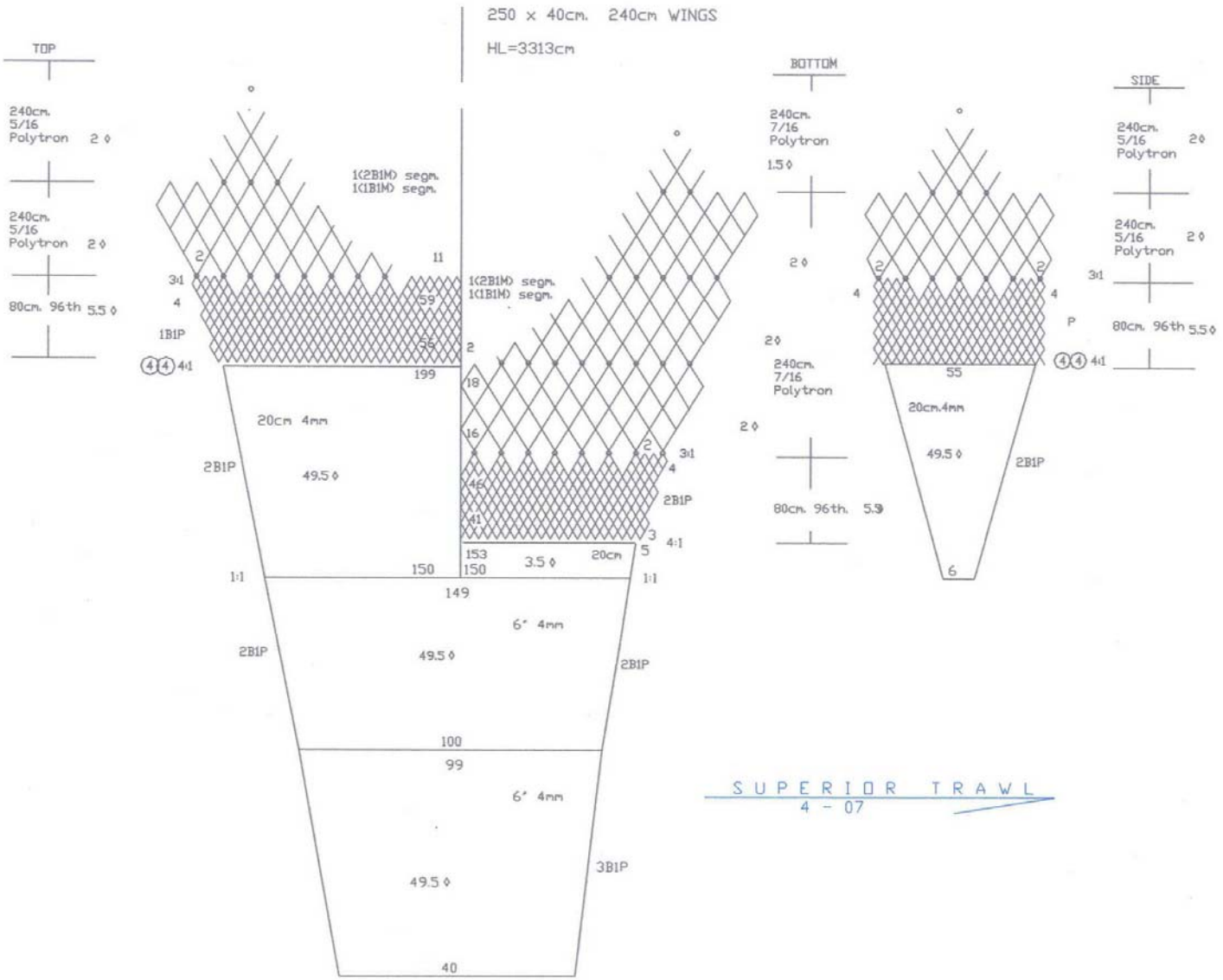

Figure 4. Net plan for the 250 x 40 cm Eliminator Trawl™.

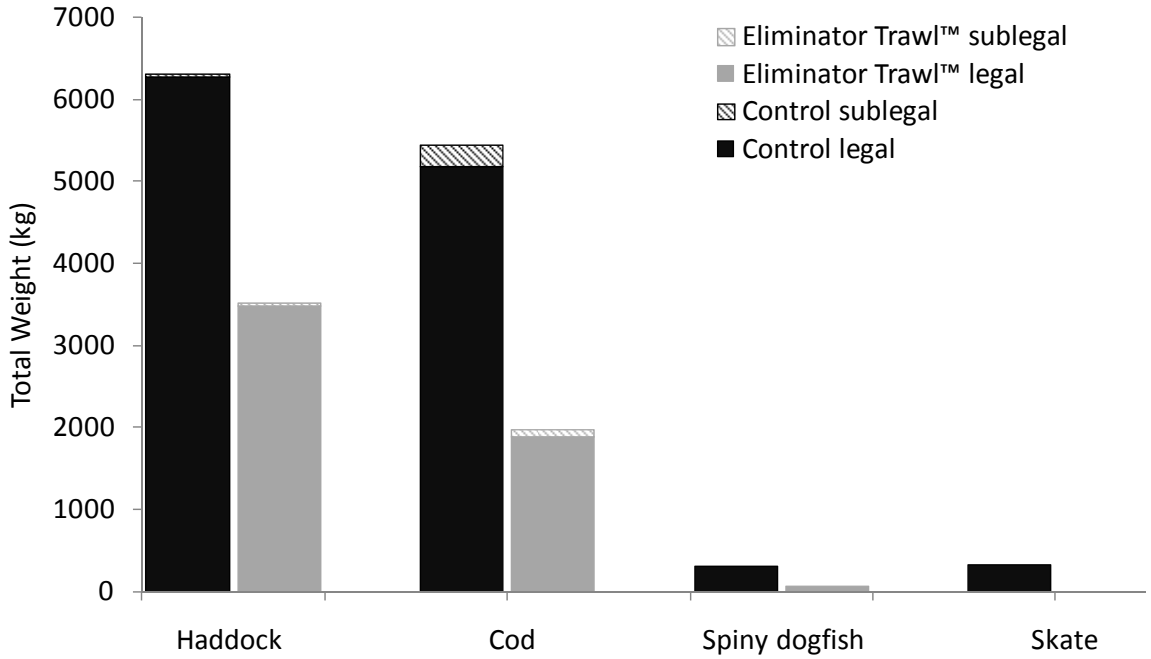

Figure 5. Total catch weight of key species for the 184 x 40 cm Eliminator Trawl™. Refer to Table 2 for exact weights.

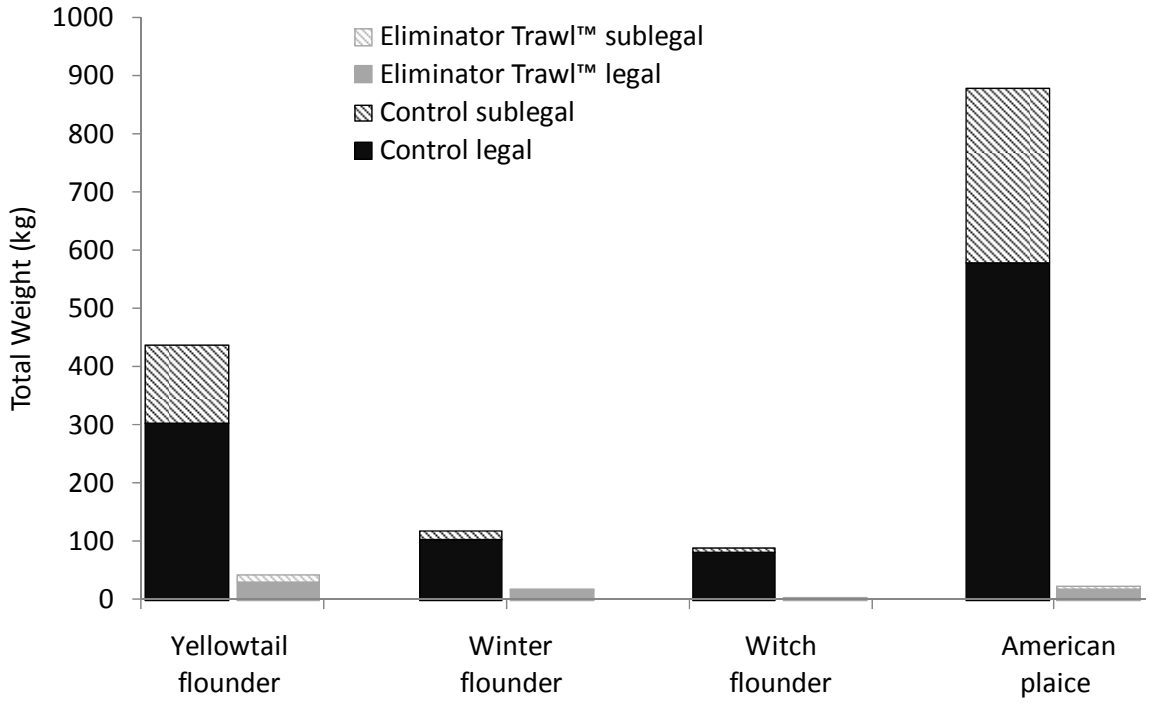

Figure 6. Total catch weight of flounders for the 184 x 40cm Eliminator Trawl™. Refer to Table 2 for exact weights.

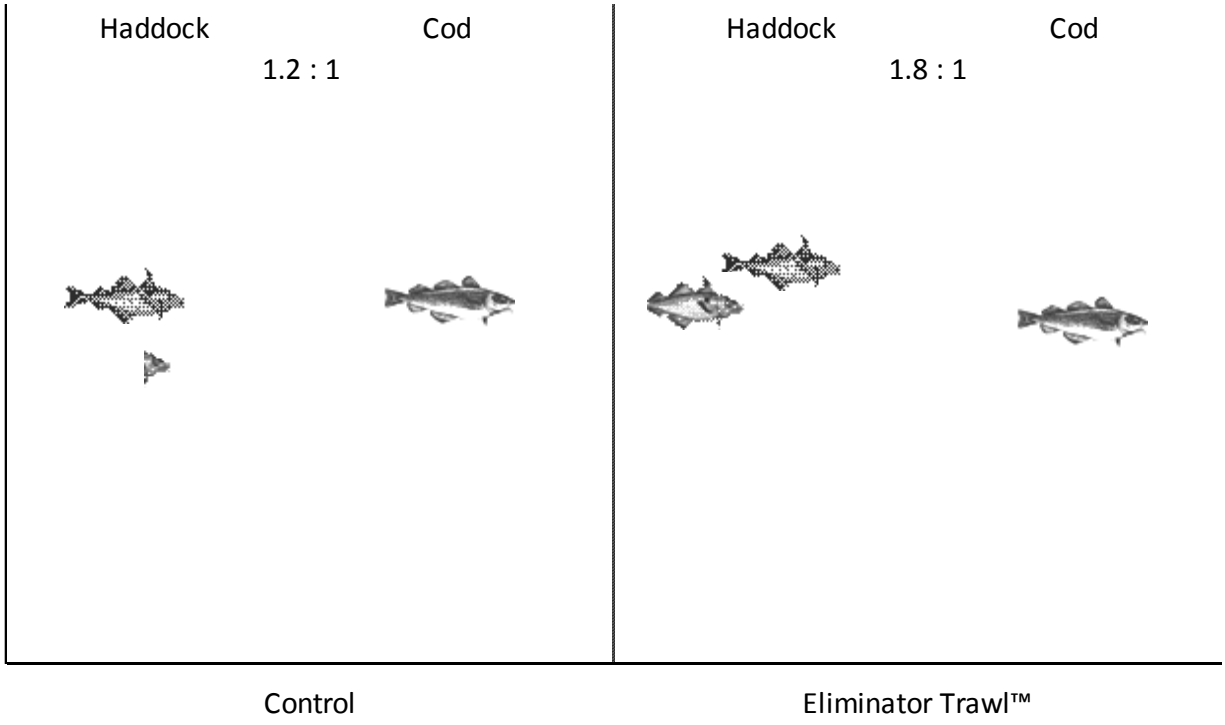

Figure 7. Visual representation of ratios of haddock to cod for the 184 x 40 cm Eliminator Trawl™.

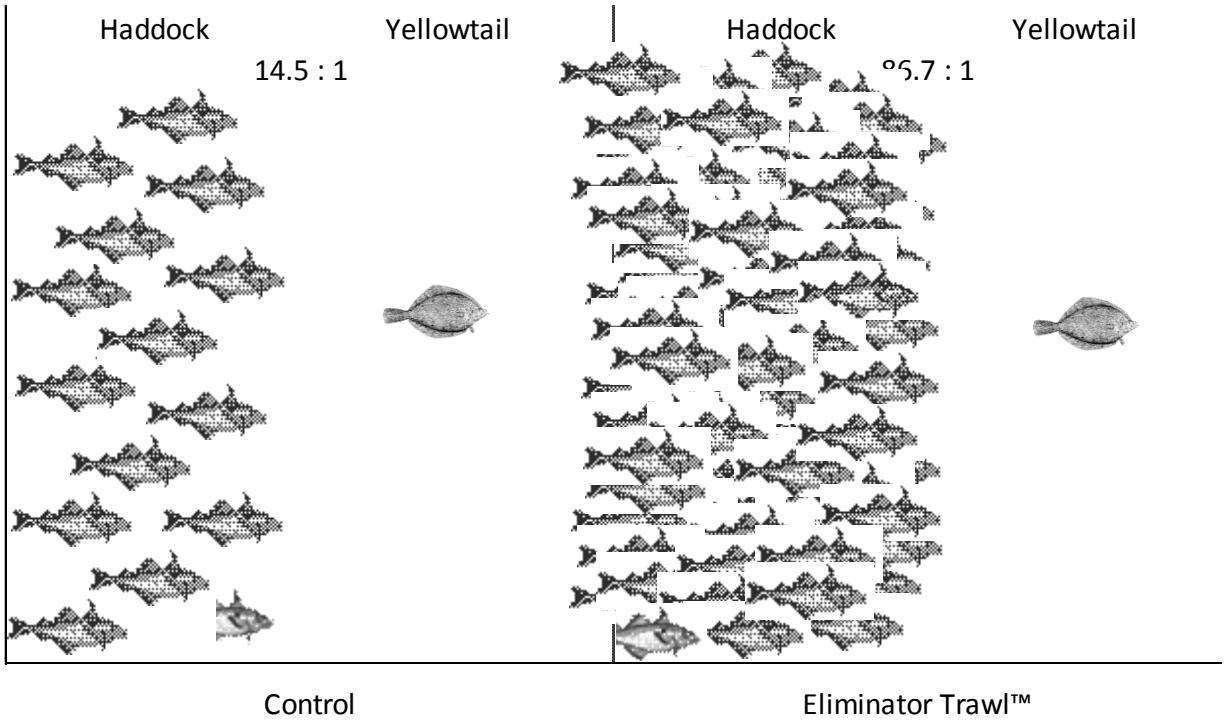

Figure 8. Visual representation of ratios of haddock to yellowtail flounder for the 184 x 40 cm Eliminator Trawl™.

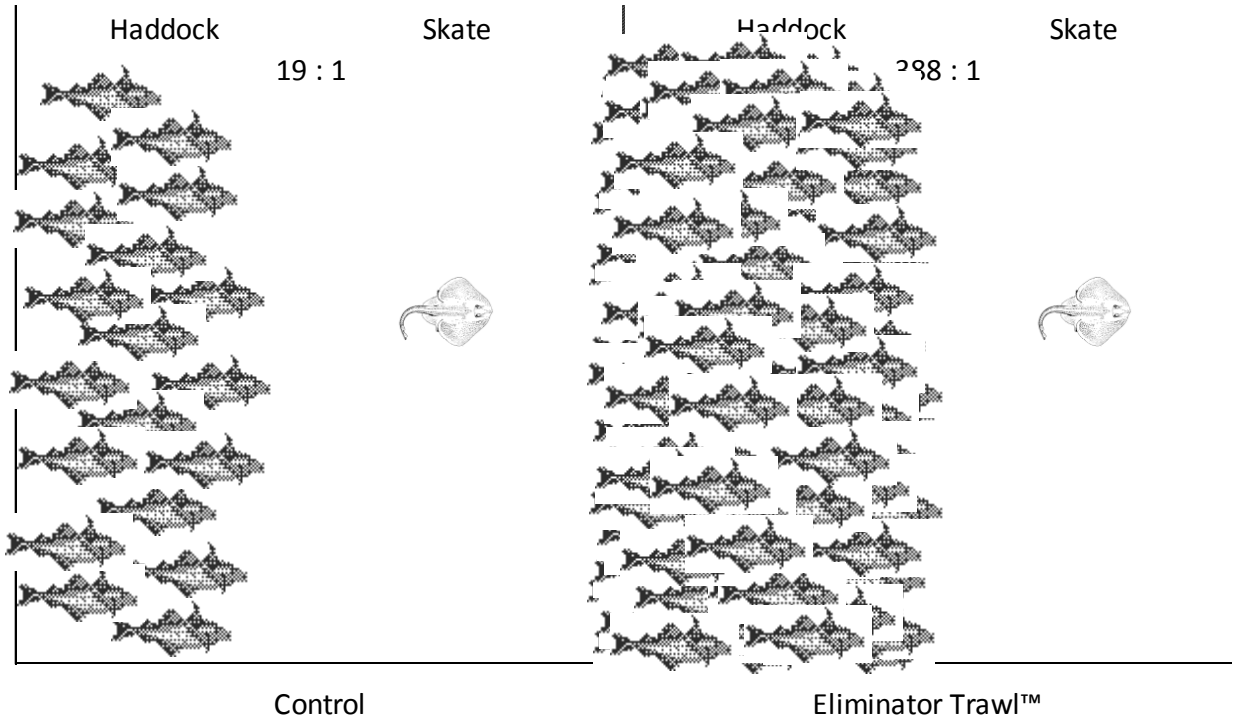

Figure 8. Visual representation of ratios of haddock to skate for the 184 x 40 cm Eliminator Trawl™.

Figure 9. Photos of the catch from the control net, top photos are from the F/V Conor and Michael and bottom photos are from the F/V Lena Pearl.

Figure 10. Photos of the catch from the 250 x 40 cm Eliminator Trawl™, top photos are from the F/V Conor and Michael and bottom photos are from the F/V Lena Pearl.

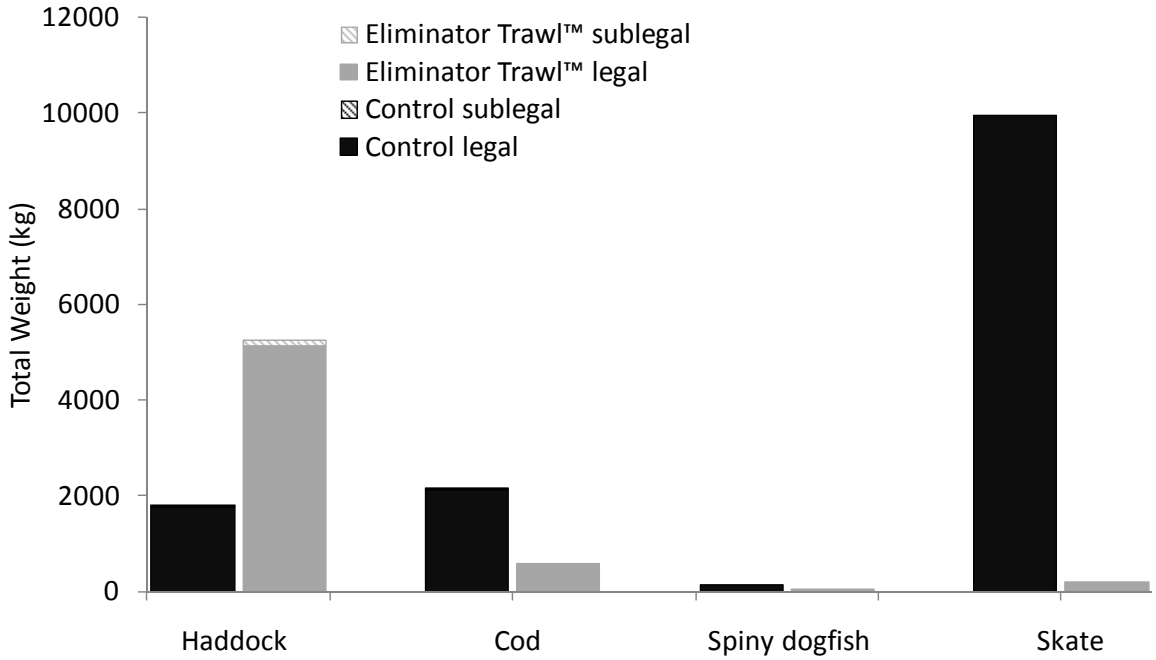

Figure 11. Total catch weight of key species for the 250 x 40 cm Eliminator Trawl™. Refer to Table 5 for exact weights.

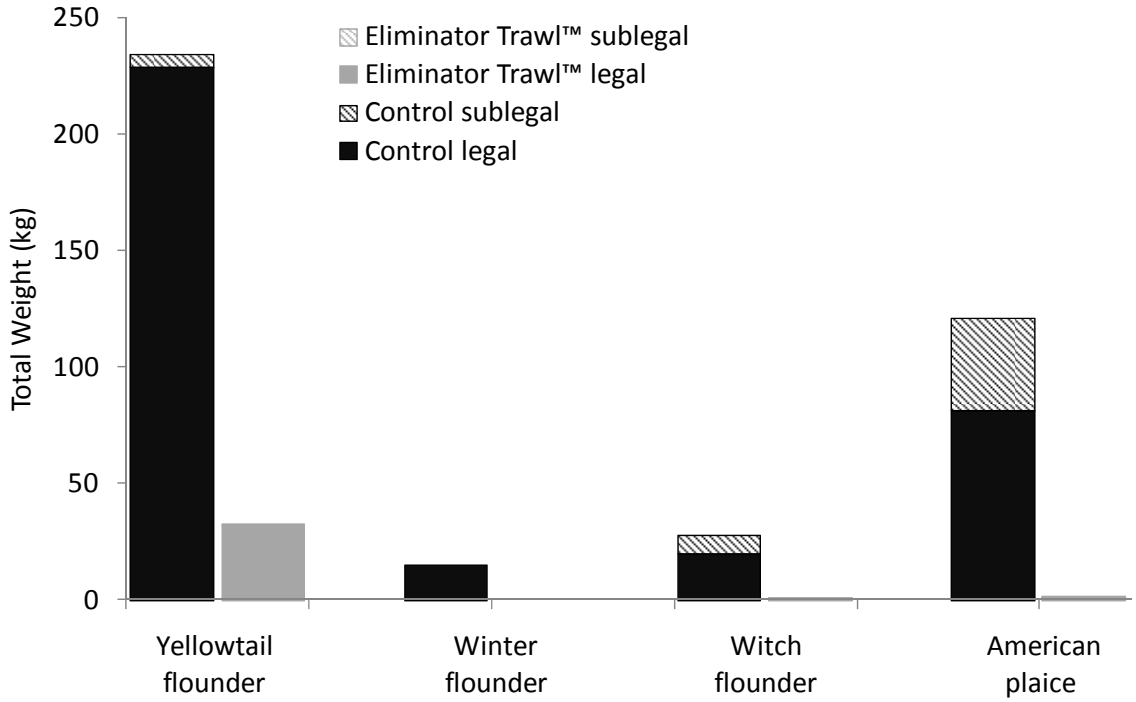

Figure 12. Total catch weight of flounders for the 250 x 40 cm Eliminator Trawl™. Refer to Table 5 for exact weights.

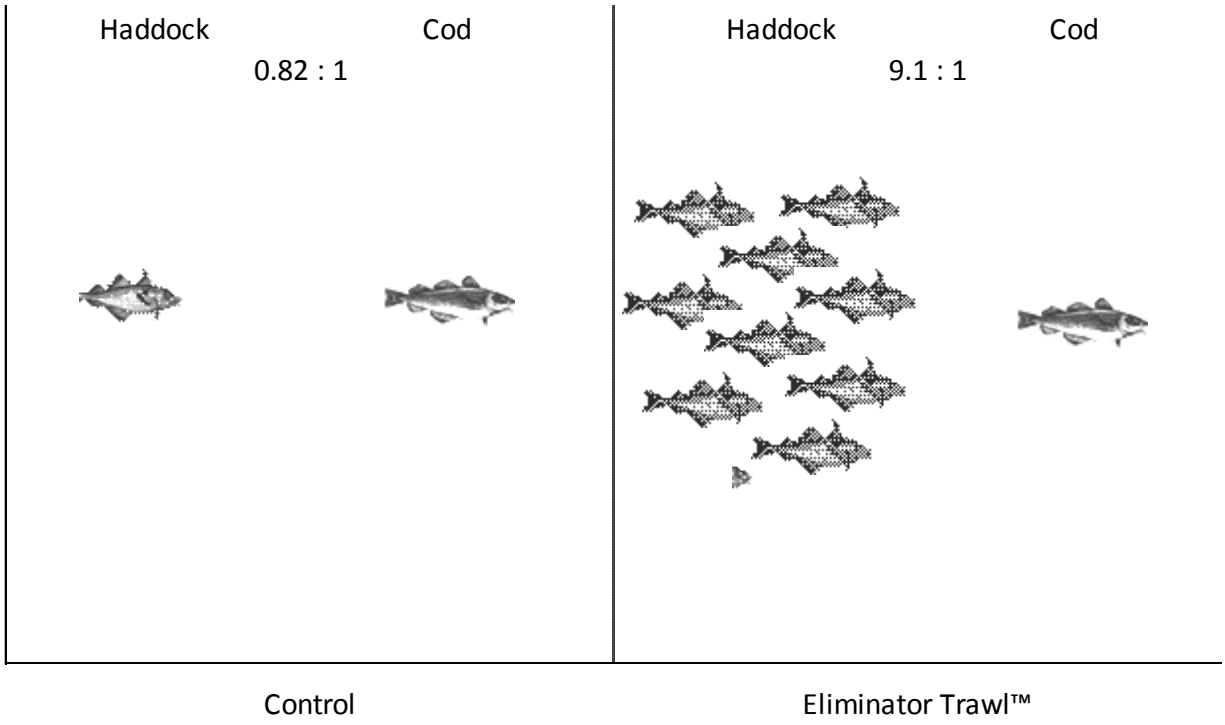

Figure 13. Visual representation of ratios of haddock to cod for the 250 x 40 cm Eliminator Trawl™.

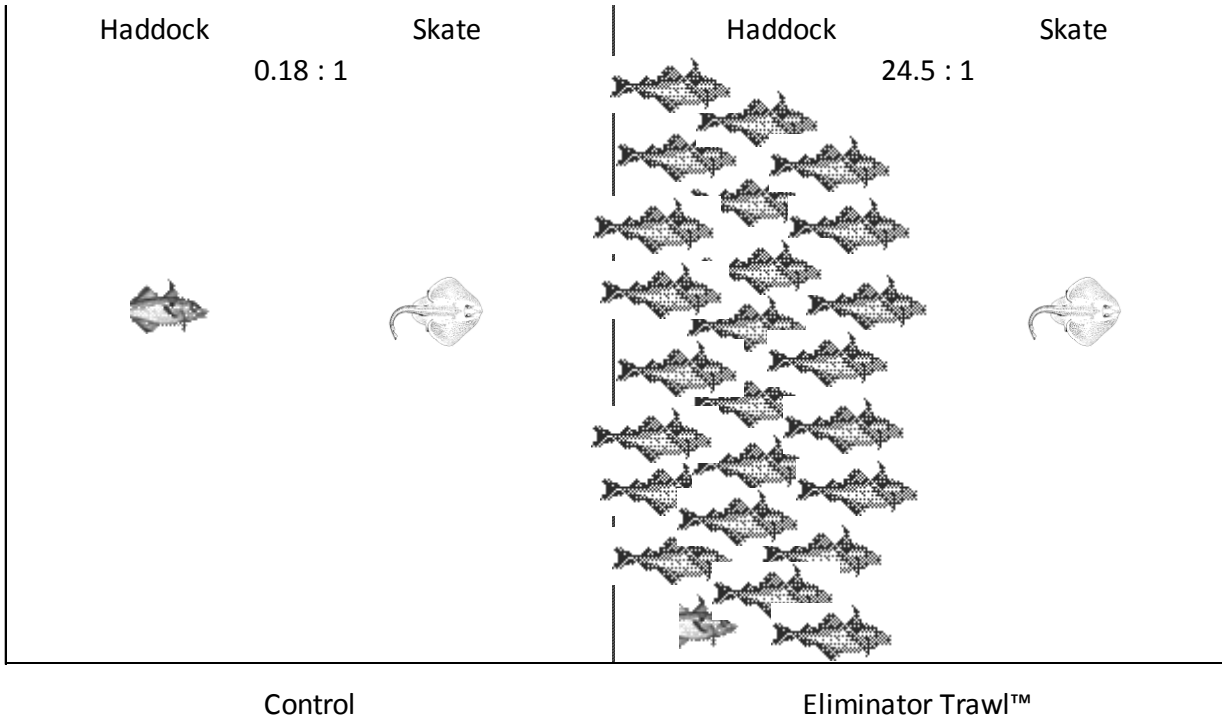

Figure 14. Visual representation of ratios of haddock to skate for the 250 x 40 cm Eliminator Trawl™.

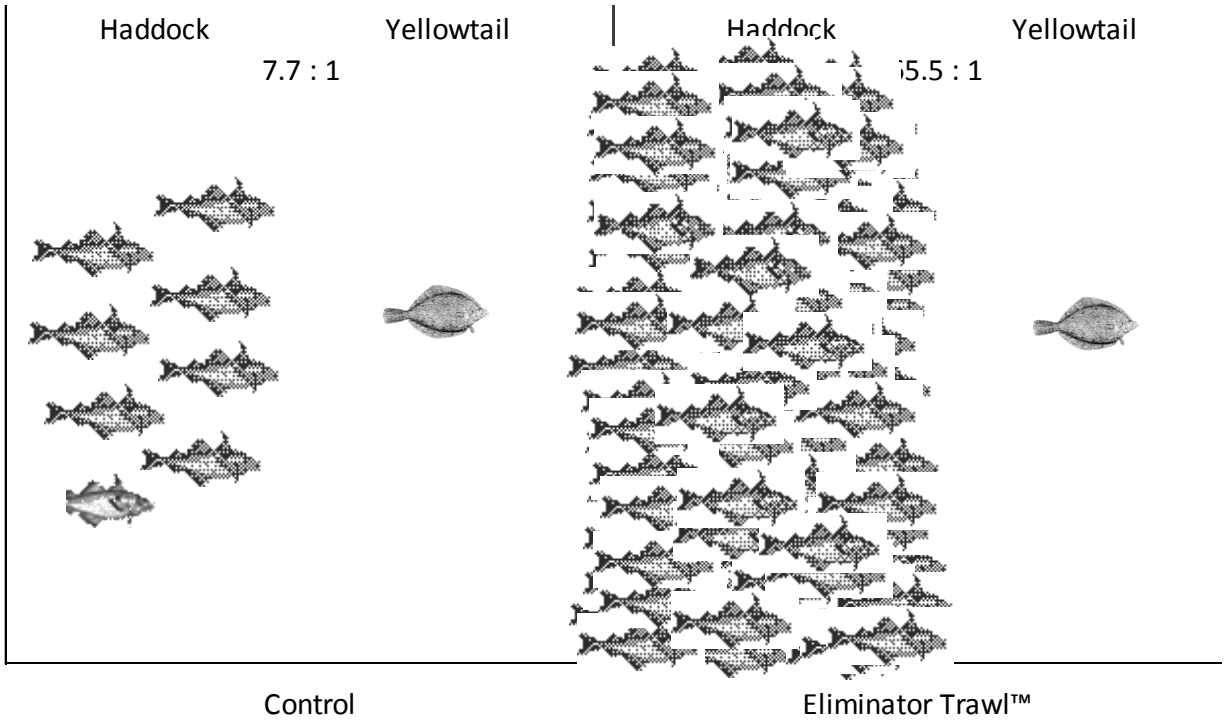

Figure 15. Visual representation of ratios of haddock to yellowtail flounder for the 250 x 40 cm Eliminator Trawl™.

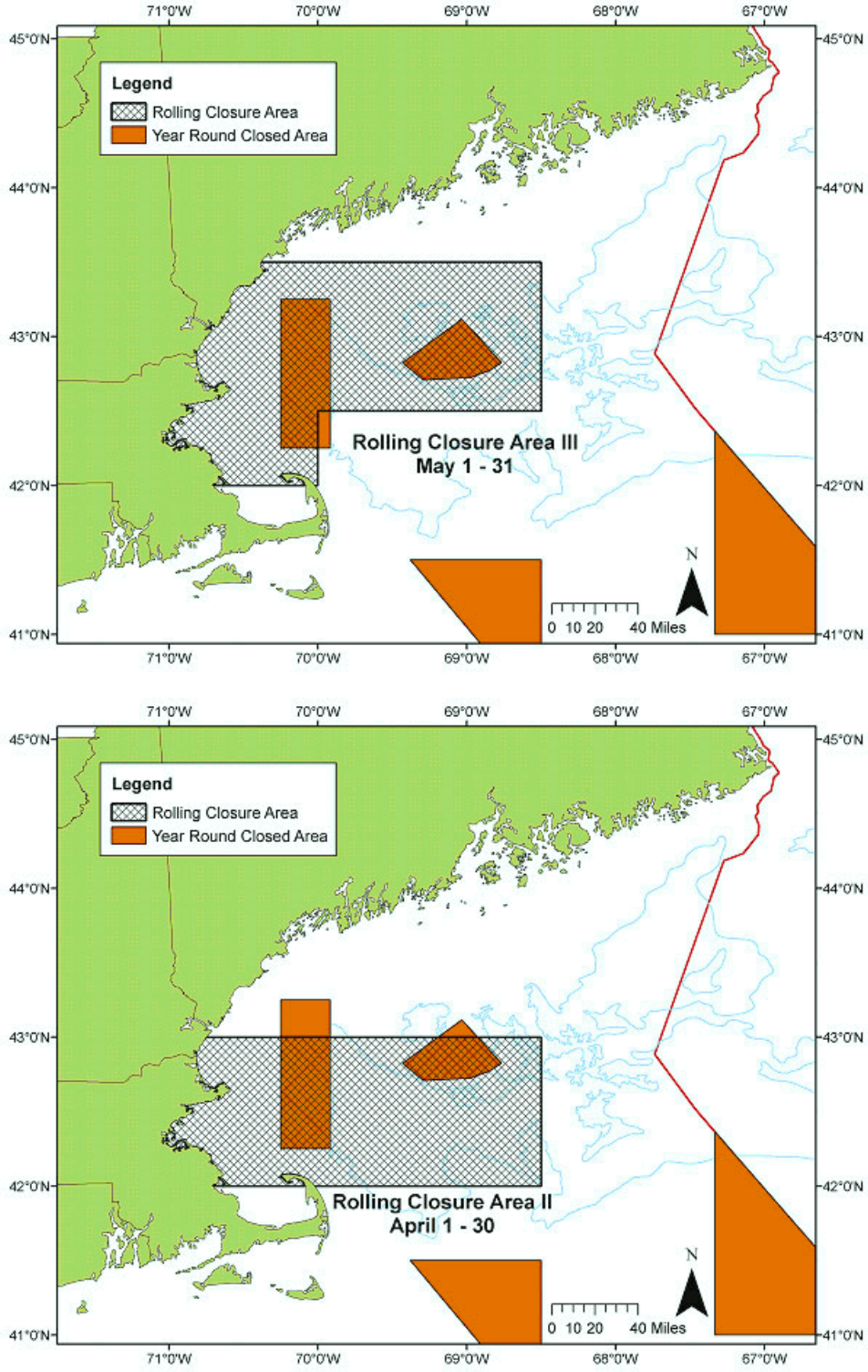

Figure 16. Map of the Northeast Multispecies Gulf of Maine Rolling Closure Areas. (Source: NMFS NERO, http://www.nero.noaa.gov/nero/fishermen/charts/mul5.html.)

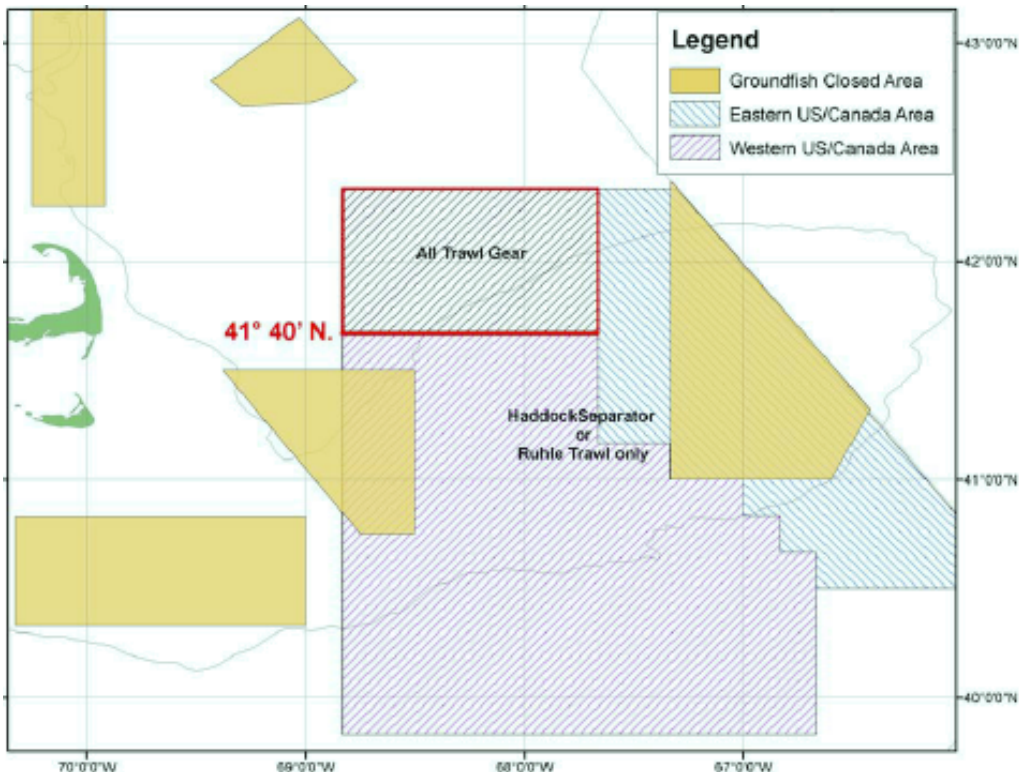

Figure 17. Trawl gear requirements in the US/Canada Management Area. (Source: NMFS Small Entity Compliance Guide dated November 17, 2009)