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Evaluating the discard of monkfish caught as bycatch on northeast multispecies DAS and directed monkfish trips: an application of the Study Fleet electronic logbook program

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Executive Summary

This report describes the results of a collaborative project aimed at evaluating and comparing the discard of monkfish during dedicated northeast multi-species DAS fishing trips (hereafter referred to as groundfish trips) and dedicated monkfish fishing trips in the Gulf of Maine. Commencing in 2008, this project attempted to use both a boat-based and a port-based sampling program to collect catch and effort information on a haul-by-haul basis. The Study Fleet program was to be incorporated into this project, by enabling the collection and entry of haul data, which hopefully would showcase the utility of the program and revitalize declining industry interest in program participation.

Early in the life of this project it became clear that project objectives were not going to be met by the proposed methodology. Problems were encountered with both the boat-based and port-based sampling procedures that ultimately rendered futile continuation using existing methodology. A revised scope of work was developed and approved based on achieving project objectives using NEFOP and SMAST Study Fleet datasets. This report describes the results and outcomes of both the initial and secondary phases of the project. The problems experienced during both phases, including limitations and issues with the data sets, are also explained in order to benefit future projects.

Comparison between both datasets was limited primarily due to the relatively modest size of the Study Fleet data set for the Gulf of Maine. Noticeably, however, the Study Fleet data set appeared to under report discarded monkfish, probably because measuring undersized monkfish is not a key goal of the program and requires considerable time and effort that detracts fishermen from their commercial focus.

Arguably the most useful outcome from this project was an insight into the magnitude and scope of monkfish discards. In both phases of this project, the number of monkfish discards were at times considerable, exceeding the kept monkfish catch several fold. While monkfish discard to kept ratios were usually low, this ratio can mask the large number of individuals that are discarded when large volumes of monkfish are landed. This discarding issue was apparent during both dedicated monkfish trips and groundfish trips, but was exacerbated during dedicated monkfish hauls. No statistical area stood out as a potential monkfish discard 'hot spot' and based on both datasets it was not possible to identify a temporal component to this issue.

Introduction

The Study Fleet program was initiated by the Cooperative Research Partners Initiative at the National Marine Fisheries Service (NMFS) just over 10 years ago to provide detailed and timely information on catch and fishing effort across the New England groundfish fishery. The program was also developed to contribute to fishery-dependent indices of stock abundance, to provide new avenues for communication and feedback among and between fishermen and scientists, and to provide a tool for monitoring changing fishery practices (GMA, 2001).

Fundamentally the Study Fleet program involves equipping fishermen with an electronic means to collect catch and effort information on a haul-by-haul basis and then transmitting this information to the Northeast Regional Office in Woods Hole, MA. Initially, fishermen collected Study Fleet data using either a Thistle Marine HMS-110 data collection unit or an electronic logbook developed by the University of New Hampshire (NOAA, 2003). The Thistle Marine unit was a portable unit that enabled fishermen to telephonically transmit Study Fleet data following completion of a fishing trip to Thistle Marine's website from home or other locale. The UNH electronic logbook was installed on a computer located in the pilot house of the fishing boat, and data was transmitted via the boat's vessel monitoring system. Both systems were also connected to the boat's GPS unit to collect positional information during every haul. By the end of 2003 a total of 15 boats were participating in the Study Fleet program. Around this time the program commenced using small sensors attached to the otter boards to provide important temperature and depth information, including confirmation of haul duration and relationship with species composition and abundance. In 2004 the Thistle Marine units were replaced with proprietary P-Sea Windplot logbook software or the UNH software.

By 2007 the Study Fleet program was in decline due primarily to problems with contracting costs and contractors meeting delivery schedules (NCRPP, 2007). A decision was then made by the NMFS to internalize development of the Study Fleet program, including development of an easy-to-use, program specific, electronic logbook software program. This software became known as the Study Fleet Fisheries Logbook Data Recording System (FLDRS). A peer review of the Study Feet program at this time commended this decision for its cost-effectiveness and greater control over software development (NRCPP, 2007). This review also noted that future program work needed to include, "…clear, quantifiable measures of improvement…" to demonstrate the benefits of the program, and that uncertainty existed regarding the application of Study Fleet data and how best to incorporate this data into stock assessment models and frameworks.

In mid-2007, the Gulf of Maine Research Institute (GMRI) commenced a research project aimed at revitalizing the Study Fleet program in the Gulf of Maine. GMRI's involvement in this program had actually commenced in the late 1990's, by providing a vital link between the fishing industry and the developers of Study Fleet equipment and software. This included acting as an information conduit between fishermen, researchers, managers, and software developers, hosting meetings, preparing reports, and training fishermen in the use and operation of Study Fleet hardware and software. The goal of the 2007 project was to equip 5 – 10 boats with modern hardware and software and to ensure seamless data collection and transmission. This project also planned to use acoustic trawl mensuration equipment to measure trawl geometry to provide a greater and more accurate understanding of fishing gear geometry and performance under a range of normal operating conditions. This information could then potentially be used to enable estimation of indices of catch per unit area or catch per unit volume swept by the fishing gear. Around this time the Massachusetts Marine Fisheries Institute, a partnership between the University of Massachusetts, the Massachusetts Intercampus Graduate School of Marine Sciences

and Technology (SMAST), and the Massachusetts Executive Office of Environmental Affairs, also attempted to revitalize the Study Fleet program, with an initial focus primarily on Georges Bank and Southern New England, and to a lesser extent the Gulf of Maine (Roman et al. 2011). This program was similar to the NMFS program but with an additional emphasis on using net mensuration equipment to measure water depth, temperature, and trawl geometry under a range of operating conditions and locations, and by requesting fishermen to measure a subsample of the catch.

In 2008 the GMRI project floundered due primarily to disinterest in the program by Gulf of Maine fishermen coupled with distraction over moves to severely ratchet down Day-At-Sea access to the groundfish fishery. Dissatisfaction and frustration with equipment and software and a need to report catch and effort data in both the vessel trip report and the Study Fleet program were commonly cited reasons for their disinterest. In 2008 GMRI again attempted to revitalize the Study Fleet program in the Gulf of Maine, this time by linking the program to concerns over the impact of fishing on discard rates of undersized monkfish. This initiative directly responded to issues raised in the peer review as well as concerns over the health of the monkfish stock that had been in existence since the late 1990's (Haring and Maguire, 2008). In this way it was hoped that fishermen would be more enthusiastic about the program and associated data collection requirements. This project report describes the outcomes and results of that initiative, which ultimately had its own share of problems that necessitated a substantial change in the project's scope of work prior to its completion.

Goals and Objectives

The principal goals of this project were to provide better estimates of the amount of monkfish discarded by the Gulf of Maine trawl fleet and compare the amount of discarded monkfish between boats using groundfish trips and directed monkfish trips.

To achieve these goals we proposed to introduce a boat-based data collection program, including Study Fleet electronic logbook equipment and protocols and a port-based sampling program. Both programs were to be complimentary and included biological sampling of both landed and otherwise discarded monkfish. This project was also to provide an opportunity to test a secondary goal, that is, to evaluate the application and efficacy of the recently refined Study Fleet logbook software.

The specific objectives of this project were:

1. Estimate and compare the bycatch and discarding of monkfish between boats using northeast multi-species DAS and directed monkfish fishing trips in the Gulf of Maine.

2. Assess the efficacy of a boat-based sampling program, using project personnel and the Study Fleet electronic logbook, to augment other data collection programs including the NMFS Northeast Fisheries Observer Program (NEFOP) and Vessel Trip Reports (VTR).

3. Evaluate the utility and application of the boat-based sampling program to provide a tool that could be used in the monkfish fishery and other fisheries, including an ability to evaluate trends in bycatch and discards over a longer time period.

4. Identify important areas in the Gulf of Maine fishery that might require more intensive sampling effort in the future, including so-called 'hotspots' of undersized monkfish catches (and other discard species), to improve temporal and spatial management of monkfish fishing.

Methods

The original sampling program was based on a blend of boat- and port-based catch sampling. However, as this program unfolded it became clear that the collected data was inadequate to satisfactorily achieve project goals and objectives (see discussion section for description of problems and issues). A revised scope of work was then approved and exercised for the remainder of the project.

Original scope of work

The original scope of work included a boat-based sampling program that relied primarily on fishermen using the FLNDRS electronic logbook software and a port-based sampling program whereby fishermen retained the entire monkfish catch from the last haul of their fishing trip for sampling at the dock by GMRI staff.

Boat-based sampling program

The boat-based program involved the application of the FLNDRS electronic logbook software and related sampling protocols. The project was to include five boats that would use this software, from September through to April, 2008, to capture the period when historically most directed monkfish trips in the Gulf of Maine occurred. Data collection was to include the precise location, timing, and duration of fishing activity on a haul-by-haul basis, temperature at depth (using data storage tags), as well as estimation of both retained and discard catch weight of major species, including skates, dogfish, and regulatory species. In total, we expected to collect data from approximately 40 boat trips over an 8 month period. Catch data from all five boats was to be standardized by trawl size (nominal fishing circle) and haul duration, and assessed for both spatial and temporal variation.

At the commencement of the dedicated monkfish fishing season in September, 2008, project personnel were to accompany each participating vessel during one fishing trip to provide training in use of the Study Fleet logbook and sampling protocols. This training was to focus especially on protocols for accurately estimating monkfish weights, both retained and otherwise discarded. This protocol was to include the use of standardized fish totes. We had planned to weigh full totes of monkfish using electronic scales to explore variation in mean tote weight, and provide this information to fishermen to facilitate their weight estimation, with a now-higher degree of precision.

During the remainder of the fishing season, project personnel were to randomly select one of the five boats each month to accompany on a normal commercial fishing trip. Identical data to that collected by the remaining four boats within the same NMFS statistical area was to be collected. This data was then to be compared to the data collected by the fishermen using FLNDRS to assess its quality and accuracy. In addition, project personnel were to conduct more detailed biological sampling on the monkfish catch for comparison with the port-based program, including length and girth measurements, and individual weights.

Port-based sampling program

The port-based sampling program was to be used to test and validate the efficacy of the boat-based program to provide an accurate, cost-effective means of obtaining useful data on retained and discard monkfish catches. It was also to be used to collect additional data not historically collected as part of the Study Fleet program such as monkfish length. Fishermen were to retain

all kept and discarded monkfish from the final haul of the fishing trip separate in the hold from monkfish caught during previous hauls. These fish were then to be made available for biological sampling upon landing in port, including measurements of fish length, girth, weight, and number. We had a strategy in place to ensure these fish were sampled prior to unloading the catch, so to avoid delaying and further impacting end-of-trip preparations. In combination with any data from the Northeast Fisheries Observer Program (NEFOP) and that collected at sea by project personnel from the same region and time, we were to be in a position to assess the variability in reported catches between all three data collection methods.

Program evaluation

At the conclusion of the project a one-day workshop was to be convened with major stakeholders to evaluate the efficacy of project data to:

i) accurately and consistently record information about retained and discarded monkfish in the Gulf of Maine trawl fishery during both ground fishing trips and directed monkfish fishing trips during an entire fishing season,
ii) identify and/or address bycatch or other fishery issues on a real-time basis, especially those with a specific temporal or spatial component,
iii) augment other fishery dependant data sources (NEFOP, Vessel Trip Report data)
iv) be utilized in the assessment of monkfish stocks, and,
v) provide cost-effective, valuable information over the long-term in the directed monkfish fishery.

Revised Scope of Work

Rather than continue to finance the originally proposed sampling design, a revised scope of work was proposed that we felt had greater chance of achieving several of the original project objectives without excessive compromise. This revision included the collection and analysis of monkfish data from NEFOP between 2007 and 2009 and the SMAST Study Fleet program between 2000 and 2010 in the otter trawl fishery in the northern management area (Table 1). We felt that a thorough analysis of this data would more likely accomplish objectives 1, 2 & 4 from the original proposal and fulfill the original goal of the project as well. In addition, the revision included the purchase of capital equipment for use in future research fieldwork. These purchases were possible using funds redirected from now-redundant fieldwork costs because the originally budgeted fieldwork was now replaced with a desktop evaluation of catch and effort data. This revision was approved in 2010 by the NMFS's Northeast Fisheries Science Center (NEFSC) Cooperative Research Program.

Data analysis

An excel dataset containing catch data and length frequency data was received from the NEFOP covering the years 2007 to 2009. The original dataset consisted of ten data fields: [YEAR], [TRIP_TARGET], [DEPTH], [TOWSPEED], [HAULDURATION], [HAUL_TARGET], [AREA], [WEIGHT], [WEIGHT_TYPE], and [FISH_DISPOSITION](Table 1). Duplicate data records were discovered in the data and an adjusted data set was later received with these records removed. Also included in the adjusted data set were the data fields: [TYPE], [ORIGINAL_WEIGHT], and [HAUL_OBSERVED?], as well as a list of the number of hauls per statistical area per year (Table 2). Catch and discard data analyzed in this study corresponds only to hauls with monkfish catch. Data from so-called unobserved hauls were excluded from any

analysis comparing kept to discard weight, as the discard data from these hauls was considered incomplete.

The number of hauls per statistical area was further separated by the trip target (monkfish or groundfish) and the haul target (monkfish or groundfish) in order to standardize catch data in these categories. The groundfish category was inclusive of all listed groundfish species options such as cod, haddock, redfish, etc., with the exception of monkfish. The procedure for determining the number of hauls for each category involved using Microsoft Access to design a query to locate multiple data records referring to a single haul. Redundant data records were subtracted from the data set, leaving a single data record for each haul that could then be categorized by trip target or haul target and enumerated. It was assumed that data records referred to a single haul if they were identical in the following data fields: [YEAR], [TRIP_TARGET], [DEPTH], [TOWSPEED], [HAULDURATION], [HAUL_TARGET], [AREA]. Subtracting data records identical in these fields underestimated the total number of hauls with monkfish catch. The procedure was then extended by searching for redundant data records identical in the additional fields of [FISH_DISPOSITION] and [TYPE]. These records were rejoined to the data set, and haul numbers were calculated for each category of trip and haul target. This process of removing redundant data records was also used before calculating the physical parameters of haul information including average values for tow depth, tow speed, and tow duration.

SMAST Study Fleet data were also received in an excel database with catch data and length frequency data (Table 1) spanning the years 2000 to 2010. Only data from 2007 to 2009 were utilized in this study due to changes in data collection protocol before 2006 and in order to match the years of the NEFOP data set. Similar to the NEFOP data, the Study Fleet data consisted of multiple records for single hauls. In order to calculate the number of hauls, a Microsoft Access query was designed to identify redundant records. It was assumed data records were referring to a single haul if they were identical in the data fields of [TRIP] and [Haul]. These records were subtracted from the data set and the number of hauls was enumerated.

For objective 1, NEFOP discard estimates were to be compared to determine if trip or haul targets resulted in significantly different levels of monkfish discarding in the otter trawl fishery. Additionally, haul depth, vessel speed, and haul duration were to be examined to determine the extent these factors have on monkfish discard rates.

For objective 2, Study Fleet discard estimate ratios were to be compared to NEFOP data discard estimate ratios to determine the efficacy of data collected through a boat-based sampling program. These comparisons were to be conducted within compatible New England Fishery Management Council (NEFMC) thirty minute square blocks to account for differences based on fishing location (Figure 1).

For objective 4, discard estimate ratios from both the NEFOP data and Study Fleet data were to be analyzed by statistical area and by NEFMC thirty minute squares in order to identify important areas in the Gulf of Maine with “hotspots” of monkfish discarding. Further, length frequency and monkfish disposition information were to be used to determine areas with high undersized monkfish discarding.

A Chi-squared non-parametric test for independence was used to compare the proportion of sublegal and legal monkfish between statistical areas or sampling methods. Based on contingency table output the standardized residual of each proportion was then determined to evaluate their relative contribution to the test statistic, using the expression:

$$\text{Standardized residual } = \frac{(\text{observed} - \text{expected})^2}{\text{expected}}$$

A standardized residual with a value greater than 2.00 was considered a major contributor to the significance of the test statistic, and the largest residual was deemed the greatest contributor to the statistic. A Kolmogorov-Smirnov two-sample non-parametric test was also used to compare length frequency distributions between statistical areas and sampling methods. This test makes no assumptions about the distribution of the data and is useful to compare distributions that are typically skewed, such as length frequency distributions. A pooled two-sample t-test was used to compare mean haul duration between monkfish trip and groundfish trip data.

Equipment

The purchase of equipment items using project funds was made after detailed consideration of equipment needs and gaps to support future research in the monkfish and other fisheries. This equipment was also purchased with the clear understanding that it would be made available to other research projects and institutions to support their research efforts. The following equipment was purchased:

Star Oddi Data Storage Tags (DST)

These portable tags can be affixed to static and mobile fishing gear to accurately measure and record water temperature and depth data. The DST Centi series tags records temperature and depth, while the DST Tilt series can additionally measure tilt in 3 dimensions. The data is then downloaded to a computer via a communication box. Four Centi series tags and two Tilt series tags were purchased along with associated housings and a communication box. Each tag has a depth rating of 270 m and a purported measurement accuracy at this depth of +/- 0.4%. They also have the capacity to record tens (or hundreds in the case of the Centi) of thousands of measurements. The Tilt and Centi tags have a battery life of 4 years and 7 years respectively.

These tags can be placed along the headline (floatline) of a gill net to obtain data on gillnet working height, including the influence of tidal cycles. They can also be used to evaluate the effectiveness of norsel lines to raise leadline height above the seabed. The DST Tilt series can additionally be fitted to trawl doors to measure their orientation under a variety of operating conditions.

Panasonic Toughbook CF-31

This is a ruggedized, all-weather laptop suitable for operation on the deck of a fishing boat. The laptop is crucial to download video files from underwater camera equipment, to collect and store acoustic mensuration data, and to record sampling data including catch and fishing effort. The Toughbook 31 offers suitable power in the ruggedized package to process and view large video files in the field.

Strain Gauge System

The strain gauge system is a portable system that can be applied on any monkfish or ground fish vessel. A strain gauge is attached to each trawl winch to yield tension data of towing warps and hauling ropes up to 2 000 lbs. This tension serves as a proxy for gear drag and fuel consumption of a trawl system, and modification to the fishing gear permits evaluation of relative changes in engine load and fuel consumption. This system avoids the time consuming and relatively expensive process of fitting fuel flow meters to vessel engines, which also require the services of a marine mechanic or engineer to fish to the main engine.

GoPro Underwater cameras

Five GoPro cameras were purchased to record video images of fishing gear in operation and associated fish behavior. They were primarily selected for their small size and weight, which allows them to be quickly and easily positioned in a variety of situations, across a variety of gear types (lobster traps, gillnets, trawl doors, etc.). The typical GoPro camera comes in a plastic housing rated to 180 feet, however to maximize flexibility and durability of the camera, custom-made deep-water housings were also purchased for each camera to permit filming at depths up to 750 feet. The GoPro camera also provide a very low cost solution to HD filming, with each camera capable of capturing full 1080p resolution video at 30 frames per second (or 720p at 30 or 60 fps) for three hours. Given their mid-range low-light capability four 1 500 lumen battery operated dive lights were also purchased.

Results

Original scope of work

Port sampling

It was only possible to collect port samples of monkfish at the end of four fishing trips by the F/V Jocka between December 2008 and April 2009. Monkfish port samples weighed between 244 lbs (n = 192 individuals) and 658 lbs (n = 107 individuals)(Table 3). The ratio of discarded to kept monkfish by number ranged from 0.15 to 2.20. Two-sample Kolmorogov-Smirnov tests detected significant differences in the size composition of monkfish between all port samples (*p*-value <0.05) with the exception of the first and second port sample. By applying a conversion factor (Wigley et. al. 2003) to all measured monkfish, the ratio of discard to kept monkfish by weight ranged from 0.12 to 0.27 for the first three port samples, but increased to 2.99 for the final port sample. The smallest and largest recorded monkfish measured 22 cm and 89 cm respectively (Figure 2).

Sea sampling

There was substantial variation in the monkfish data recorded from each boat (Table 4). Study Fleet data was provided by the F/V Black Beauty for 6 fishing trips, including discard data, and a GMRI sea sampler collected all data including monkfish lengths from one trip. Data from the F/V Jennifer & Emily was collected by the sea sampler on one trip, including monkfish lengths, before the boat departed from the project. Study Fleet data was provided by the F/V Jocka for five trips and port sampling of the last haul in 4 corresponding trips (as described in the port sampling section) resulted in the collection of haul specific monkfish catch and discard data. No monkfish discard data was provided or reported in the Study Fleet data for the F/V Jocka (Table 4; Appendix 1).

A maximum of four statistical areas were reported per fishing trip by any one boat, and in decreasing order of frequency the most commonly reported areas were 515, 521, and 514 (Table 4). There was substantial variation in kept to discard ratios of monkfish within a trip and between trips (Table 4; Appendix 1). A GMRI sea sampler was available during the first trip of the F/V Black Beauty and measured all monkfish from a total of 24 hauls (4 hauls caught no monkfish)(Table 4; Appendix 2). This enabled predicted discard and kept whole monkfish weight data to be estimated using the Wigley et al. 2003 conversion factor. The average discard to kept ratio was 0.15 +/- 0.10 monkfish by weight (n = 24) and the range was 0.00 – 0.38 discards to kept monkfish. Total monkfish catch weights during this trip were not measured by the sampler, although hail weights of monkfish tails ranged from 10 to 350 lbs per haul and averaged 139 +/- 98.9 lbs. Two-sample Kolmorogov-Smirnov tests detected significant differences in the size composition of monkfish between all port samples (*p*-value<0.05).

Monkfish catch data from the remaining trips from the F/V Black Beauty were reported using Study Fleet, and similarly to trip 1 the mean monkfish discard to kept ratios by weight were low (Table 4; Appendix 2). This ratio was typically less than 0.4 for each haul, but occasionally was as high as 1.4 (Figure 3). Three of six reported fishing trips recorded monkfish discard to kept ratios less than 0.5 in all hauls, although in one trip 26% of hauls recorded ratios greater than 0.4.

The F/V Jennifer Emily completed only one trip comprising a total of 21 hauls in statistical area 51. Monkfish were measured by a sea sampler in nine hauls, and the average discard to kept ratio was by weight 0.19 +/- 0.04 individuals. This ratio ranged from 0.12 to 0.27 discarded monkfish

for each kept monkfish (Figure 4). Total catch weight from the measured hauls ranged from 332 lbs to 588 lbs. The average ratio of observed (recorded) to predicted monkfish weight per measured haul was 91.9% +/- 0.05 and the range was 82.2% to 96.5%. Two-sample Kolomorogov-Smirnov tests detected significant differences in the size composition of monkfish between all port samples (p-value <0.05)(Appendix 3).

Revised scope of work

NEFOP hauls – monkfish samples by weight

A total of 20 745 hauls across 9 statistical areas were included in the 2007 – 09 NEFOP data set (Table 2; Figure 6), although only 17 368 (83.7%) hauls were observed; the remainder of the hauls were categorized as "unobserved" meaning that sampling of discards was incomplete. A total of 11 260 (54.3%) hauls were observed with monkfish catch over the entire sampling period. The process of removing redundant data records in order to enumerate haul numbers in various categories isolated 11 258 hauls (99.99%).

Statistical areas 521 and 522 dominated haul numbers and accounted for 30.6% and 53.0% of all hauls respectively (Figure 6). By year, areas 521 and 522 respectively accounted for 17.6 – 37.6% and 46.7 – 60.5% of all hauls. Statistical areas 464, 465, 511, and 512 were sampled rarely compared to the remaining areas. Monkfish were caught in all observed statistical areas but not in all hauls. Over the entire three year period, monkfish were recorded in at least 50% of observed hauls in all statistical areas with the exception of areas 511 and 514 (Figure 7).

Just over 2.1 million pounds of monkfish were recorded by observers across all statistical areas (Table 5). Monkfish from statistical areas 515, 521, and 522 dominated the samples, and represented 17.5%, 25.5%, and 41.8% of total monkfish samples respectively. Monkfish landings from dedicated monkfish trips represented only 21.1% of the total monkfish sampled, but ranged from 8.5% to 80.0% of all monkfish sampled by statistical area. In most statistical areas the monkfish discard to kept ratio was higher during dedicated monkfish trips compared to ground fish trips, including areas 521 and 522. Monkfish weight per NEFOP haul averaged less than 100 lbs in statistical areas 514, 521, and 522, while in areas 464, 465, 513, and 515 this average was greater than 250 lbs (Figure 8).

Irrespective of the trip target, average haul duration was substantially longer when monkfish were the haul target compared to groundfish (Table 6). When monkfish were the trip target, monkfish haul duration was on average 10% longer than that for groundfish hauls, and there was little obvious difference in towing speed and fishing depth. When groundfish were the trip target, monkfish haul duration was on average 19% longer than that for groundfish hauls, and this difference was statistically significant (t-ratio = 7.84; df = 201; p-value<0.05). There was little difference in towing speed between monkfish hauls and groundfish hauls irrespective of trip target, although during dedicated groundfish trips mean towing speed was 0.22 knots greater than mean towing speed during monkfish trips. A t-test was not used to compare this difference because it was deemed operationally unimportant.

During dedicated groundfish trips the average depth of groundfish hauls was substantially less than that of monkfish hauls (Table 6; Figure 5). The fishing depth data for groundfish hauls was clearly bimodal, with two distinct preferred ranges of fishing depth, one less than 65 fathoms and the other greater.

NEFOP hauls – monkfish samples by length

With the exception of monkfish measured from statistical area 464, there was little difference in the mean length of all monkfish samples (including undersized individuals)(Table 7). The average length of Monkfish from statistical area 464 was at least 12 cm larger than the average length of monkfish from other areas. All comparisons of monkfish length frequency distributions from each statistical area were significantly different (p-value<0.05).

NEFOP hauls – monkfish discard to kept ratio

In each statistical area, observed monkfish discards from all hauls combined (irrespective of trip or haul target) did not exceed 16% of kept monkfish by weight (Figure 8). Discard weight was greatest in areas 464, 512, 513, and 515. By number monkfish discard to kept ratios ranged from 0.12 in statistical area 464 to 4.39 in statistical area 513 (Table 7). With the exception of statistical area 464, discarded monkfish by number exceeded kept monkfish by at least 38%, and in statistical areas 512 and 513 this increased to 378% and 439% respectively. Chi-squared comparison of discard to kept ratios by statistical area revealed three key trends. First, there was significantly (p-value<0.05) fewer discards in area 464 than all other sampled areas. Second, there was no significant difference (p-value>0.05) between areas 512 and 513 but these areas were significantly difference to all remaining areas. Three, aside from the two aforementioned trends all discard to kept ratios in each statistical area were significantly different from each other.

Chi-squared comparison of monkfish discard and kept ratios (by weight) per haul indicate no significant difference (p-value>0.05) between dedicated monkfish and groundfish trips in statistical areas 465, 515, and 522 (Figure 9). A significant difference (p-value<0.05) in this ratio was detected in all remaining statistical areas. Comparing these ratios during dedicated monkfish hauls and groundfish hauls (irrespective of trip designation), no significant difference (p-value>0.05) was detected in any statistical area except 522 (Figure 10). In all remaining areas a significantly lower weight of monkfish discards were reported in ground fishing hauls compared to monkfish hauls.

Study Fleet hauls

A total of 1, 169 hauls were sampled by fishermen involved in Study Fleet over the period 2007 - 09 across 6 statistical areas (Table 8; Figure 11). The process of removing redundant data records in order to enumerate haul numbers revealed 276 redundant records, which were removed from the data set of 1, 445 records. By monkfish weight, catches from statistical area 522 were typically several orders of magnitude greater than the remaining areas (Figure 11). Annual discard to kept ratios for each statistical area were typically less than 6%, and the maximum was 18% (274 lbs) from area 522. Monkfish weight per haul was typically around 100 lbs or less in each statistical area (all years combined), although in areas 522 and 464 this increased to 340 lbs and 550 lbs respectively (Figure 12). Monkfish discard to kept ratios were no more than 4% from any area.

Relatively few monkfish were measured for length as part of the Study Fleet program. Monkfish were measured from three statistical areas, but were dominated from statistical area 522 (Table 8). Monkfish discard to kept ratios ranged from 0.22 to 0.58 and were significant (p-value<0.05) between areas 522 and 561. Length frequency distributions (Figure 13) between statistical areas were not compared due to low catch numbers in areas 561 and 525.

Comparison of NEFOP and Study Fleet hauls

In terms of monkfish weight per haul, only statistical areas 464, 521, and 522 were common to both NEFOP and Study Fleet data sets, and the discard to kept ratios for monkfish were always substantially less in the Study Fleet data than in the NEFOP data irrespective of trip or haul targets.

The only statistical area common to both NEFOP and Study Fleet data in which monkfish lengths were measured was statistical area 522. The discard to kept ratio of the measured monkfish sample from this area (0.58) (Table 8) was substantially less than that from the NEFOP data (1.68) and chi-squared evaluation of these ratios indicated they were significantly different (p-value<0.05). The mean length of monkfish measured during Study Fleet hauls in this area was approximately 5 cm larger than that for NEFOP hauls.

Equipment

To date some of the equipment has already been utilized and played a pivotal role in several other research projects. The DST tags were loaned to the Northeast Groundfish Gear Conservation Engineering & Demonstration Network (GEARNET) to help monitor the influence of vertical profile and reduced mesh depth on gillnet selectivity and operational performance. An important objective of this project was to evaluate the relationship between these gear modifications on catch, and the tags were required to record gillnet height under varying operating conditions and enable comparison between different gillnet designs. This work was spearheaded by the New Hampshire Sea Grant program in collaboration with other GEARNET personnel and commercial fishermen.

The ruggedized laptop has been used in several research projects, including evaluation of a topless trawl that was part of another GEARNET project, and evaluation of a large-mesh, fine-diameter trawl study funded by the National Fish and Wildlife Foundation. In both instances netmind acoustic mensuration equipment was used to measure and compare trawl geometry, such as door spread and headline height, between control and experimental trawls, and this laptop served to record and store all netmind data in a format suitable for post-fieldwork analysis. Both projects were managed by GMRI in collaboration with other GEARNET personnel and commercial fishermen.

The underwater cameras have been used on multiple occasions to observe lobster behavior in a baited lobster trap. This work is a collaboration with a Portland-based lobster fisherman, is largely unfunded, and represents a willingness on the part of GMRI and the fisherman to collaborate and learn more about lobster behavior with a mind to generate ideas to improve catching efficiency and selectivity. We have also begun negotiating with the same fisherman regarding use of the cameras to observe the behavior of cusk as they are returned to the seabed after being hauled in a lobster trap. Cusk are an extremely data poor species yet currently under consideration for listing as an Endangered Species. A source of indirect fishing mortality of cusk is thought to be the effects of barotrauma from rapid ascent in a lobster trap. Our proposed camera work will explore the feasibility of returning cusk to the seabed inside a lobster trap based on the hypothesis that they may be able to exit the trap and survive. This is also an unfunded project and will therefore be modest in scope. The cameras are also earmarked for additional use in a GEARNET project, attached to sink gillnets to observe groundfish behavior to the fishing gear and their predation by seals. Seal predation is a major issue affecting the viability and profitability of the Cape Cod gillnet fishery, and cameras may provide qualitative data of this problem and stimulate new ideas for mitigating their impact on groundfish stocks.

Discussion

Original scope of work

The original scope of work in this project was beset with issues and problems from the onset. The official go-ahead from NMFS/NEFSC to proceed with FLNDRS data collection was expected in May or June, 2008. Unfortunately, official notification was not received until late November, by which time prime fishing opportunities had been lost. Furthermore, the overall mood of the fishing industry had darkened. Increasing uncertainty and concern over reduced groundfish DAS coupled with proposed moves to a catch share management program resulted in an enhanced groundswell of dissatisfaction with both management and research bodies. Another difficulty experienced was convincing fishermen to participate in the Study Fleet program. Many fishermen were uninterested in participation because of the additional time required to collect and enter data, and a perceived inability to understand and appreciate the importance of the Study Fleet program. This, combined with the aforementioned sentiment towards management and research, meant that we struggled to find willing project participants despite the best efforts of the projects' fishing industry consultant.

After securing the involvement of three boats, further problems were encountered. One boat dropped out after the initial training trip. The captain stated that he was not interested in participating given that FLNDRS data collection and VTR call-in was a burden on his time in addition to that required to complete his normal reporting using VTR paper logs. He commented that he would have remained interested if his Study Fleet data reporting could have been used as a substitute for the paper VTR rather than increasing his reporting requirements.

The amount of data collected during the port sampling component of this project had to be curtailed due to the significant amount of time required to collect all data elements that were originally proposed. As most of the monkfish to be sampled were also to be processed for sale, this altered the normal routine of the captain and crew fishermen at the end of the trip. Having spent up to 10 days at sea they did not welcome this change, despite limiting our data collection strategy to sample weight and monkfish lengths and the completion of sampling prior to commencement of unloading the catch. While the overall port side data collection protocol was feasible, it relied very heavily on the patience and goodwill of the captain and crew, and given the environment at that time they somewhat understandably had little enthusiasm for our efforts.

We also encountered a problem whereby GMRI sea samplers were at sea for periods substantially longer than planned or budgeted. Our original plan was for observed trips of about 4 days in duration. This was typical of trip duration during the proposed period of sampling, however, by the time we were able to commence this project fishing trip duration had substantially increased, and both sea samplers were at sea for 10 days each. This was unsustainable and significantly impacted on our field work for other GMRI projects, and after completion of two fishing trips we were unable to continue to dedicate staff to such lengthy periods without compromising the needs of other projects.

With so few fishermen involved in this project and difficulties dedicating staff to lengthy periods at sea, completion of the proposed number of observed trips was not possible and data from only 13 Study Fleet trips, 4 port samples were recorded. No randomly observed trips were completed. At this stage of the project it had become clear that events were conspiring to hamper our progress to an extent that project goals were not going to be accomplished satisfactorily. We then approached the NMFS/NEFSC regarding a proposed no-cost revision to the scope of work that promised to achieve almost all original project goals and objectives. This revision also included

plans to abandon the project workshop, primarily due to lack of industry interest in project outcomes.

Given the aforementioned issues, the results do not conclusively support any hypothesis about the fishery although they do permit two very general comments to be made, one of which has important implications for monkfish stocks. The first is that discard to kept ratios for monkfish by weight were with few exceptions not too different between the port and the sea samples, and between boats, despite considerable variation in this ratio. Some hauls did result in ratios well above 1.00, and while these should be a particular concern, there was no consistency in their occurrence by time or space that could allow consideration of remedial action. The second is the number of monkfish discards in some hauls was substantially larger than the number of kept monkfish. In one haul the number of discards exceeded the number of kept monkfish by 220%, and in others, where discard to kept ratios (by weight) exceeded 1.0, the number of undersized monkfish could have substantially exceeded this percentage. This result, although seemingly inconsistent in this study, should be cause for concern given it represents waste and a potential threat to stock health and viability of the fishery.

Revised scope of work

Based on the NEFOP data set there appeared to be a substantial difference in fishing behavior when groundfish were both the haul and trip target by fishing shallower and for less time compared to the remaining haul and trip target combinations. While the number of hauls reported for all other haul combinations was two orders of magnitude less than that for the groundfish haul and trip target combination, the results nonetheless suggest monkfish hauls are typically located in deeper water and extend over a substantially longer duration.

While the discard to kept ratios for monkfish are modest and reasonably consistent across most statistical areas, by weight some 172 000 lbs of monkfish discards were reported over three years in the NEFOP dataset (Table 5). The long term discard to kept for monkfish across the northern and southern management zones is 0.15 (NFSC, 2010), and is slightly higher to that reported in in this study. Based on length-weight estimations reported in Wigley et al. (2003) and Richards et al. (2007) these discards were estimated to represent more than 43 000 individual under-sized monkfish. While discard to kept ratios based on numbers of monkfish were highest in statistical areas 512 and 513 (Table 7), most undersized individuals were caught in areas 521 and 522 where fishing effort was substantially higher (Figure 6). Somewhat ironically, while greater monkfish catches per haul can be realized by avoiding areas 521 and 522, to do so also results in substantially higher discard weights (Figure 8). Thus at this scale these results do not lend support any notion regarding possible spatially-based management to reduce the incidence and magnitude of under-sized monkfish catches. Instead, they may be reflecting a need to explore gear-based options such as larger square-mesh codends during dedicated monkfish hauls and trips.

In almost all instances the average weight of monkfish per haul was greater when monkfish were the designated trip target and when they were the haul target. Such a result seems logical and testament to the ability of the fishermen to seek out monkfish when they are the designated target species. Interestingly though, given that statistical areas 521 and 522 dominated the data set and are adjacent one another, statistical evaluation of the ratio of discards to kept monkfish is inconsistent between these two areas. The weight of monkfish discards in area 521 was significantly less in groundfish hauls and trips than that for monkfish trips (Figure 9) and hauls (Figure 10), but no significant difference in monkfish discards was found between hauls or trips in area 521 irrespective of haul or trip designation. Why this difference exists is not known.

While the number of entries in the Study Fleet data set was relatively modest, reported catches of legal-size monkfish from statistical area 522 appeared similar to that for the same area reported in the NEFOP data set. This lends a degree of credibility to the Study Fleet program in terms of providing a useful data set to evaluate trends in the commercial catch by location, and will only improve as data is collected over a longer time period and with greater industry participation. This data set did, however, underestimate discard to kept ratios compared to the NEFOP data set, primarily because measuring the entire catch is not a key requirement of fishermen involved in Study Fleet. While the SMAST Study Fleet program invites fishermen to measure a sample of the catch, the incentive to do so is less than that for recording catch, effort, and positional information on computer and doing away with paper vessel trip reports. Remuneration to fishermen is required for this, but even this is at risk when it conflicts with their commercial focus, and so in the foreseeable future NEFOP will most likely remain the primary source of length-based catch data.

Data Issues

Data from NEFOP and Study Fleet program were received in excel spreadsheets containing the requested data fields (Table 1) and were imported into Microsoft Access database for organization and preparation of analysis. Additional data on the number of hauls was then requested from NEFOP (Table 2). As analysis progressed further data fields were requested to clarify data interpretation including Weight Type and Original Weight. The original data set only included a Weight data field which represented the initial measurement of a whole monkfish or a gutted or tail weight multiplied by a conversion factor to yield a whole monkfish weight. The dataset also contained monkfish liver weights. Currently there is no factor calculated to convert a liver weight to a whole weight, resulting in any liver measurements in the data set appearing as a zero value, but they were assumed to have been obtained from sampled monkfish that had been gutted or tailed. The additional requested data fields allowed us to see the order of operations of measurements and conversions, and clarify the zero values in the data set.

The data field of Observed/Unobserved hauls was also added to our database. Unobserved hauls were defined as those hauls that included incomplete discard data due to extenuating circumstances on the vessel or observer priority events (ie. marine mammal take). Contained within the dataset were records of unobserved hauls with kept monkfish only and records of unobserved hauls that contained both kept and discarded monkfish. As per the at-sea monitoring program manual (NMFS, 2011) no discard information is meant to be recorded other than for incidental takes of mammals, sea turtles, and sea birds, and other animals that require recording in an Individual Animal Log. Contrary to this instruction our dataset contained a small number of unobserved hauls with monkfish discard data. We therefore removed all so-called unobserved hauls from analysis irrespective of the presence of discarded monkfish because we had no way to determine if this record represented all discarded monkfish or not.

An additional complication was encountered when attempting to standardize kept and discarded monkfish by the number of hauls. The NEFOP data set had inherent variability with some hauls having only kept monkfish, some hauls having only discarded monkfish, and many having a mix of both. The corresponding data set lacked a standard entry per haul, i.e. if there were no kept monkfish on a given haul this is not entered as zero, but simply not recorded. This made counting the number of hauls in the data set difficult, without doing so manually, which was not feasible on such a large data set. In order to calculate a number of hauls we first identified the number of data records entered for each haul. This was done in Microsoft Access using a query to list all the

duplicate records in the data set for a given number of data fields. It was then assumed that if a record was identical in the data fields of Year, Trip Target, Depth, Tow Speed, Haul Duration, Haul Target, and Area that it was referring to a single haul. These duplicate records could then be counted and subtracted from the total number of records in the data set, yielding a number of hauls. Subtracting these duplicates proved to remove too many records, using the total number of observed hauls with monkfish catch as a guide. The next step was to get more specific in our search for duplicate records, adding the data fields of Fish Disposition Code and Weight Type to the aforementioned fields. This query returned 173 records that were identical in the nine data fields chosen, but referred to separate hauls, and were then added back to the total number of hauls. Unfortunately this process was not able to account for all the hauls in the data set, leaving us 2 short of the total (11,260). These records were apparently identical in all data fields but referred to separate hauls, so would have to be identified manually from the data set of approximately 20,000 records. Due to time and effort constraints it was decided that the identified number of hauls (99.99% of the total) would be sufficient for analysis.

While the NEFOP dataset was substantial and contained data from over 11,000 hauls, it still contained data that was clearly at odds with normal fishing practice and behavior. In a handful of hauls, for example, reported fishing depths were less than 10 fathoms and for others greater than 700 fathoms. These entries were rare[1], however their inclusion did cast some doubt over the accuracy of the remaining data – they were clearly a reporting error and indicative of a failure in the data validation process to identify and remove them from the dataset. This issue additionally points to a need for clear meta-data to ensure correct data analyses and interpretation using appropriate analytical techniques. In the above example it may be obvious to most that fishing for monkfish does not occur in these depths, while for those less familiar with the fishery this may not be the case, and such erroneous data may inadvertently be retained and used for analysis. Additional examples of the need for clear meta-data include the clarification of so-called unobserved hauls and the circumstances leading to this designation. Some of these hauls had both kept and discarded monkfish entries and others had just kept entries. It would have been somewhat understandable to retain hauls with kept and discarded entries for analysis in the belief that they represented the entire monkfish catch for that haul and that unobserved designation was due to problems elsewhere with data collection. It would also have been understandable to assume that unobserved hauls with entries for kept monkfish but no discards was the result of zero discards and not because they were not recorded. Clearly inconsistencies in data reporting can lead to inappropriate assumptions and incorrect data use, analysis, and interpretation. In this project clarification of the dataset was sought several times, and ultimately we were sufficiently satisfied to commence detailed analysis of the datasets. Such an approach, however, puts the responsibility on the recipient of secondhand data sets to question and query how the data were collected, entered, and validated. This may be the most expedient option for all but the recipient of the data, but it heightens the risk of unintentional data abuse and misinterpretation that could lead to incorrect or flawed conclusions.

The Study Fleet data set gave us a similar challenge when attempting to enumerate the number of hauls recorded. A majority of the data set contained only one record for each haul, listing both the kept and discarded monkfish weight, while some hauls had one record for discards and one record for kept catch. The Study Fleet data set had an individual number associated with each trip and haul, therefore isolating hauls with two records as opposed to one was more straightforward than with the NEFOP data set. A Microsoft Access query was designed to locate records that were identical in the data fields of trip number and haul number. This yielded 276 records that were subtracted from the original dataset to count the total number of hauls.

[1] Our analyses were based on the dataset with these hauls removed.

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Tables

Table 1: Specific data fields requested from NEFOP and Study Fleet programs.

a. NEFOP

table	field	criteria
trip	year	2007 – 2009
trip	target	monkfish, groundfish, flounder or specific groundfish species
haul	gear	bottom otter trawl, fish
haul	observed	yes or no
haul	depth	
haul	speed	
haul	duration	
haul	target	monkfish, groundfish, flounder or specific groundfish species
haul	end position	monkfish northern fishery management area
haul	statistical area	
species	species	monkfish or monkfish, tail
species	weight	
species	weight type	
species	disposition code	
species	type	gutted, livers, tails, whole
species	original weight	
length	species	monkfish
length	length	
length	frequency	
length	disposition code	

b. Study Fleet

table	field	criteria
trip	sail date	2007 - 2009
effort	gear	otter trawl, bottom
effort	depth	
effort	soak duration	
effort	haul start position	monkfish northern fishery management area
effort	area code	
catch	species	monkfish
catch	grade	
catch	hail amount	
catch	disposition	

Table 2: Number of NEFOP hauls by major category. Some hauls were "unobserved" due to incomplete collection of discard data, observer illness, or for safety reasons.

Year	Total hauls	# observed hauls	# hauls observed with monkfish
2007	6 803	5 772	4 023
2008	7 911	6 591	4 131
2009	6 031	5 005	3 106
Total	20 745	17 368	11 260

Table 3: Monkfish port catch details by sampling date for the F/V Jocka. D – discard; K – kept. Predicted catch weights are based on conversion factors in Wigley et al. 2003.

Date	Stat area	Measured catch				Predicted catch			
		Wt. (lbs)	Nos.	Mean length $\bar{x}\ (cm) \pm sd$	D:K (nos.)	Wt. (lbs)	Kept (K)	Discard (D)	D:K (lbs)
12/07/08	512	262	62	47.68 ± 13.32	0.61	296.1	233.1	63.1	0.27
01/14/09	515	306	47	54.89 ± 14.81	0.32	332.2	296.3	35.9	0.12
02/06/09	515	658	107	54.50 ± 11.29	0.15	686.1	569.1	117.0	0.21
04/01/09	515	244	192	33.55 ± 7.31	2.20	201.3	50.4	150.9	2.99

Table 4: Monkfish tail discard and kept details per fishing trip by boat and trip-end date, including mean and range of discard to kept ratios of monkfish per haul. Haul # represents number of hauls with kept monkfish tail records. D – discard; K – kept. Predicted catch weights are based on the application of conversion factors in Wigley et al. 2003 to individuals of each length class that were caught in each haul.

Boat	**Trip #**	**Date**	**Haul #**	**Stat area**	**Reported catch**					**Predicted catch**				
					K. (lbs)	**D (lbs)**	**D:K**	**Mean +/- sd**	**range**	**K. (lbs)**	**D (lbs)**	**D:K**	**Mean +/- sd**	**range**
F/V Black Beauty	1	01/27/09	26	514,515, 521	-	-	-	-	-	11468	1722	0.15	0.17 +/- 0.08	0.00 – 0.38
	2	02/03/09	12	514, 521	1000	215	0.22	0.42 +/- 0.38	0.07 – 1.00	-	-	-	-	-
	3	03/01/09	17	514, 521	1420	154	0.11	0.26 +/- 0.16	0.08 – 0.40	-	-	-	-	-
	4	03/10/09	26	514, 515, 521, 522	1598	552	0.35	0.41 +/- 0.41	0.00 – 1.43	-	-	-	-	-
	5	03/17/09	12	513, 514, 515, 521	976	160	0.16	0.17 +/- 0.13	0.00 – 0.50	-	-	-	-	-
	6	04/02/09	20	464, 515, 561	3395	368	0.11	0.17 +/- 0.33	0.00 – 1.40	-	-	-	-	-
	7	04/29/09	15	521, 522	131	-	-	-	-	-	-	-	-	-
F/V Jennifer & Emily	1	12/09/08	9	512	-	-	-	-	-	3943	729	0.18	0.19 +/- 0.04	0.12 – 0.27
F/V Jocka	1	12/06/08	1	512	-	-	-	-	-	233	63	0.27	-	0.27
	2	01/12/09	1	515	-	-	-	-	-	296	36	0.12	-	0.12
	3	02/06/09	1	515	-	-	-	-	-	569	53	0.09	-	0.09
	4	02/08/09	0	515, 521	3470	-	-	-	-	-	-	-	-	-
	5	03/29/09	1	515	-	-	-	-	-	151	50	0.33	-	2.99

Table 5: Monkfish catch (pounds) by fishing trip type and statistical area based on NEFOP data. D – discard; K – kept. P = proportion of monkfish caught in dedicated monkfish trips compared to total monkfish catch in each statistical area.

Stat area	**Trip type**	**Catch weight**				**P**
		Kept	**Discarded**	**Total**	**D:K**	
464	Ground fish	13 919.2	512.3	14 431.5	0.03	
	Monkfish	7509.84	2954.8	10 464.64	0.39	42.0
465	Ground fish	4 628.08	157.5	4 785.58	0.03	
	Monkfish	932.92	63.00	995.92	0.06	17.2
511	Ground fish	146.08	0.00	146.08	0.00	
	Monkfish	498.00	87.00	585.00	0.17	80.0
512	Ground fish	21 367.28	4 244.80	25 612.08	0.19	
	Monkfish	16 002.40	1 768.00	17 770.40	0.11	40.9
513	Ground fish	60 978.38	1 106.50	62 084.88	0.01	
	Monkfish	55 847.06	5 723.00	61 570.06	0.10	49.7
514	Ground fish	67 285.33	7 973.10	75 258.43	0.11	
	Monkfish	55 943.11	550.35	56 493.46	0.01	42.8
515	Ground fish	181 764.89	16 893.00	198 657.89	0.09	
	Monkfish	161 646.56	19 619.72	181 266.28	0.12	47.7
521	Ground fish	471 679.13	28 334.69	500 013.81	0.06	
	Monkfish	45 337.08	7 075.72	52 412.8	0.15	9.4
522	Ground fish	774 955.58	53 971.32	828 926.90	0.06	
	Monkfish	71 270.30	6 394.36	77 664.66	0.08	8.5
Total	**Ground fish**	**1 596 723.95**	**113 173.21**	**1 709 897.16**	**0.07**	
	Monkfish	**414 987.27**	**44 235.95**	**459 223.22**	**0.10**	**21.1**

Table 6: Fishing trip information including designation of target species from NEFOP (only observed and unobserved hauls with monkfish) and Study Fleet data.

Data source	Trip Target	Haul Target	# of Hauls	Duration +/- sd (hours)	Speed +/- sd (knots)	Depth +/- sd (fathoms)
NEFOP	Monkfish	Monkfish	103	5.94 +/- 1.88	2.84 +/- 0.15	106.94 +/- 19.43
	Monkfish	Groundfish	939	5.38 +/- 1.79	2.83 +/- 0.23	107.31 +/- 28.13
		Combined	***1042***	***5.43 +/- 1.81***	***2.83 +/- 0.22***	***107.27 +/- 27.38***
	Not specified	Monkfish	300	5.22 +/- 1.72	2.92 +/- 0.22	102.44 +/- 27.72
	Groundfish	Monkfish	197	4.86 +/- 1.60	2.96 +/- 0.24	100.08 +/- 26.83
	Groundfish	Groundfish	10952	4.01 +/- 1.60	3.01 +/- 0.29	78.71 +/- 34.08
		Combined	***11149***	***4.02 +/- 1.60***	***3.01 +/- 0.29***	***79.10 +/- 34.08***
	Not specified	Groundfish	11891	4.12 +/- 1.65	3.00 +/- 0.29	81.00 +/- 34.52
S. Fleet	Groundfish		1169	3.69 +/- 1.01	-	78.47 +/- 34.90

Table 7: NEFOP monkfish length frequency data for each statistical area and chi-squared (χ2) output comparing discard to kept ratios between statistical areas by number. D – discard; K – kept. s = significant difference between statistical areas (*p*-value < 0.05).

Reference stat area	**Nos.**	**Mean length** $\bar{x}\ (cm) \pm sd$	**Discards (nos.)**	**Kept (nos.)**	**D:K (nos.)**	χ^2 **comparison by stat area**						
						511	**512**	**513**	**514**	**515**	**521**	**522**
464	591	55.40 ± 10.91	62	529	0.12	s[1]	s[2]	s[2]	s[2]	s[2]	s[2]	s[2]
511	152	43.03 ± 07.89	88	64	1.38		s[2]	s[2]	s[2]	s[2]	ns	ns
512	1201	38.88 ± 10.29	950	251	3.78			ns	s[3]	s[3]	s[3]	s[3]
513	4035	37.05 ± 11.19	3287	748	4.39				s[3]	s[3]	s[3]	s[3]
514	4597	39.79 ± 12.40	3342	1255	2.66					s[3]	s[3]	s[3]
515	8894	41.97 ± 11.89	6262	2632	2.38						s[3]	s[3]
521	16493	42.53 ± 14.89	10377	6121	1.69							s[2]
522	28682	41.64 ± 12.03	18595	10089	1.84							

1 = higher than expected discards in area 511;
2 = higher than expected kept monkfish in reference area;
3 = lower than expected kept monkfish in reference area

Table 8: Study Fleet monkfish length frequency data for each statistical area and chi-squared ($\chi 2$) output comparing discard to kept ratios between statistical areas by number. D – discard; K – kept. s = significant difference between statistical areas (*p*-value < 0.05).

Reference stat area	**Nos.**	**Mean length** $\bar{x}\ (cm) \pm sd$	**Discards (nos.)**	**Kept (nos.)**	**D:K (nos.)**	χ^2 **comparison by stat area**
						522
561	96	52.55 ± 10.42	17	79	0.22	s[1]
525	33	60.61 ± 8.82	0	33	-	-
522	377	46.01 ± 10.20	139	238	0.58	

1 = lower than expected discarded monkfish in reference area

Figures.

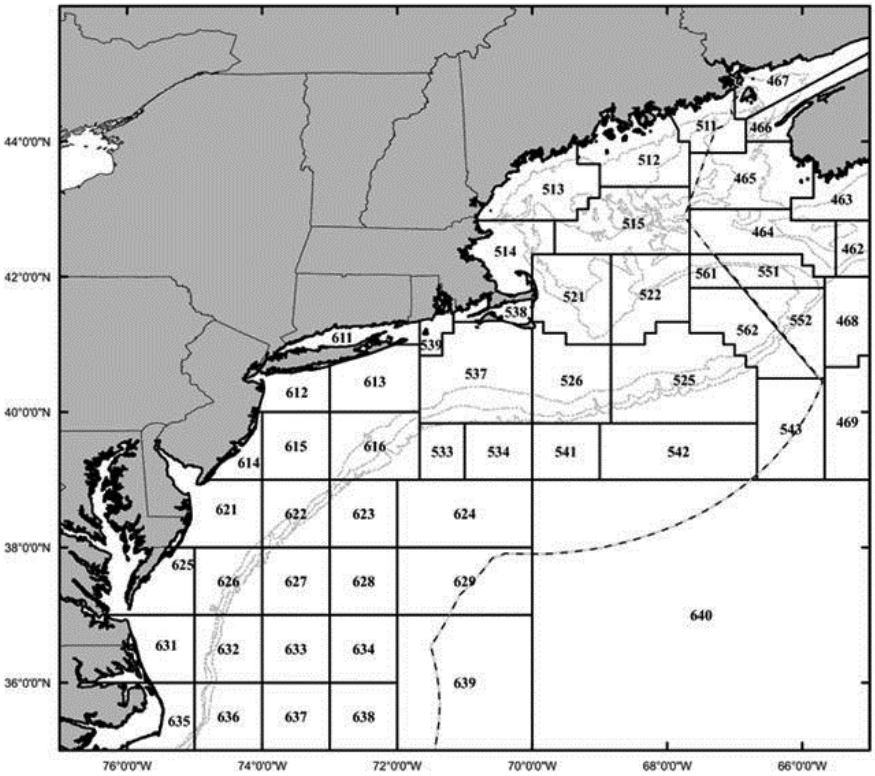


Figure 1: NEFMC Statistical areas for data collection in the Northeast region.

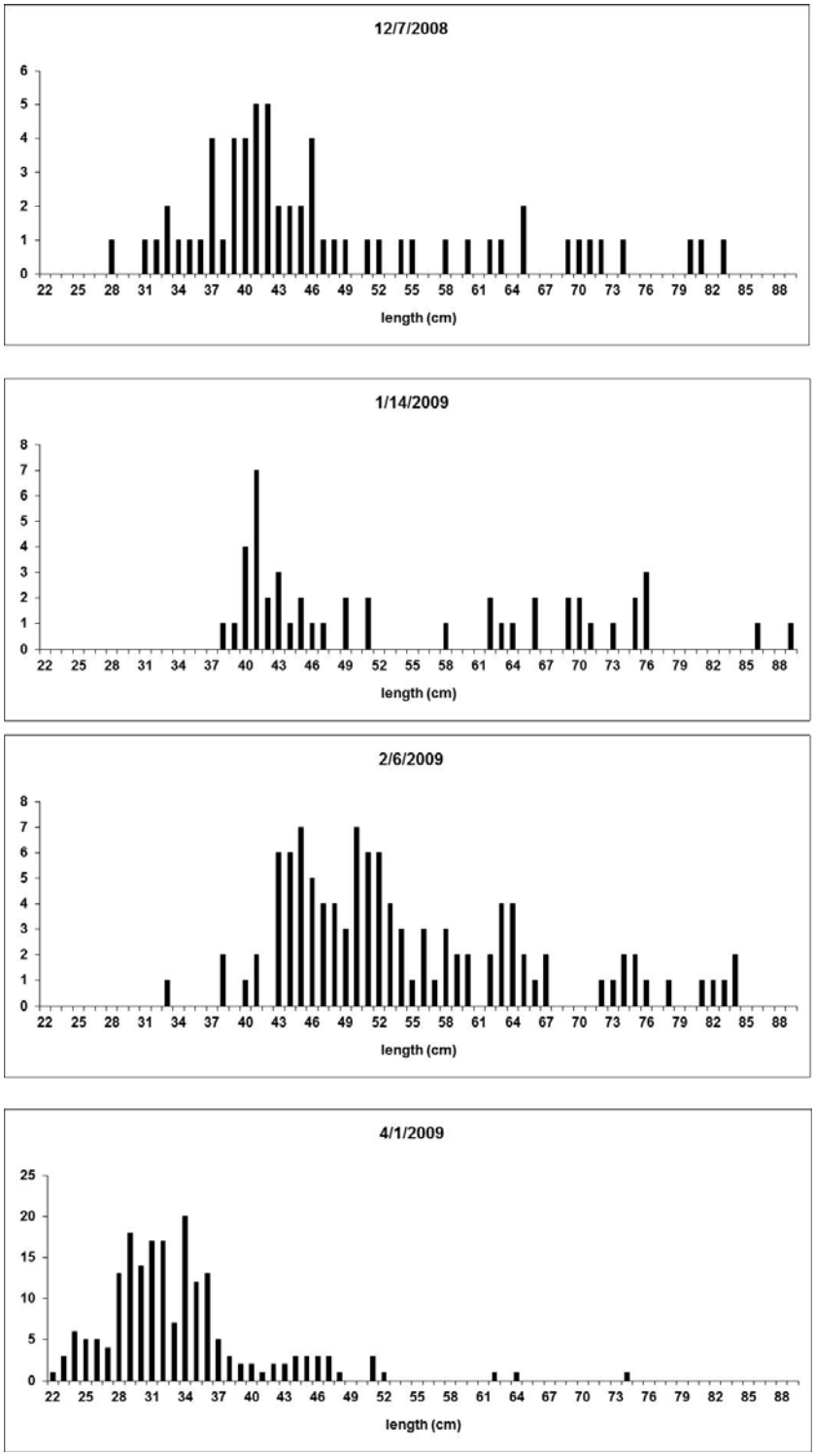


Figure 2: Monkfish length-frequency charts based on port sampling of last haul of four F/V Jocka fishing trips. Minimum landing size is 43.2 cm (17 inches).

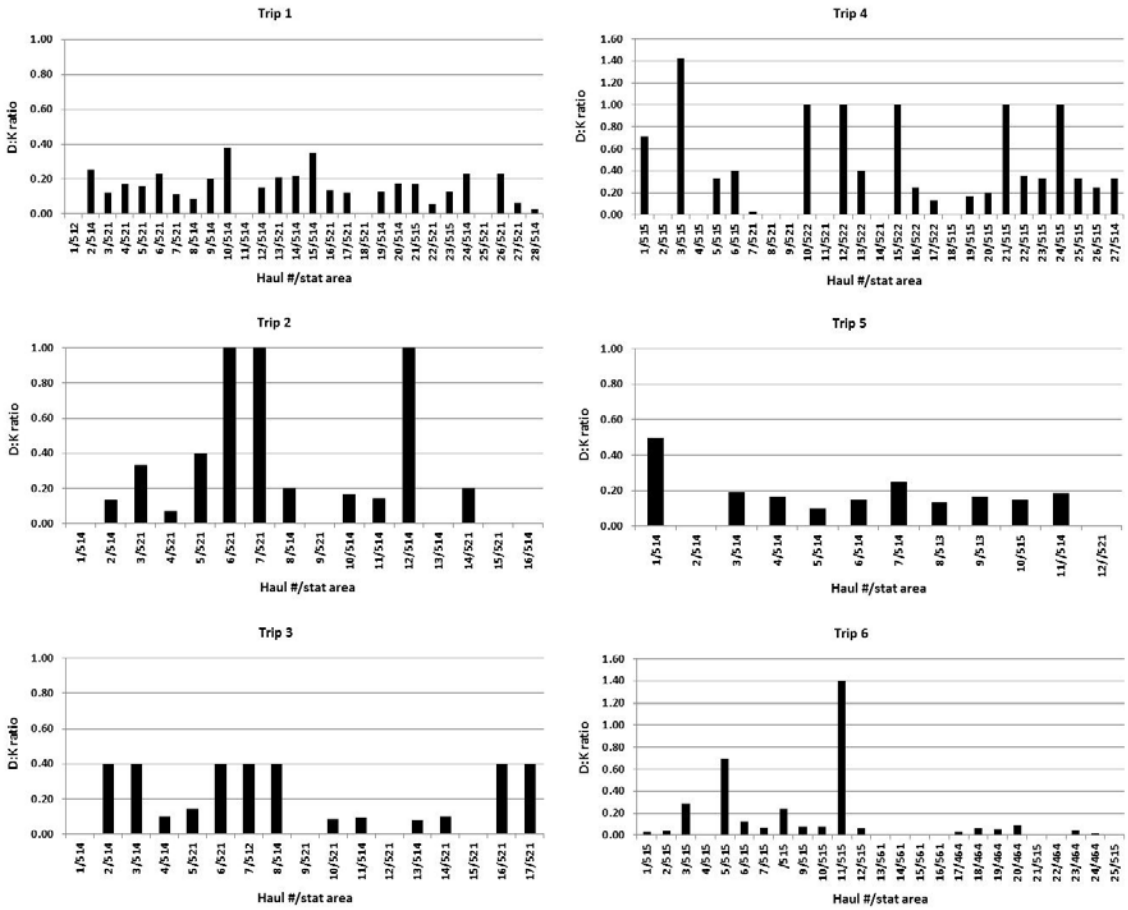


Figure 3: Monkfish discard to kept (D:K) ratios by weight for all hauls and statistical areas from the F/V Black Beauty. Hauls with no D:K ratio indicate the absence of monkfish in the catch or only kept monkfish were reported.

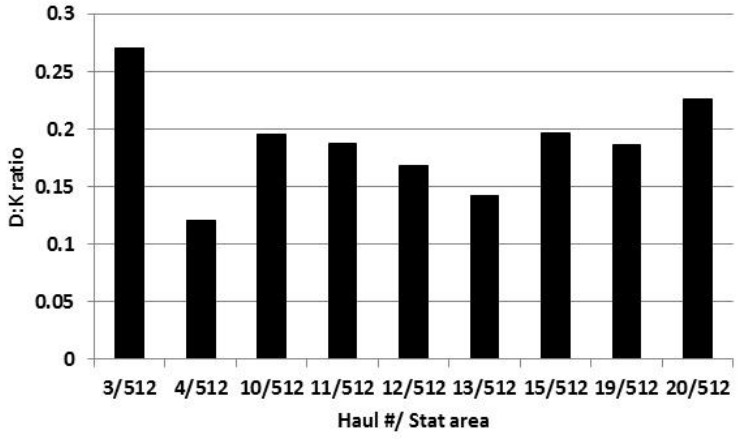
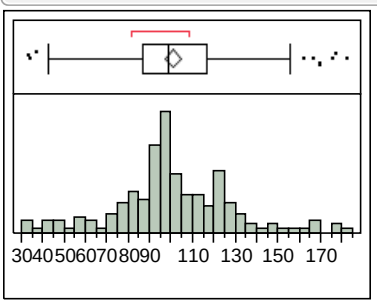


Figure 4: Monkfish discard to kept ratios by weight by haul and statistical area from the F/V Jennifer & Emily.

Monkfish haul



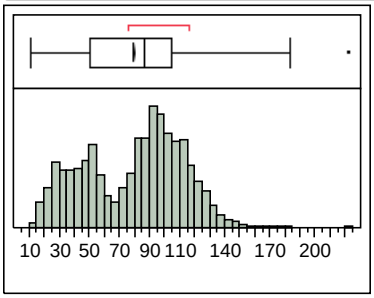
Quantiles

100.0%	maximum	182
99.5%		182
97.5%		169
90.0%		129.3
75.0%	quartile	116
50.0%	median	98
25.0%	quartile	86
10.0%		70.4
2.5%		41.625
0.5%		31
0.0%	minimum	31

Moments

Mean	100.08163
Std Dev	26.834411
Std Err Mean	1.9167436
Upper 95% Mean	103.86184
Lower 95% Mean	96.301423
N	196
Sum Wgt	196
Sum	19616
Variance	720.08561
Skewness	0.1966843
Kurtosis	1.1054039
CV	26.812523
N Missing	10733

Groundfish haul



Quantiles

100.0%	maximum	222
99.5%		146
97.5%		131
90.0%		117
75.0%	quartile	104
50.0%	median	86
25.0%	quartile	50
10.0%		31
2.5%		21
0.5%		16
0.0%	minimum	10

Moments

Mean	78.657369
Std Dev	32.315872
Std Err Mean	0.3121178
Upper 95% Mean	79.269178
Lower 95% Mean	78.045561
N	10720
Sum Wgt	10720
Sum	843207
Variance	1044.3156
Skewness	-0.199508
Kurtosis	-0.931883
CV	41.084353
N Missing	209

Figure 5: Frequency of fishing depth for monkfish hauls (upper) and groundfish hauls (lower) when groundfish were the trip target (hauls less than 10 ftm and greater than 220 ftm removed).

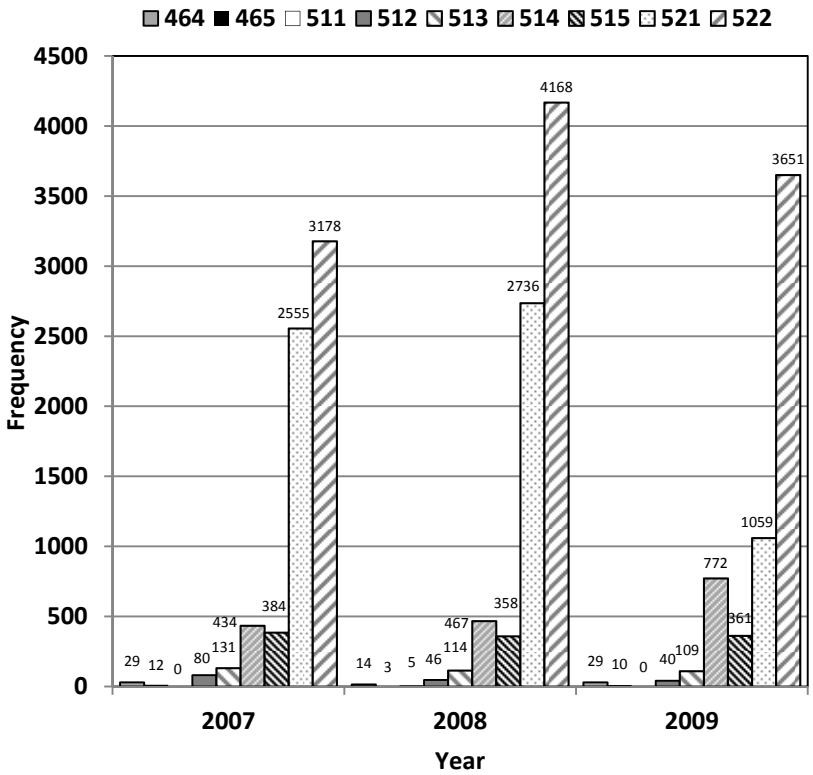


Figure 6: All NEFOP recorded hauls (observed + unobserved = 20 745 hauls) by statistical area, with number of hauls in each area indicated.

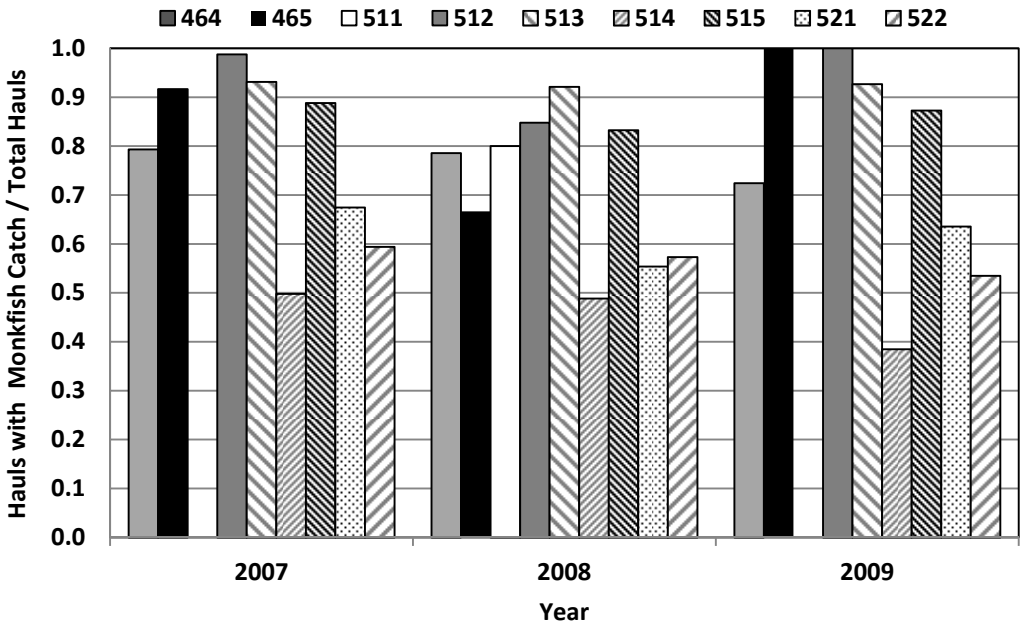


Figure 7: Proportion of all NEFOP recorded hauls (20 745 in total) with monkfish by statistical area.

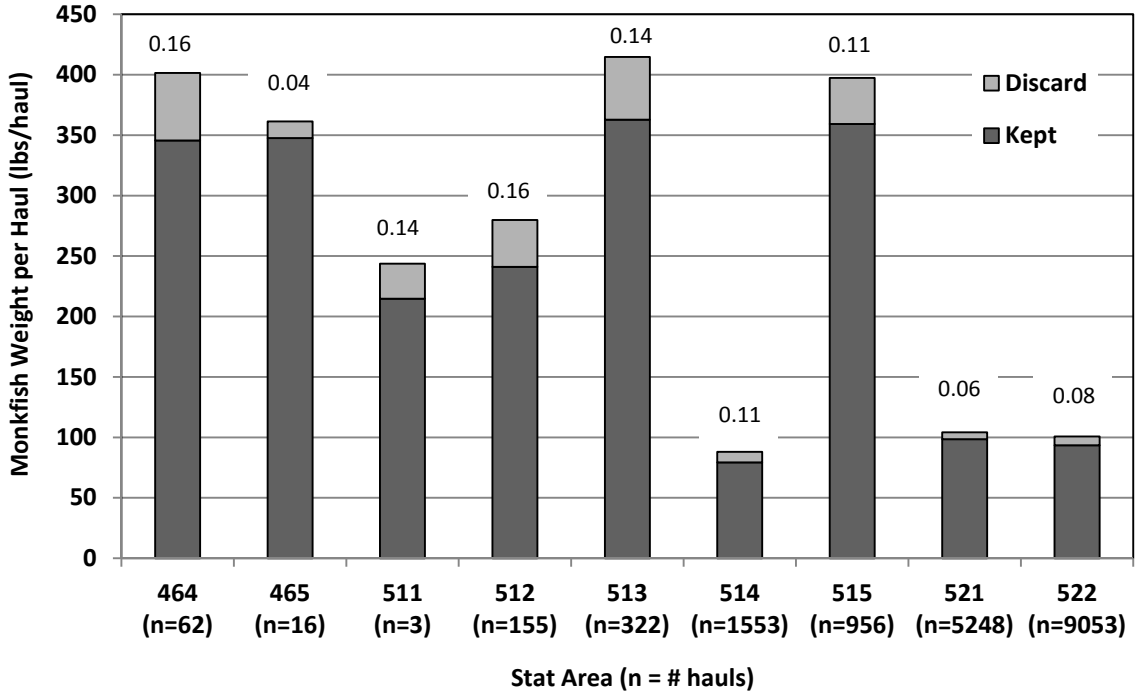


Figure 8: Monkfish weight per observed NEFOP haul (17 368 in total) and discard to kept ratio by weight by statistical area.

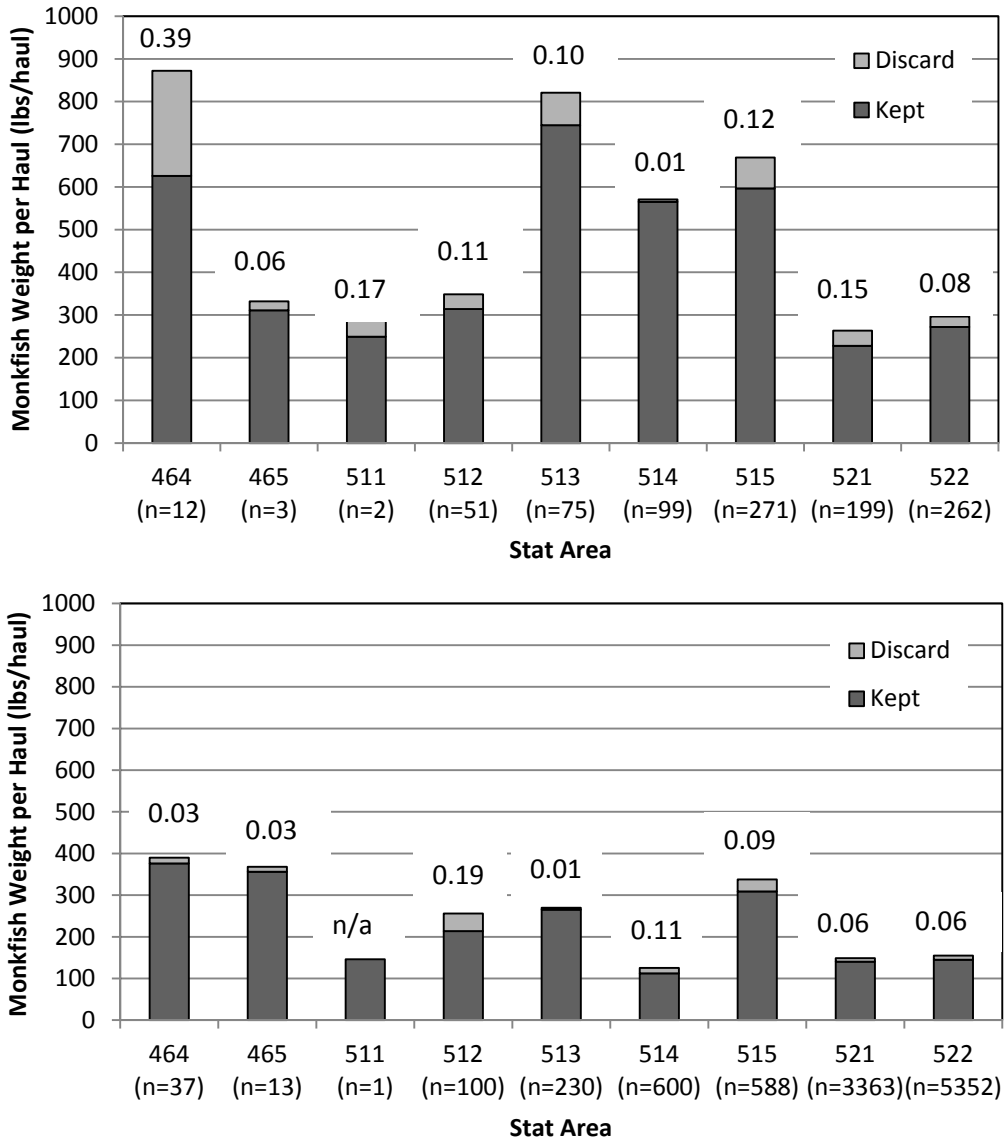


Figure 9: NEFOP kept and discard monkfish weight per haul by statistical area during dedicated monkfish trips (upper) and groundfish trips (lower), irrespective of haul designation. Discard to kept ratios for each statistical area also shown.

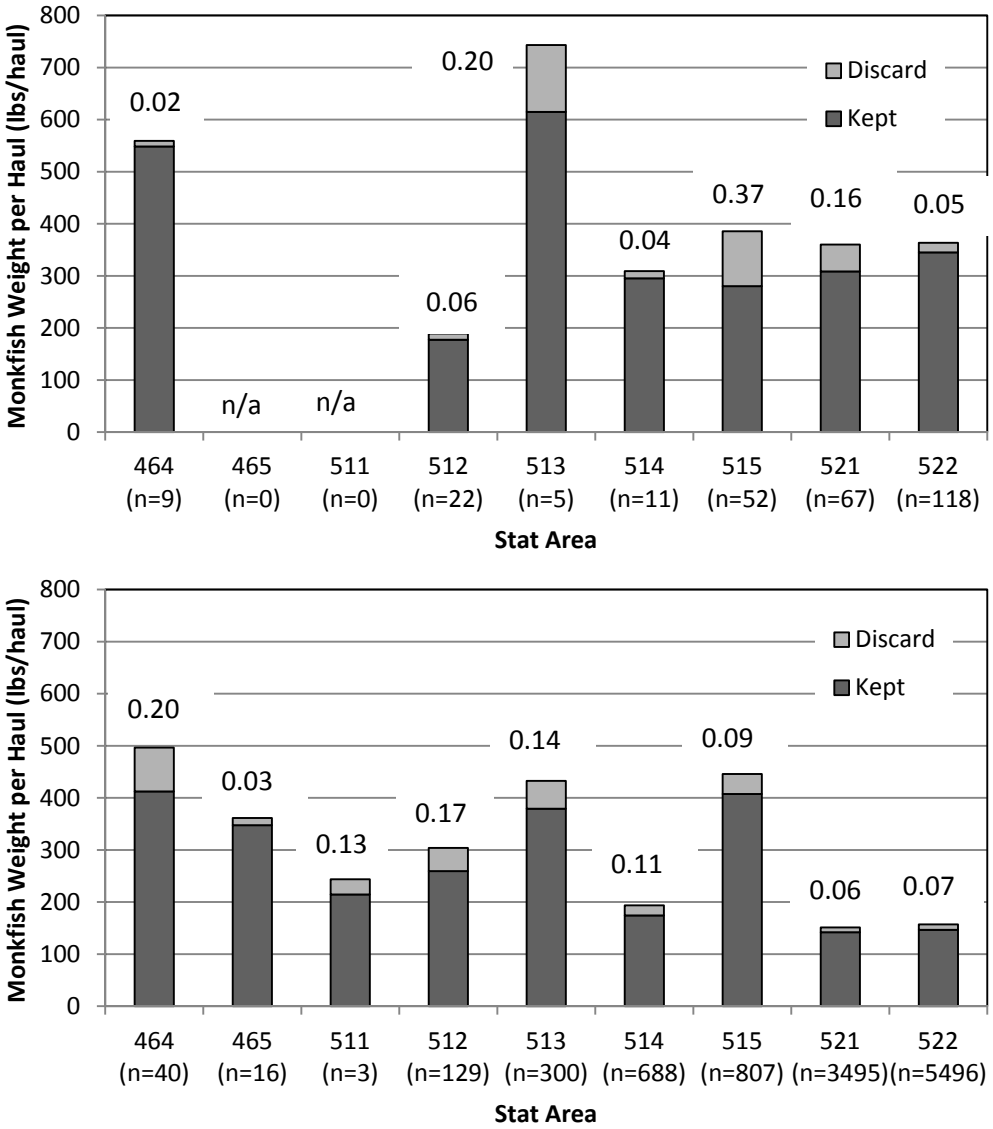


Figure 10: NEFOP discard and kept monkfish weight per haul by statistical area during dedicated monkfish hauls (upper) and groundfish hauls (lower), irrespective of trip designation. Discard to kept ratios for each statistical area also shown.

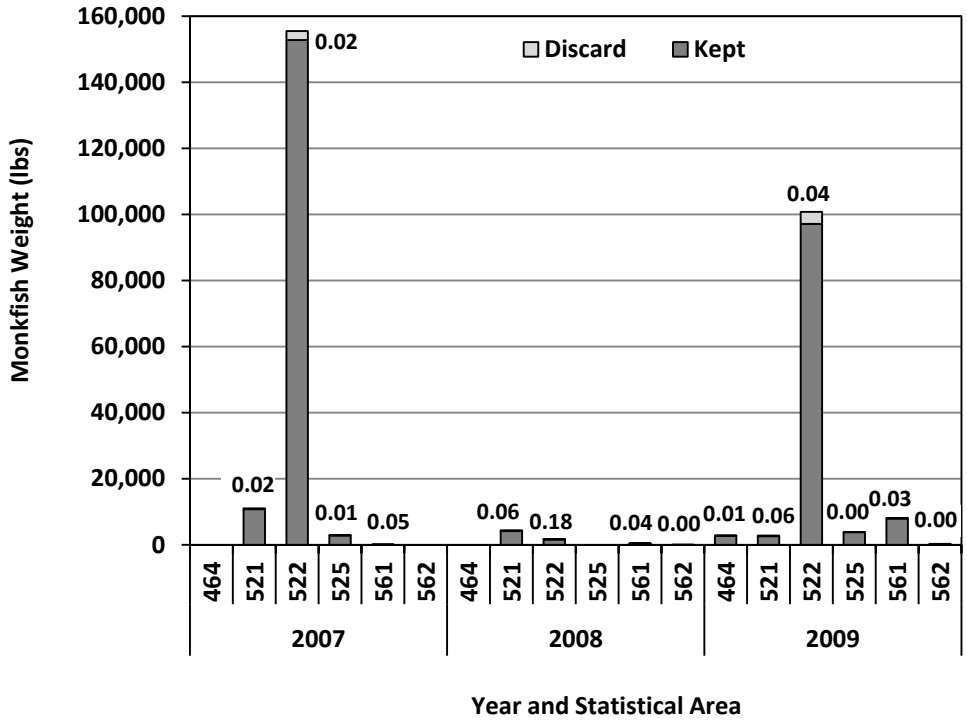


Figure 11: Study Fleet monkfish weight and discard to kept ratios by weight by statistical area and year.

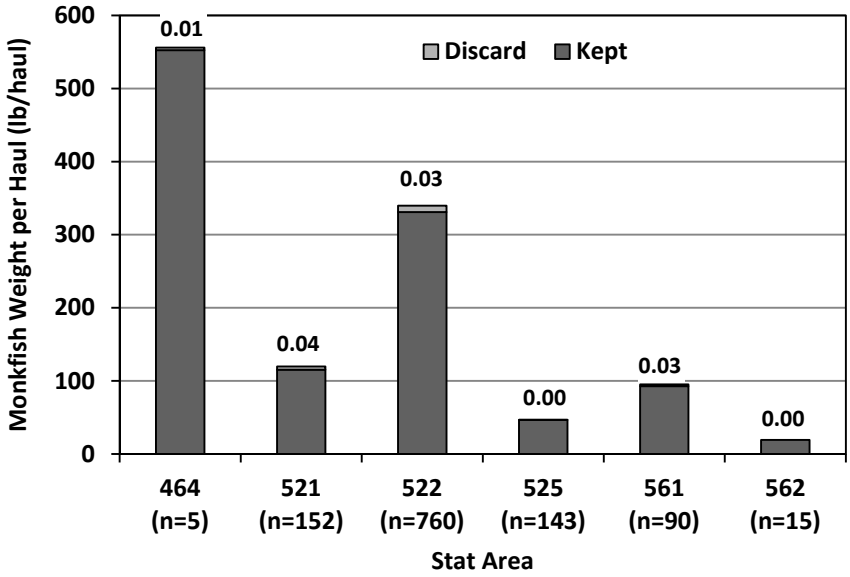


Figure 12: Study Fleet monkfish weight per haul and discard to kept ratios by weight by statistical area (2007 – 09).

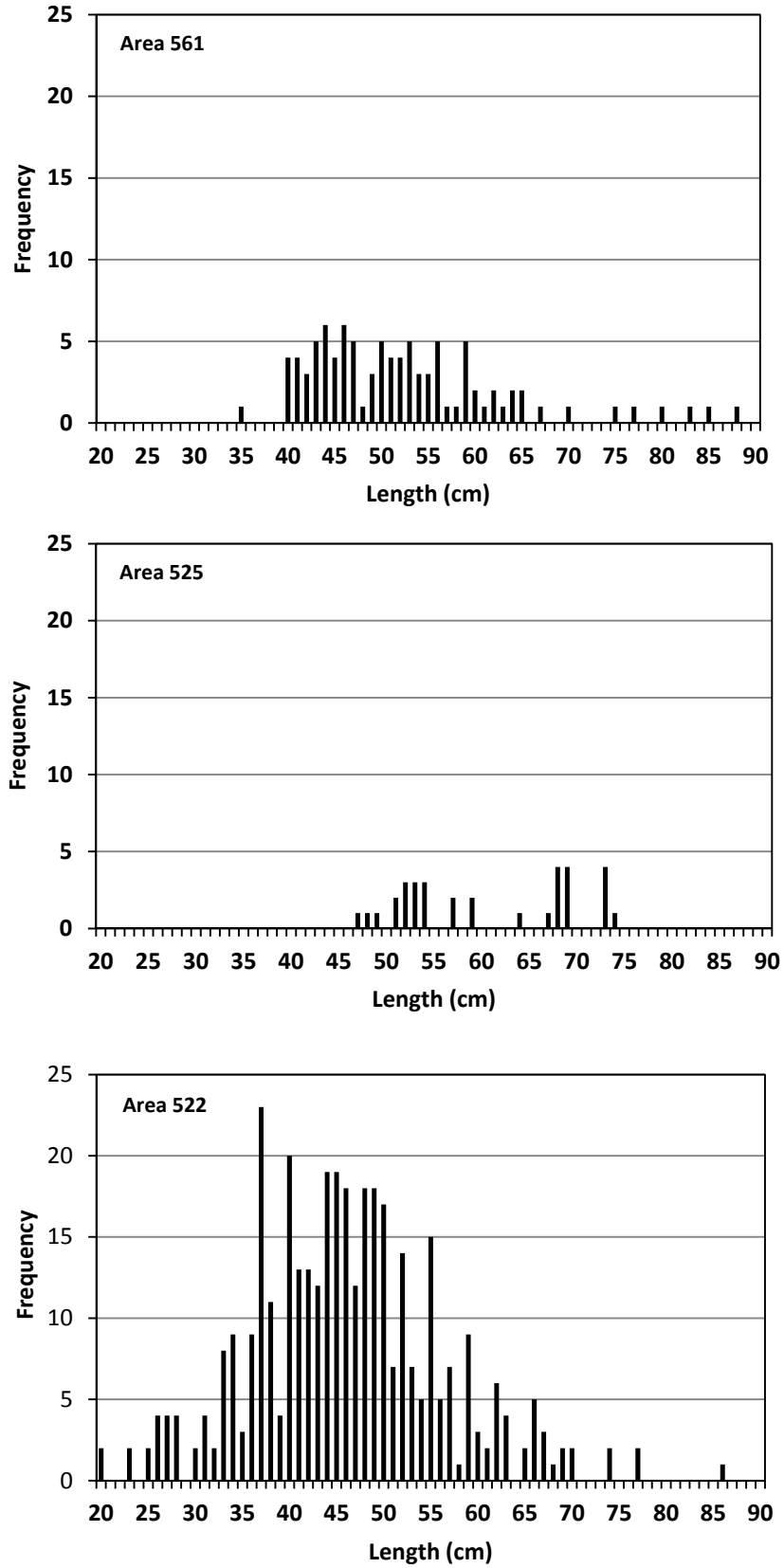


Figure 13: Study Fleet monkfish length frequency distributions by statistical area.

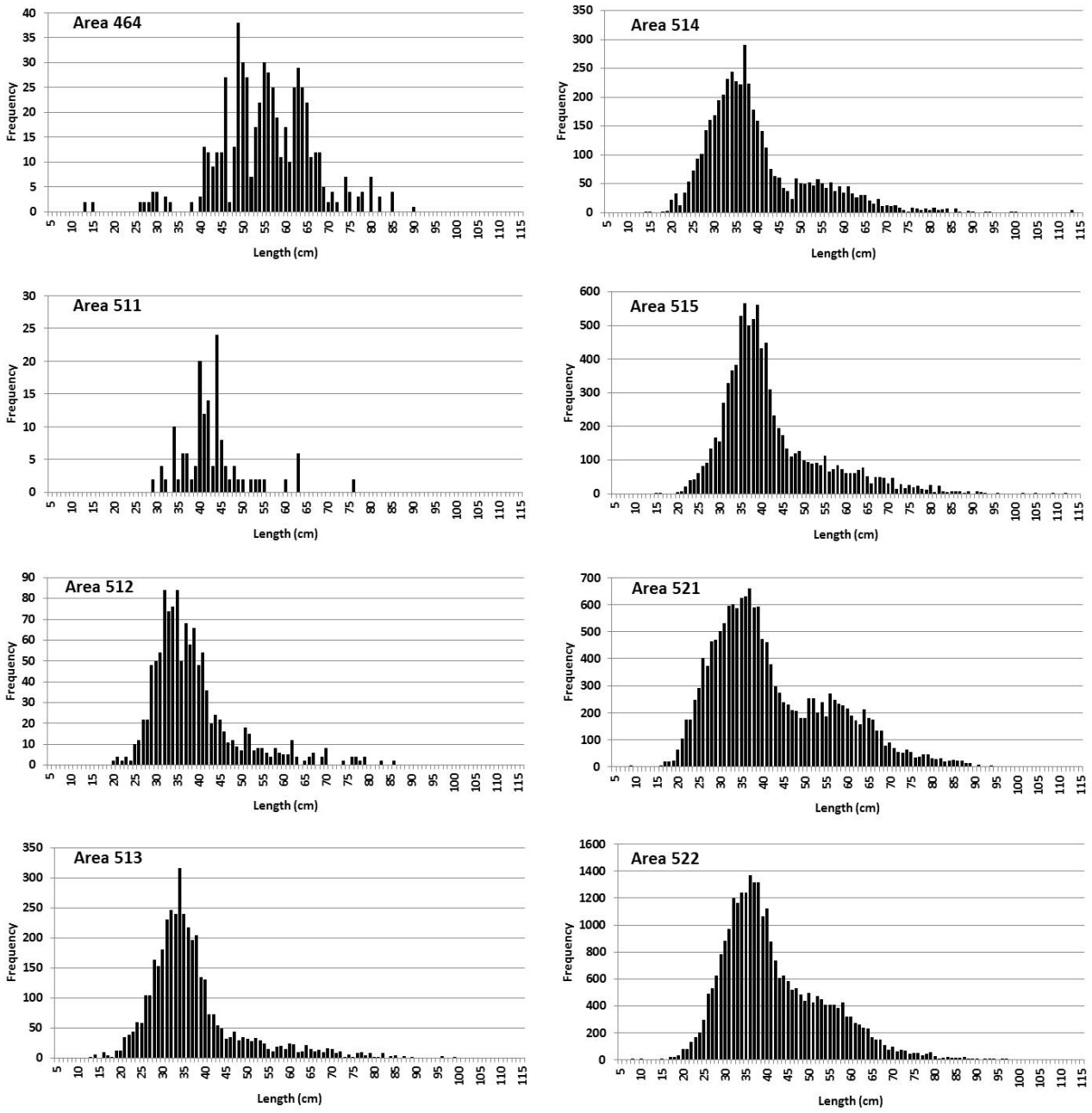
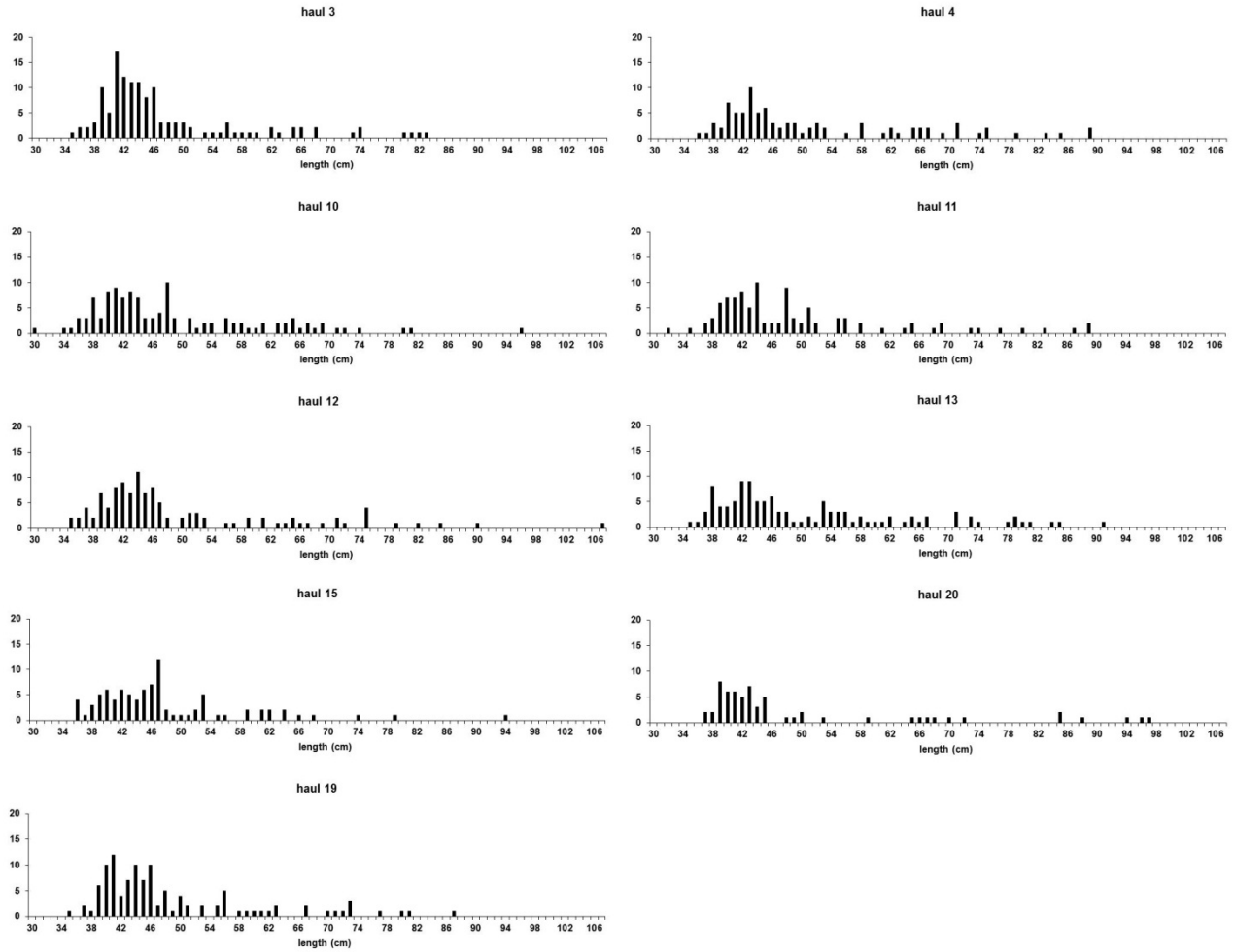
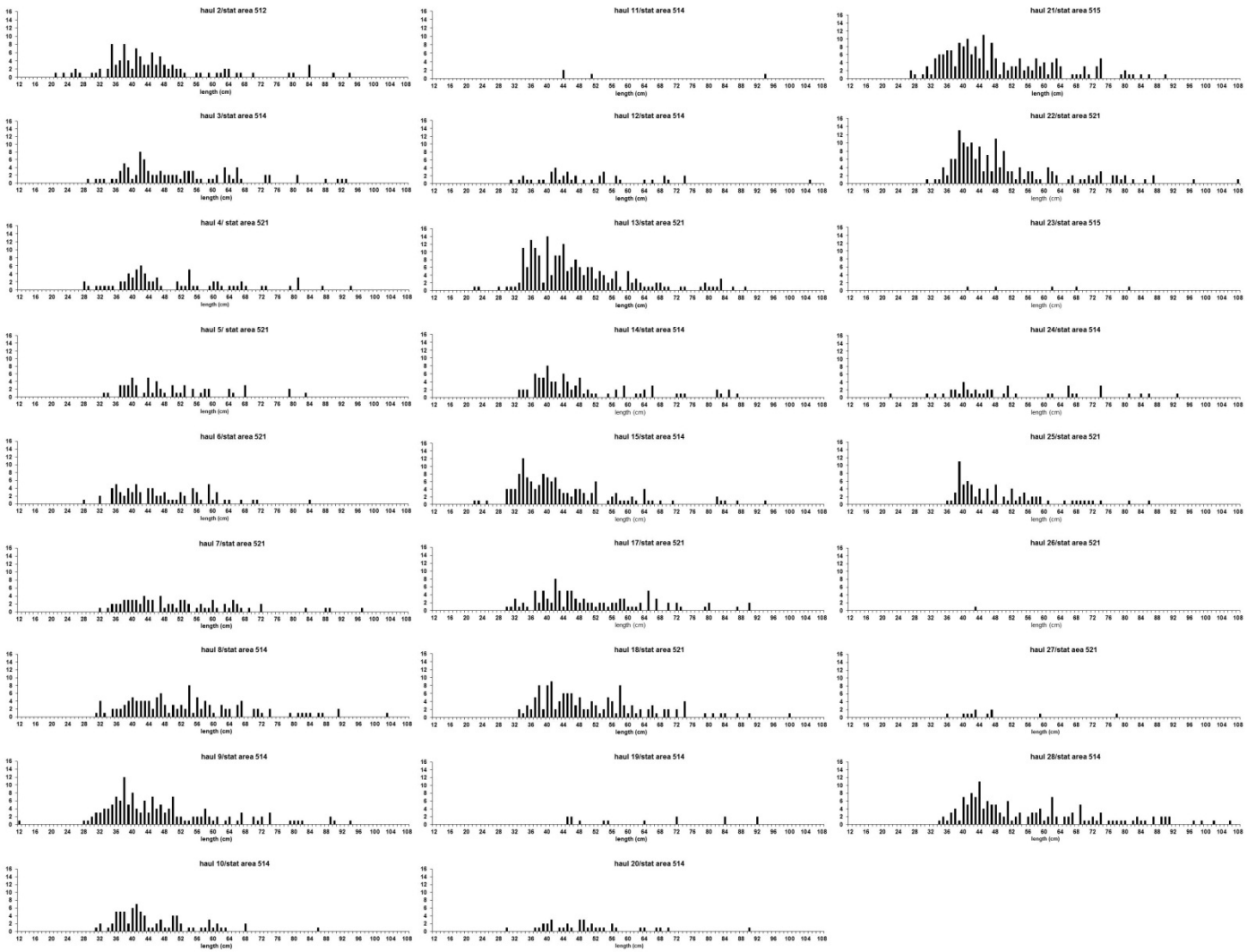


Figure 14: NEFOP monkfish length frequency distributions by statistical area.

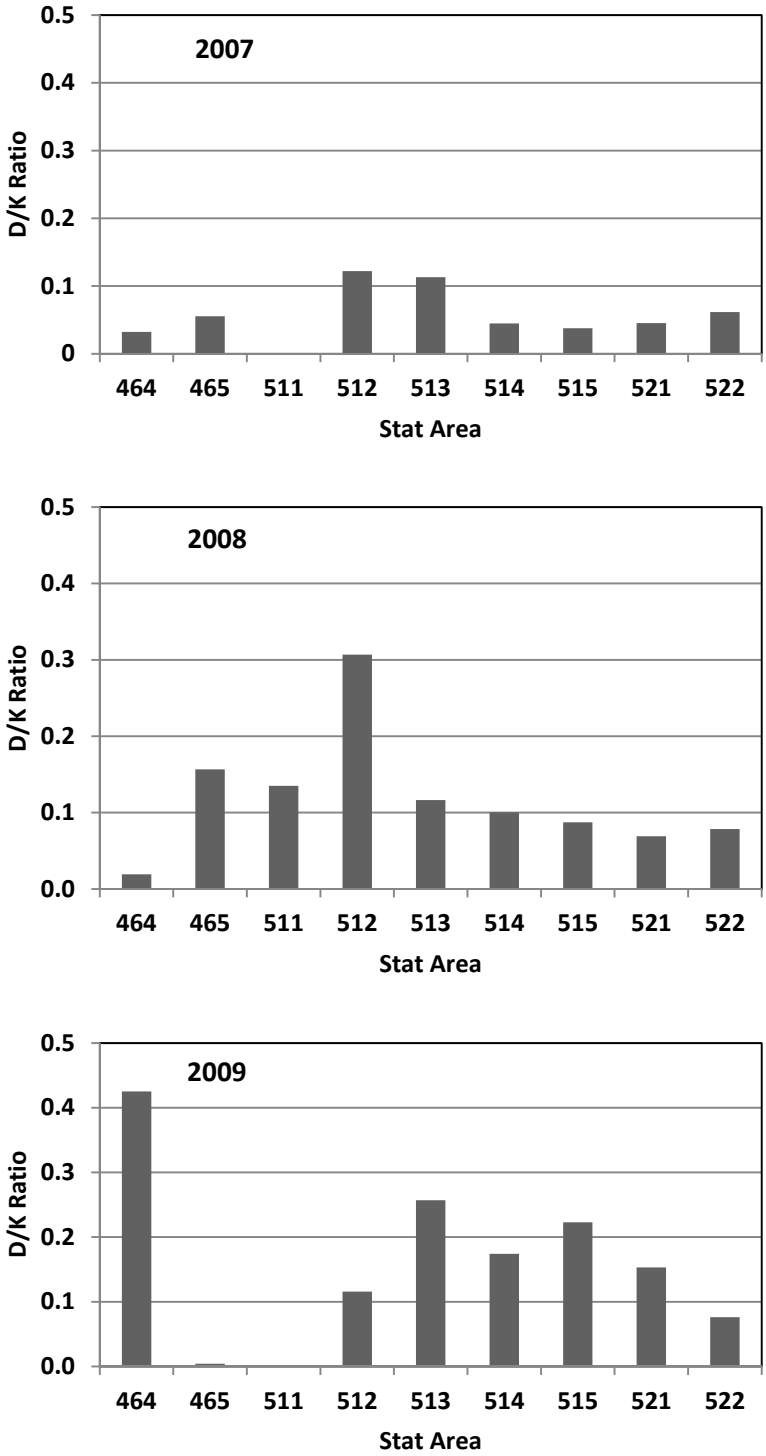
Appendices



Appendix 1: Length-frequency distribution of all monkfish caught from 1 trip onboard the F/V Jennifer & Emily. All hauls were located in statistical area 512.



Appendix 2: Length-frequency distribution of all monkfish caught from 1 trip onboard the F/V Black Beauty trip.



Appendix 3: NEFOP monkfish discard to kept ratios by statistical area and year.