The School for Marine Science and Technology

The High-Resolution Industry-Based Trawl Survey Data Report

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by

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ABSTRACT

The High-Resolution Trawl Survey project was established in November 2000 as a collaboration between the New Bedford Massachusetts commercial fishing industry and the School for Marine Science and Technology (SMAST) of the University of Massachusetts Dartmouth. A major incentive for the project was to recognize the desire of the commercial fishing community to participate more directly in the management of the resource. The primary focus of the project has been to create an industry-based program for the collection of trawl catch and environmental data suitable for use by researchers and fisheries managers. Project goals included: 1) to obtain fisheries data with higher spatial and temporal resolution than that available through industry independent surveys, 2) to involve industry in collection of fisheries data and management of resources, 3) to develop methods for training commercial fishermen to record scientifically acceptable data during normal fishing operations, 4) to demonstrate the feasibility of a cooperative project between the fishing fleet and scientists, and 5) to characterize the effects of environmental conditions and fishing operations on spatial and temporal patterns in catch statistics. The purpose of this report is to provide an overview of the data generated by this project. We present a brief summary of the raw data and set the stage for more comprehensive reports on factors affecting catch per unit effort (CPUE) for total, kept and discarded catch components.

Environmental, fishing effort, and catch data were collected from 20 vessels from the New Bedford fleet of trawlers that fish primarily on Georges Bank. Fishermen were trained to record catch and environmental data as part of their normal fishing operations, using methods modeled after the NMFS Observer Program. Data were collected from November 2000-October 2001, and again from August 2002-July 2004. During these periods, data were collected from a total of 221 fishing trips and 8,421 individual trawl tows. Catch data were recorded from 7,911 trawl tows from 209 trips. A total sampling effort of 1,552 days at sea and 23,247 hours of trawling resulted in the capture of over 12 million lbs of fish, of which 8.7 million lbs were kept and 3.8 million lbs were discarded. Fourteen species or species groups were targeted by the fishermen, with multispecies groundfish, monkfish, Atlantic cod, winter flounder, monkfish, haddock and yellowtail accounting for 95% of the effort. The catch composition consisted of 51 species/species groups, with skates, monkfish, Atlantic cod, haddock and winter flounder predominant. In this report we describe variations in the catch, fishing gear characteristics and trawling operations among vessels, gear types, seasons, and target species.

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INTRODUCTION

The High-Resolution Trawl Survey project was established in November 2000 with a grant from the NOAA Cooperative Research Partners Initiative Program as a collaboration between the New Bedford Massachusetts commercial fishing industry and the School for Marine Science and Technology (SMAST) of the University of Massachusetts Dartmouth. One of the major incentives for the project was to recognize the desire of the commercial fishing community to participate more directly in the management of the resource. The primary focus of the project has been to create an industry-based program for the collection of trawl catch and environmental data suitable for use by researchers and fisheries managers. The design and implementation of the project relied on the ability of SMAST researchers to design a data collection system that made sense to fishermen and produced scientifically sound data. Goals of the project included:

- to obtain fisheries data with higher spatial and temporal resolution than available through industry-independent surveys;
- to involve industry in collection of fisheries data and management of resources;
- to develop methods for training commercial fishermen to record scientifically acceptable data during normal fishing operations;
- to demonstrate the feasibility of a cooperative project between the fishing fleet and scientists;
- to characterize the effects of environmental conditions and fishing operations on spatial and temporal patterns in catch statistics.

The purpose of this report is to provide a brief summary of the raw data and set the stage for more comprehensive reports on factors affecting catch per unit effort (CPUE) for total catch, kept catch and discarded catch, by species and all species aggregations. In addition, we summarize data generated by this project on the fishing practices of the New Bedford fleet, including fishing operations data and gear used.

MATERIALS AND METHODS

The data collection goal of the project was to record fishing data for individual tows made during normal fishing operations for commercial trawlers operating on Georges Bank. Fishing data included catch, vessel, fishing

operations, and environmental. The work has been in collaboration with 20 vessels from the New Bedford fleet of trawlers that fish primarily on Georges Bank (Table 1). Trawl data collections began in November 2000 and continued for a period of 12 months until temporarily stopping after October 2001. After a six- month gap (November 2001-July 2002), sampling resumed in August 2002 and continued through July 2004.

It is important to note that the participating vessels operate under a standard commercial fishing regime; they follow all normal regulations and receive no special research permits. The captains choose the methods, gear, location, and time of each trawl, based on their personal knowledge and commercial considerations. While vessels that participate in the project are paid $300/day to collect the required data, their primary role at sea is to catch fish. The vessel captains oversee data-logging activities by the crew, and are important participants in the data collection effort. SMAST researchers provide information and guidance on sampling techniques, log keeping, and observed results, and oversee the quality of the information returned. The returned log sheets and electronic sensors are processed by SMAST technicians using the methods described in a separate report[1]. Since the fishing locations and catch quantity are implicitly sensitive information among economically competing commercial vendors, data availability is controlled during the processing cycle and stored on computers to which access is restricted. Except for a list of participating vessels (Table 1), vessel and captain identities are "blinded" in all data sets and reports produced by this project to preserve the confidentiality of vessel operations.

Fishing Boats

The participating New Bedford fishing vessels are groundfish trawlers that traditionally target cod and haddock during the spring and summer and flatfish during winter months (Table 1). The participating vessels' primary fishing grounds extend from Nantucket Shoals through Great South Channel across Georges Bank. In early October 2000, vessels associated with the New Bedford Trawler Survival Fund (TSF) began to work collaboratively with SMAST to collect data while fishing. A TSF representative to the project, a fisherman and vessel owner, was instrumental as a liaison between the fleet and SMAST. The TSF boats, which are in the 75-100 foot range, are required to have current Coast Guard safety inspections. These boats normally carry a crew of five. Roughly half the participating vessels have crews of Portuguese-speaking fishermen of Azores and Cape Verde Islands heritage. The vessel captains oversee the crew

[1]Rountree, R.A., R. Kessler, G. Strout, D. Martins, D. Jones and F. Bub. 2004. The High-Resolution Industry Based Trawl Survey Methodology and Data Processing Procedures. SMAST Technical Report # 05-0301.

data-recording activities and participate in the data collection themselves. For this project, the vessels were paid $300/day to collect the required data once they had signed a contract with the University. Due to budget constraints, only the seven vessels that performed the most complete and reliable data recording were retained for subsequent years.

Vessel Inspection and Training

Steps taken to train fishermen to collect fisheries data during commercial fishing operations are detailed in a separate methodology report [1]. Before a vessel can independently collect data, it must first undergo a training trip. All vessels receive one training trip prior to beginning in the program, and at least one additional training trip during each year of the program. Training trips are otherwise normal fishing trips in which an SMAST technician participates and provides training to the captain and crew.Training consists of an iterative process whereby the SMAST technician observes the fishing activities, instructs the captain and crew in the proper recording methods, and reviews the results following each tow for the duration of a fishing trip. After the initial training trip the captain and crew record data without the aid of a technician during fishing operations on subsequent trips. While the technician is aboard ship, he/she and captain record information on the vessel and gear used on each participating boat. SMAST observers participated on approximately 15 % of the 221 trips conducted during the two survey years.

Overview of Field Operations

Data collection and processing is a complex task. Before the ship leaves the dock, the captain is given a packet of logsheets, measuring boards, and length-frequency template sheets, and Tidbit temperature data loggers are placed on either the trawl doors or the nets. In the first year, the Tidbit recorders were generally placed on the nets, while in subsequent years, they were typically placed on the trawl doors. The captain generally knows what fishes he will be targeting for the trip before setting sail, but target species can change from haul to haul depending on fishing success, economic news and chance catches. The captain readies the logsheets once on the fishing ground and a trawl tow is about to take place. The location and time when the net is "set" is recorded on the environmental log. The net is considered "set" when it reaches the bottom, the doors have spread out the desirable distance and the engine is put into gear initiating towing. Trawl tows were typically of three-hours duration, but could be as long as 7.6 hours. Towing speeds were typically around three knots, but varied by vessel and gear. During a tow it was often necessary for the captain to change course by turning about. During turns the net is typically, but not always, raised off the bottom to avoid fouling and tangling, but it is not taken on board

ship. How high the net is raised depends on the circumstances and is at the captain's discretion. Captains were instructed to record all the data required on the environmental log (i.e., location, time, depth, wire out, weather, etc.) for each haul event. Haul events were defined to include the set, major turns, and the haul-back. The time and location for the start of the tow were recorded at the time of the set, while the time and location for the haul-back were recorded at the time the net was begun to be raised. Once the codend is brought on board, the catch is released into a checker box or directly onto the deck for processing. Since this is a commercial fishing operation, the crew has often developed detailed fish processing routines that insure economic efficiency. Fishermen make minimal adjustments to their routine in order to collect scientific data.

Fishes to be kept for sale are culled from the catch and placed either into standard fish baskets or fish boxes. Fishes to be discarded are typically quickly swept, shoveled or thrown overboard. It is in the fishermen's interest to do this as quickly as possible to: 1) decrease mortality of discarded species to the extent possible, and 2) to minimize the loss of valuable time and energy better reserved for fishing and processing the kept fish. For these reasons, data on the discard species are poorly quantified. Fishermen estimate the total weight of each discarded species. They further partition the discard into weights for specific discard reasons. For example, it's possible that a given fish might have both a minimum size limit and a maximum size limit. In that case some fish might be discarded that are too small or too large. It must be recognized that similar looking fishes of no economic value may not be distinguished by the fishermen (e.g., the various sculpin species). Likewise, similar looking species that are economically important, but that are sold under the same market name, are usually not distinguished by the fishermen. For example, although fishermen can be trained to distinguish red and white hake, it is not economically feasible for them to take the time and effort to do so during commercial fishing. Therefore, red and white hake are classified as a "red and white hake mix."

Many species of fishes kept and processed by the fishermen are dressed (i.e., butchered and cleaned) in various ways according to market demands. For this reason, the National Marine Fisheries Service has developed correction factors to convert the weight of dressed fish to an estimated whole fish weight. The SMAST trawl survey program uses the NMFS conversion data tables with a few minor changes (details can be found in a separate methods report[1]). Because the SMAST High-Resolution Industry-Based Trawl Survey was initially modeled after the National Marine Fisheries Service (NMFS) Observer Program, we strongly recommend readers to review of the NMFS Observer Manual (current copies can be downloaded @ http://www.nefsc.noaa.gov/femad/fsb/). Fishermen may estimate the weight of the catch for a given species either before or after dressing. The method used can change from haul to haul, and even between species within a given haul. Fishermen estimate weights based on visual inspection of the number of baskets or fish boxes that are filled or partially filled. It should be noted that fishermen have developed very specific methods of filling

baskets and boxes because their livelihood depends on efficiency. Therefore, a packed basket or box of a particular species tends to be a standard quantity, and weights are relatively efficiently estimated. To date quantification of the weight estimation error made by fishermen during this survey has not been attempted. In the future, we hope to obtain species-specific and dressed-specific data on weight estimation errors.

Gear

The New Bedford Massachusetts trawler fleet uses various types of otter trawls throughout the year (Table 2). Otter trawls are large funnel-shaped nets that are pulled through the water behind the vessel. What makes an otter trawl effective is its ability to open wider than the stern of the vessel as it is being towed. This is achieved by attaching the net to two "otter boards" or "doors" that spread the net apart due to hydraulic pressures as they are towed behind the boat. In addition, the top opening of the net is made to be positively buoyant while the bottom opening is made to be negatively buoyant. These factors cause the net to open vertically and horizontally.

At least fourteen otter trawl variations were used during the survey (Table 2). These can all be grouped into one of three general trawl types described below. Keep in mind that most if not all of the nets used in the trawl project have been modified in some way to suit individual vessels, captains, and tow-by-tow fishing conditions.

Flat nets - are a type of yankee trawl used primarily for flounder and monkfish and in smooth bottom (sand, mud, etc.) areas. The yankee is the "classic" flat net that the others are derived from. Some identifying characteristics of a yankee net include a footrope that is 20' longer than the headrope and a 9' tall mouth when fishing. In most cases, flat nets are fished with a cookie sweep or small rollers. A cookie sweep is made by attaching 3" diameter rubber discs all along the sweep (bridal, footrope, etc). When fishing for flounders, fishermen usually choose a square meshed codend. The flat net is built to stay on the bottom and sweep the entire towed area. Some specific flat nets used in this project were the Levin Marine, flat 5" sweep, 76x96, and 76x97 (Table 2).

Roller and rock hopper nets - are made for fishing in the hard bottom (rocky terrain). The large rollers and rock-hopper-like sweeps allow the nets to ride, bounce, or spring over large obstructions. These nets do not stay on bottom as well as a flat net. The ability to get over obstructions without being damaged is a compromise that fishermen choose when building and designing their nets. These nets are often named after the size of the rollers used. Center roller 12",

roller 18", and yankee rock hopper nets were used in this project.

Hi-rise nets - have taller mouth openings than flat nets in order to maximize their ability to catch roundfish such as cod, haddock, pollock, and other demersal fishes that might avoid a flat net by swimming over the top of the headrope. A diamond meshed codend is also used in most cases on these nets. Types used in this project include the Shuman, Gurock and balloon trawls (Table 2).

RESULTS

Vessel Characterization

Twenty commercial vessels participated in the trawl survey (Table 1). All were otter trawlers. New Bedford, MA was the home port for 16 vessels, while Fairhaven, MA, Hyannisport, MA, Dennisport, MA, and New York, NY were each the homeport for a single vessel. However, during the course of this project all vessels operated out of New Bedford. Vessels were steel hulled and ranged in size from 62-86 ft and 65-198 gross tons in weight (Table 3). One vessel had a second diesel engine, the rest relied on a single diesel engine for power. Capacity of the fish hold ranged from 25 to 119 tons, averaging 66 tons. Power ranged from 365 to 850 horsepower, averaging 623 horsepower. Vessels were built between 1964 and 2000, with most built around 1979. However, current engines were built between 1968-2001, with a mode in 1992. Vessels typically carried a crew of 4, ranging from a minimum of 2 to a maximum of 6 for the smallest and largest vessels, respectively. Most vessels were outfitted with significant electronics, with highly redundant systems for communication and navigation (Table 4).

Gear Characterization

Many types of nets were used by commercial fishermen during this project (Table 2). Most were variations of three major net categories, including flat nets (32 nets), hi-rise nets (13 nets), and roller/rockhopper nets (6 nets, Table 5). Thirteen nets were not classified to category because the net types were not recorded. Each vessel used from 2 to 6 different nets during the course of the project. Most nets were constructed with polypropylene netting (n=57), but a few were made with nylon (n=3) or Spectra (n=4) in the net body. Similarly, the codend was constructed of polypropylene (n=59), nylon (n=3), or kevlar (n=2). The codend mesh were mostly diamond (n=42) or square (n=21). Three nets had a wrapped square netting in the codend. Nets were predominantly green (n=42) with a few black (n=10), or yellow-green (n=1), with color not recorded for 11 nets. Most nets were made with double strand twine (n=46). Fourteen were

single strand and 4 were not recorded. Mesh size was predominantly 6 inch (n=26) or 6 ½ inch (n=26), though a few nets were 6 3/4 inch (n=8) or 7 inch (n=2). All nets had chafing gear.

Various materials were often placed along the ground cable, bridle or footrope (Table 6). Rubber cookies were most frequently placed on the ground cable (n=32), while chain (n=25) and rubber cookies (n=16) were most frequently added to the bridle, and rubber cookies (n=20) and rollers (n=15) were most frequently added to the footrope (Table 6).

It is important to note that there is a wide variation in the dimensions and construction of specific nets within each of the net categories, as fishermen frequently modify and customize their nets (Table 5). For nets where data is available, most averaged a 78-ft horizontal opening (range 25-150 ft), and a 14-ft vertical opening (range 5-26 ft). Ground cable lengths were highly variable, averaging 204 ft, but ranging from 0 to 480 ft. Each door weighted 610 lbs on average, and ranged between 400 and 900 lbs (Table 5). Large differences in net dimensions were apparent among each of the net categories, but high variation is also noted within all categories (Table 5, Fig. 2). The high-rise net tends to have the largest dimensions and heaviest doors, while the flat net tends to have the smallest dimensions (Fig. 2).

Trip Characterization

Although 223 trips were initiated, no data were obtained from two trips. There were 221 trips with a total of 8,421 trawl tows where at least some data were recorded (Table 9). However, the types of data recorded were not always consistent for all trawl tows. Sometimes only environmental data were recorded, and at other times only catch data were recorded. In addition, most trips experienced some type of problem for a few tows, resulting in loss of data (e.g., tear-up tows, recording error, data loss, etc.). As a result, some catch data were recorded for a total of approximately 7,911 hauls during 209 trips. In addition, fishermen did not reliably estimate catch discard for about 14% of the tows during the first program year (7% overall). Discard catch and total catch data have been set to zero values for these tows (leaving only kept catch data). Therefore, the effective sampling effort for total and discard catch data is 7,332 hauls over 202 trips (Table 9).

An average of 36 (Stdev=13) hauls were made per trip (range 2-72) where catch data were recorded. An SMAST technician participated on 34 (15%) of the trips, providing quality control oversight of data, and additional training of fishermen. Catches were landed in New Bedford, MA for 96% (n=213) of the trips. Additional landings were made at Hyannis (3), Boston (2), Fairhaven (2), and Gloucester (1). Although the dealer was not reported in 31% of the trips, Whaling City Seafood Display Auction, Bergies Seafood Inc., and Atlantic Coast Seafood Inc., Boston were the predominant dealers reported (Table 8).

Twenty vessels were piloted by 20 Captains (Tables 10 and 11); however,

one vessel had two different Captains, and one Captain served on two different vessels over the course of the project. Because the Captain has a strong influence on fishing activity (selection of target species, vessel speed, tow duration, and gear types), it is important to account for the lack of a one-to-one correspondence between vessels and Captains. Target species changed an average of 3.1 (standard deviation, SD, 1.6) times per trip, and ranged from 1-8 times per trip. Nets were changed an average of 1.9 (SD 0.6, range 1-4) times per trip. Net type was changed 1.3 (SD 0.5, range 1-3) times per trip, and net category was changed 1.2 (SD 0.4, range 1-3) times per trip. Therefore, a change in target species did not always result in a net change, and a net change did not always mean a change in net type (brand) or category (i.e. flat net versus roller net).

The distribution of trips by season and year of the project reflects temporal changes in fishing practices and our sampling effort (Table 12 and 13, Fig. 1 and 3). Note the higher sampling effort first year of the project and the six month lack of sampling between the first two surveys (Tables 9 and 12, Fig. 1). About 66% of the effort was concentrated during the winter and spring (Table 13, Fig. 3).

Trips averaged 7 days in duration, but ranged between 1 and 13 days (Table 7). Often, trips are cut short by mechanical problems or by foul weather (compare Days at sea to expected trip duration in Table 7). Crews size averaged 5, including the Captain. An average of 14 tons of ice, and 3,610 gallons of fuel were expended per trip. A total sampling effort of 1,552 days at sea (DAS) and 23,247 hours of towing time were expended during the coarse of this project (Tables 7 and 14). This effort resulted in the capture of approximately 12 million lbs of fish, of which 8.7 million lbs were kept and 3.8 million lbs were discarded (Tables 14 and 15) [2]. An average of approximately 59 thousand pounds of fish were caught per trip, of which 40 thousand pounds were kept and 19 thousand pounds were discarded (Tables 14 and 15).

Station Data

A total of 8,421 stations (trawl tow locations) were occupied during the project (Fig. 1, Tables 9 and 16). Summary statistics for the environmental data, trawling data, and total catch data are provided in Table 16. Note that many variables have differing sample sizes due to differences in recording rates. Some catch data were recorded in 7,911 out of the 8,421 tows. Lack of discard reporting and tear-up tows account for this difference. Some catch or length frequency data may have been recorded for some tear-up tows, but this should not be considered quantitative. Discard data were not considered to have been reliably recorded in 579 tows (14% of the first year survey, 7% overall). For

[2] Note that the total catch and discard values are biased by a frequent lack of reporting of discard by the fishermen, which we have attempted to account for, herein.

these tows, the kept catch data are reliable, but the discard and total catch data have been set to missing values. Due to these various issues, only 7,332 tows provide complete catch data (see Table 9). A more detailed explanation of the recording issues for the discard and total catch data can be found in a separate methods report.[1] Summary statistics for station data were very similar for data pooled over all observations (Table 16) compared to data pooled over stations with reliable catch data (Table 17). Therefore, all further summaries of station data and sampling efforts reported, herein, are based only on data pooled over tows where at least some catch data were recorded (N=7,911 tows).

The average depth was 68 fm, and average tow duration was 2.8 h (Tables 16 and 17). There was an average of 2.4 tow events per station, ranging from a minimum of 1 when only the set data were recorded to a maximum of 8 when 6 turns, the set and the haul were recorded. A single turn occurred in approximately 30% , and 2 turns in 4% of the tows for which turn data were recorded (Table 18). Trawl tows were conducted around the clock in approximately equal proportions (Table 19). Most tows were conducted during good weather conditions (Table 20). Sampling effort was most intense during 2001 and the winter and spring months, with a peak of 886 tows conducted in April 2001 (Table 21).

The catch averaged 1,639 lbs/tow, of which an average of 1,099 lbs were kept and 530 lbs were discarded (Table 17). On average 27% of the catch was discarded. Trawls caught an average of 761 lbs/hour, of which 459 lbs/hour were kept and 300 lbs/hour were discarded (Table 17). An average of 7, 5, and 4 species were captured, kept and discarded per tow, respectively (Table 17). Fourteen species or species groups were targeted by the fishermen (Table 22). Scallop were targeted in a few tows during the third year. Multispecies, monkfish, Atlantic cod, winter flounder and haddock were the most frequently targeted species accounting for 95% of the effort (Table 22).

As might be expected, station data varied strongly among fishing vessels (Table 23, Fig. 4, 5, 6 and 7), gear (Table 24, Fig. 8, 9, 10 and 11), season (Table 25, Fig. 12, 13, 14 and 15) and target species (Table 26, Fig. 16, 17, 18 and 19). For example, vessel 11 had a mean tow duration nearly twice that of vessel 3, while vessels 2 and 20 fished in the deepest and shallowest waters, respectively (Table 23, Fig. 4). Mean total catch per tow and total CPUE for vessels 5 and 20 were nearly three times greater than for vessels 7 and 13 (Table 23, Fig. 5 and 6). In contrast, percent discard was greatest for vessel 20 (at nearly 60%), and least for vessel 7 (Fig. 7).

Tow speed and duration were greater for flat nets, and roller nets were fished in the shallowest depths (Table 24, Fig. 8). Total catch and total kept catch were greater in the hi-rise nets, while discard was lowest in the flat nets (Fig. 9). A similar pattern is seen for CPUE data, except roller nets also have the lowest discard CPUE (Fig. 10). However, the percentage of the catch discarded was greatest for roller nets (Fig. 11).

Trawling was conducted in the deepest waters during the winter, and shallowest during the summer (Table 25, Fig. 12). Tow speed was greatest, and

tow duration least, in the summer (Fig. 12). Total and kept catch (lbs/tow) were highest during the winter, while discard was highest during the summer and fall (Fig. 13). The pattern for catch CPUE was similar (Fig. 14). The percentage discard of the catch was greatest during the summer and fall (Table 25, Fig. 15).

Because fishermen adjust their gear type and fishing methods to optimize catch of targeted species, target species had a strong effect on station data (Table 26, Fig. 16, 17, 18 and 19). The highest tow speed was used when targeting lobster, and the lowest when targeting pollock (Table 26, Fig. 16). Longer tow durations were used when targeting mixed hake, monkfish, and American plaice, and shorter durations when targeting redfish and scallop. Haddock, multispecies, mixed hake, and redfish were targeted in the deepest waters, while Atlantic cod, witch flounder and lobster were targeted in the shallowest water (Table 26, Fig. 17). Total combined species catch was greatest when targeting skates, and least when targeting redfish, witch flounder and American plaice (Fig. 17). The weight of the total kept catch was greatest when skate, pollock, monkfish or haddock were targeted. However, discard was greatest when targeting winter flounder, yellowtail and scallop (Fig. 17). Standardizing the catch by tow duration (CPUE) had the effect of reducing the importance of skate (Fig. 18). The highest total catch weight per tow hour occurred when scallop, skate, redfish and haddock were targeted. The highest kept weight per tow hour occurred when skate, redfish, and scallop were targeted. The highest discard CPUE occurred when scallop lobster and winter flounder were targeted (Fig. 18, Table 26). The greatest percentage of the catch discarded occurred when winter flounder, scallop, yellowtail and lobster were targeted, and least when monkfish, redfish, hake mix, or skate were targeted (Fig. 19).

Catch

A total of 51 species (or species groups) of fish were collected during the program (Table 27). The five dominant species by mean total weight per tow were skates (35%), monkfish (19%), Atlantic cod (11%), haddock (11%) and winter flounder (5%) (Table 28, Fig. 20). Dominant species kept by the fishermen were monkfish (27%), Atlantic cod (17%), haddock (15%), skate (13%) and winter flounder (8%). Skate shifted from being ranked first by total catch to 4th by kept catch because they are usually discarded. Skate constitute the dominant discard species (80%) followed by spiny dogfish, barndoor skate, sea raven, and monkfish (Table 28, Fig. 20). Note, that all skates were lumped into a mixed skate species group, except for barndoor and clearnose skates which were recorded separately (the mixed skate grouping is used because fishermen do not have time to correctly identify skate species and the market does not distinguish among species). The species rankings shift somewhat when catches are standardized by tow duration (CPUE in lbs/tow-hour), but skate (41% of catch), haddock (13%), monkfish (12%), Atlantic cod (12%), and winter flounder (7%) and remain the top five species (Table 29, Fig. 21). Skates account for 80% of the

discard CPUE (Fig. 21).

Species composition and catch data were influenced by many factors during this study, including vessel, captain, gear, season, and target species effects. We recognize that many of these factors are statistically confounded with one another and with sampling location. However, a comparison of the single factor effects is useful for developing a good conceptual understanding of the trawl data. Therefore, we include, herein, a brief summarization of catch differences by vessel, gear (net_category), season and targeted species (Fig. 22-45, Tables 30-37).

Catch by Vessel: Strong differences in catch were observed among the 20 fishing vessels participating in this study (Tables 30 and 31). Pie charts for the nine vessels with the greatest sampling effort are shown for discard, kept and total catch per tow (Fig. 22, 23 and 24, Table 30) and discard, kept and total CPUE (lbs/tow-hour, Fig. 25, 26 and 27, Table 31). Skates dominated the discard of most vessels (Fig. 22 and 25), but vessel 11 had an unusually high diversity of discard, including significant contributions of monkfish and spiny dogfish. Species kept by the vessels were highly variable (Fig. 23 and 26). For example, vessel 19 was dominated by winter flounder, vessels 11, 17, and 6 by monkfish, and vessel 9 by haddock (Fig. 23 and 26). While skate typically dominated the total catch for most vessels, vessels 11, 17 and 6 were notable in that monkfish either dominated or equaled the skate contribution (Table 30 and 31, Fig. 24 and 27).

Catch by Gear: Strong differences in catch were observed among the gear types (net_category, Tables 32 and 33). Pie charts comparing catches among gear types for discard, kept and total catch per tow (Fig. 28, 29, and 30) and discard, kept and total catch CPUE (lbs/tow-hour, Fig. 31, 32 and 33), illustrate these differences. The pie charts indicate the dominant species by relative weights for each gear. In general, flat nets have a composition more similar to the hi-rise net than to the roller net.

Skates dominated the discard for all net types (Fig. 28 and 31, Tables 32 and 33). Barndoor skate and spiny dogfish were important components of the discard catch in hi-rise nets, while sculpins (mostly longhorn sculpin) and Atlantic cod were important in the roller nets. That cod contributed disproportionately more to the roller net discard, compared to other gear is notable, though absolute values are still quite (20 lbs/tow or 14 lbs/tow-hour, Tables 32 and 33).

The catch kept by the fishermen was least diverse for the high-rise net (Fig. 29 and 32). Flat nets were dominated by monkfish, Atlantic cod, skate and haddock, hi-rise nets by haddock, Atlantic cod, monkfish and skates, and roller nets by cod, skate, yellowtail and American plaice based on mean kept catch per tow (Fig. 29, Table 32). Similar patterns were observed based on CPUE, except that winter flounder replace haddock in the flat net and American plaice in the

roller net (Fig. 32, Table 33). The importance of the flatfish in the kept catch of the roller nets is surprising given that flat nets are traditionally used for founder fishing.

Skates dominated the total catch per tow and CPUE of all net categories accounting for over a third of the catch by weight (Fig. 30 and 33). Monkfish was the second most important species in flat nets, while haddock and Atlantic cod were second in the hi-rise and roller nets, respectively. American plaice were uniquely important in the roller nets (Table 32 and 33).

Catch by Season: Catch weights and species composition varied strongly among seasons (Tables 34 and 35). These differences are summarized in pie charts for mean discard, kept and total catch per tow (Table 34, Fig. 34, 35 and 36) and mean CPUE (lbs/tow-hour, Table 35, Fig. 36, 37 and 38). Discard in all seasons were dominated by skates, with some barndoor skate and spiny dogfish in winter and spiny dogfish and sea raven in summer (Fig. 34 and 37). The fall kept catch was dominated by monkfish and winter flounder, winter by haddock, monkfish and Atlantic cod (Fig. 35 and 38). Kept catch composition in spring and summer were more diverse with an increase in flatfishes. Skate dominated the total catch composition for all seasons (Fig. 36 and 39). Winter catches are dominated by skate, monkfish, haddock and Atlantic cod. Spring by skate, Atlantic cod, monkfish and yellowtail. Summer by skate, monkfish, winter flounder and Atlantic cod, and fall by skate, monkfish, winter flounder and haddock (Fig. 36). Total catch standardized by tow duration (CPUE lbs/tow-hour), differs mainly in that the ranking of monkfish declines. Haddock and Atlantic cod rise to the second rank in winter and spring, respectively, while winter flounder moves to second in both summer and fall (Fig. 39, Table 35).

Catch by Target Species: The influence of target species on the trawl catches is complex, and will be the subject of more detailed analyses in a future report. With the exception of frequent dominance of skate, most target species were dominated by the species targeted for total catch per tow and CPUE statistics (Tables 36 and 37, Fig. 42 and 45). Discard of all target species groups was dominated by skates (Fig. 40 and 43). Discard was most diverse for monkfish and haddock targeted tows, where spiny dogfish and barn door skate contributed. Small amounts of discard of the target species were typical of each group (Tables 36 and 37, Fig. 40 and 43). The kept catch was dominated by the target species in all cases except for when lobster were targeted (Fig. 41). When lobster were targeted lobster made up only 10% of the kept catch per tow (Fig. 41) or 14% of the kept catch per tow-hour (Fig. 44).

DISCUSSION

The High-Resolution Industry-Based Trawl Survey resulted in a wealth of data on fishing practices, methods, and catch for the Georges Bank groundfish

fishery. Although collection of scientific data by the fishermen during normal fishing operations posed several challenging data quality control problems that potentially limit the use of some data components (e.g. discard data), it is apparent that the resulting data set provides a significant source of information to fishery scientists and resource managers. This project follows in the spirit of Hall-Arber and Pederson[3], who argued that industry-based data collection could provide unique and valuable data important for fishery management. Data presented in this report, and in forthcoming reports, convincingly demonstrate the usefulness of industry-based fisheries surveys. The brief data overview presented in this report suggests that this study will provide significant information in at least the following areas: 1) quantification of fishing methods and activities of the Georges Bank groundfish fishing fleet (e.g., gear used, towing speed, duration, etc.), 2) quantification of the effect of gear variation on fishing activity and methods and on the resulting catch composition and catch per unit effort, and 3) quantification of the influence of the fishermen's ability to target species on the resulting catch composition and CPUE. The importance of targeting practices is particularly emphasized and may have the most important implication for management. If fishermen can successfully target particular species and thereby reduce discard and other impacts on other species, then that provides them with a powerful tool for management of the resource. Policies and practices by the fishermen that enhance targeting efficiency are likely to become more important components of fisheries management.

Each of the five overall goals targeted by the project were achieved. First, we were able to obtain fisheries data on a higher spatial and temporal resolution than possible in most industry independent surveys, with nearly 6,000 trawl tows completed in two years. Second, this project relied the committed involvement of the industry and has helped to increase the industries ability to provide input into the management process through the inclusion of the data collected. Third, we have developed training methods and data collection methodologies that provide acceptable scientific data, and yet are tailored to the capabilities and limitations of the fishing industry's use during normal fishing operations. Fourth, the project successfully demonstrates the feasibility of cooperative projects between industry and scientists that focus on the aquisition of high-resolution fisheries data. And finally, data generated by this project are being used in studies focused on characterizing the relationships among environmental conditions, fishing practices, and catch.

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[3] Hall-Arber, M. And J. Pederson. 1999. Habitat observed from the decks of fishing vessels. *Fisheries* 24(6):6-13.

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