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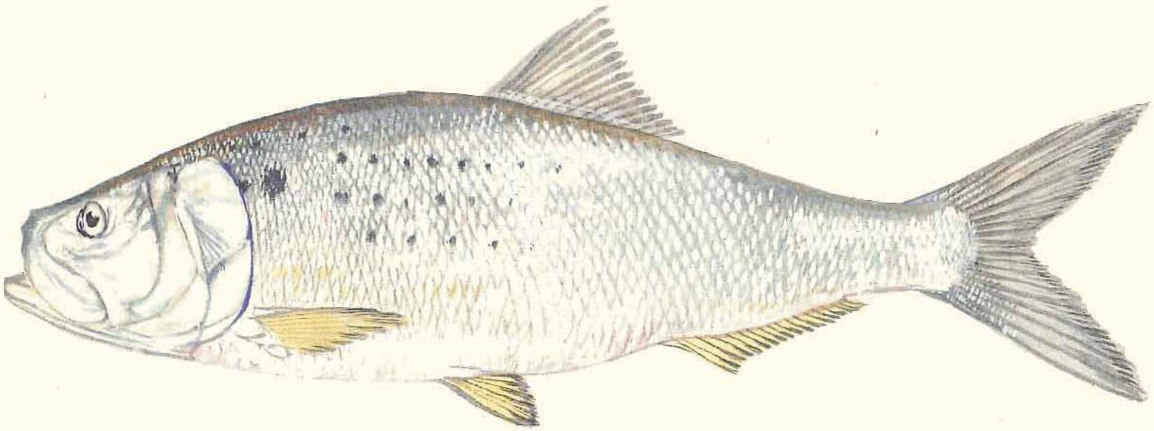
An Assessment of the Nature and Extent of By-catch



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BY-CATCH AND THE FISHERY FOR ATLANTIC MENHADEN, BREVOORTIA TYRANNUS IN THE MID-ATLANTIC BIGHT: AN ASSESSMENT OF THE NATURE AND EXTENT OF BY-CATCH

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Numerous individuals were responsible for this study being initiated and completed. The National Fisheries Institute and National Meal and Oil Association together with individual members of industry proposed this study in 1990. Through their efforts, the National Marine Fisheries Service, under Saltonstall-Kennedy funding, proposed that a by-catch study be conducted for the U.S. menhaden industry. We are especially appreciative of the assistance provided by Mr. John Barnes of AMPRO and Mr. Steven Jones of Zapata Haynie. They and their companies made their plants available for inspection and their fishing vessels available for conducting at-sea experiments. Moreover, they offered valuable constructive criticism of the methodology proposed to conduct the by-catch study. We are also appreciative of the assistance provided by Mr. Richard Marks of the National Fisheries Institute. Mr. Marks provided constructive criticism of the proposed methodology and served as liaison between the researchers and members of industry.

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Last, we thank the students that worked with us on the project. We are particularly appreciative of the efforts by Mr. Joe Defosse, Ms. Tracy Holton, Paul Ruderhauser, Alex Austin, and Brian Lucy. These individuals made numerous trips to the plant and at-sea. They diligently worked under unfamiliar conditions. Without their efforts, we would not have been able to have collected all data necessary to complete the study.

EXECUTIVE SUMMARY

Incidental harvesting or by-catch of fish and shellfish has become an issue of increasing concern to fishery administrators, managers, research scientists, and industry and recreational fishing associations. Much of this concern stems from the belief that the incidental harvests of some species is quite high and may have important ramifications for the ecosystem and for the populations of important commercial and recreational species of fish. The Atlantic menhaden fishery in the mid-Atlantic Bight (MAB) is one fishery in which there are major concerns about the nature and extent of by-catch. These concerns are partly because of the large volume of menhaden harvested and partly because menhaden are primarily harvested within the waters of the Chesapeake Bay. Fishery administrators, research scientists, and recreational anglers are concerned that menhaden vessels are harvesting important recreational species.

Because of these concerns, the National Marine Fisheries Service, Saltonstall-Kennedy grant, provided funds to assess the nature and extent of by-catch in the Atlantic menhaden fishery. This study presents a framework for assessing the extent of by-catch and an analysis of by-catch in the menhaden fishery. A regulatory-enforcement type sampling scheme in which all inspections were unannounced was designed and sampling was conducted at the docks during off-loading and on-board the vessels during harvesting.

Sampling was conducted between June and November 1992. A total of 45 off-loadings and 43 at-sea sets were sampled between June and November. Following industry practices, all counts of menhaden caught or landed were measured in terms of standard fish (1,000 standard fish weight approximately 670 pounds). The total number of menhaden offloaded during dockside sampling was 13.6 million standard fish; 2.5 million standard

menhaden were harvested during at-sea sampling. Thus, a total 16.1 million standard (10.8 million pounds) menhaden were offloaded or harvested while sampling was conducted. A total of 16,145,400 menhaden were actually sampled. Total by-catch observed was 1,413 fish or shellfish. Based on sample information obtained from at-sea sampling and dockside observations, by-catch was estimated to equal 6,617 fish or shellfish other than menhaden. Relative to the total harvest (menhaden and by-catch), by-catch was estimated to account for 0.04097 percent. On a monthly basis, maximum percentage by-catch (4,932 fish or shellfish) occurred during August when by-catch accounted for approximately 0.14 percent of total catch. Minimum by-catch (53 fish or shellfish) occurred during September when by-catch accounted for 0.002 percent of total catch. In terms of eight major recreational species--bluefish, weakfish, spot, Atlantic croaker, Spanish mackerel, striped bass or rockfish, false albacore, and summer flounder or fluke, bluefish accounted for the largest by-catch--1,206 bluefish or approximately 0.0075 percent of total catch. Lastly, no marine mammals, sea turtles, or other protected species were killed, captured, entangled or observed during sampling.

Another major concern was whether or not dockside sampling would yield results equivalent to at-sea sampling. If differences were not detected, regulatory inspections could be conducted dockside or at-sea; the preference is dockside because of costs and logistic concerns. Unfortunately, the differences in percentage by-catch were substantial: (1) dockside by-catch accounted for 0.003, 0.011, 0.04, 0.002, 0.005, and 0.002% of the total catch in June, July, August, September, October, and November; (2) at-sea by-catch accounted for 0.376, 0.291, and 0.243% in the months--August, October, and November--in which at-sea samples were collected.

This study suggests that the catch of species other than menhaden in the Atlantic menhaden fishery was minimal in 1992. By-catch concentrations were extremely variable, but low, on a set-by-set or dockside off-loading basis. Mathematical and statistical analyses indicated that that the proportion of total catch consisting of by-catch was well below most states' legal by-catch limits of one percent. Virginia law, however, requires that by-catch cannot exceed 1% of the total weight. By-catch was not sampled for weight, but assuming a 3 pound upper limit for by-catch, by-catch was estimated to be well below the 1% by weight requirement. There is a potential for by-catch estimates based on at-sea samples to be biased because of captain's behavior given the presence of researchers (e.g., the captain may have directed a set to an area where by-catch is typically low). It is offered, however, that any bias associated with behavior is likely to be low because samples were taken from areas where many other vessels were fishing and researchers could inspect the catch of any vessel in the same area. Moreover, the at-sea by-catch was higher than the dockside-determined by-catch.

A more precise assessment of by-catch for the fleet would require an extended sampling scheme. Sample size, particularly the number of at-sea samples, should be increased, and the fishery should be sampled over several years. It is not possible to accurately estimate total by-catch for the fleet using data obtained in this study. It is possible, however, to qualitatively conclude that by-catch was extremely low in the Atlantic menhaden fishery in 1992 and probably typical of the relative species abundance for the early 1990's.

Four major conclusions emerge from the study: (1) dockside sampling is inadequate to precisely determine the nature and extent of by-catch because at-sea discards and

associated mortality cannot be determined; (2) by-catch of recreational species was extremely low in numbers and relative to the harvest of menhaden in 1992; (3) a more precise assessment of by-catch for the fleet requires considerably more sampling than done for this study; (4) current "off the shelf" video technology is not an adequate tool for assessing by-catch.

INTRODUCTION

By-catch has become a major national concern to fishery administrators, researchers, and recreational anglers. The concern stems from the perception that by-catch is high in many fisheries, decreases the abundance and availability of prey or forage fish, and diminishes the populations of important game fish. For most fisheries, however, precise estimates of by-catch do not appear to be available; this appears to be particularly the case for the northwest Atlantic and Gulf of Mexico fisheries in which a routine sea sampling or an on-board observer program is not mandated.

During public meetings, recreational anglers have argued that the U.S. menhaden fishery, particularly the Atlantic menhaden fishery, is a commercial fishery in which the by-catch of important recreational species is very high. Smith (1895) appears to have been the earliest researcher to address the problem of by-catch in the Atlantic menhaden fishery. Smith indicated that the total catch of two vessels fishing out of Connecticut and Virginia ports was 27,965,755 menhaden and 94,795 other fish. Alewives were the dominant by-catch; shad and bluefish were the major other types of fish harvested as by-catch.

The Atlantic menhaden fishery has historically been prosecuted within the 20m isobath, and most by-catch has occurred within 1-3 nautical miles of shore (Smith 1895, Smith 1991). During the late 1880's, by-catch was primarily bluefish and alewives near shore and butterfish, sharks, and bluefish offshore (Smith 1895). Turn-of-the-century reports (Friedlaender 1882, Smith 1895) suggested by-catches of predatory species were primarily bluefish and sharks. Later studies (Filipich 1947, Knapp 1950, Miles and Simmons 1952) indicated that predators also caught with menhaden included weakfish, sharks, Spanish mackerel and bluefish. Throughout the period from the late 1880s to mid 1900s, alewives

and shad were dominant by-catch species. Knapp's (1950) study, in Texas, reported clupeoids as the most abundant group followed by sharks, weakfish, spot, Spanish mackerel and bluefish. Christmas et al (1960) noted that in-shore Mississippi by-catch was largest when menhaden catches were smallest, and that large by-catches were generally associated with a single species (mullet) in one or two sets. Spot, croaker and butterfish were the principal by-catch species with bluefish and Spanish mackerel rarely taken. White and Lane (1968) found scup, weakfish and butterfish as the dominant by-catch species in Delaware Bay during 1966-1967; bluefish ranked a distant fourth.

Some differences between earlier studies and those of the mid-1900s may be, in part, reflected by differences in geography since earlier studies were conducted off Long Island and the later studies in the Delaware Bay and Gulf of Mexico. Additionally, changes in stock composition may have accounted for some of the reported differences. In the 1880s, the menhaden catch was composed of larger, older fish--three to five years old which tend to migrate farther north and offshore. Bluefish stocks were depressed during the mid-1960s and the mid-Atlantic scup stock was in excellent condition which may have also accounted for differences. The distribution and abundance of the menhaden stock and the potential by-catch species also changed during recent decades (Austin et al. 1992).

The National Marine Fisheries Service provided funding under Saltonstall-Kennedy to the Virginia Institute of Marine Science to assess the nature and extent of by-catch in the Atlantic menhaden fishery thereby addressing concerns expressed by recreational anglers and fishery researchers and managers. Interestingly, however, the need for this study was initially recommended by members of the United States menhaden industry and the National Fish Meal and Oil Association in 1991. The College of William and Mary, School

of Marine Science, Virginia Institute of Marine Science was awarded the contract in February 1992 and the study commenced in May 1992--the beginning of the Atlantic menhaden fishing season. A companion study was undertaken by researchers at Louisiana State University for the Gulf of Mexico menhaden fishery.

The primary objective of the study was to assess the nature and extent of by-catch in the Atlantic menhaden fishery in 1992. An additional objective of this study was to determine a framework for estimating by-catch (i.e., evaluate various methods which might be used to estimate by-catch). Results of this study apply only to 1992 and by-catch profiles could be different in other years. A second year request for funding under Saltonstall-Kennedy was unsuccessful. The second year study was to ascertain whether or not there were notable annual differences in by-catch and to build on the techniques and experience gained from the first year study.

The report is organized as follows: (1) section II provides a brief overview of the menhaden fishery; (2) section III presents the sampling strategy and associated methodology; (3) section IV presents and discusses the results and findings of the study; (4) section V is a summary and conclusions section.

The Industry

The following synopsis of the menhaden and their fishery is taken from a special issue of the Marine Fisheries Review (Vol. 53, No. 4, 1991). Of the four species of menhaden taken by the U.S. industry, only one, *Brevoortia tyrannus*, is harvested in the Atlantic coast fishery. The other three are pursued in the south Atlantic off Florida's east coast and in the Gulf of Mexico. Since development of the FMP in 1981, management has been, by states from Maine to North Carolina, coordinated through the Atlantic States Marine Fisheries Commission (ASMFC) (Vaughan 1991, Smith 1991).

Menhaden are spawned in the ocean from off North-South Carolina during winter, to the waters around Long Island and Block Island Sounds during spring and fall. Recruitment is dependent upon subsequent physical environment conditions (Nelson et al 1977, Checkley et al 1988). Although spawning is reported during all months, it appears that the winter spawn off the Carolinas is the most productive. The reader is referred to Ahrenholz (1991) for a definitive review of the life history.

In addition to their importance as the major contributor to the most significant Atlantic coast, single species, fishery, menhaden are an important prey species for striped bass, bluefish, Spanish mackerel and sharks. Menhaden account for approximately 40% of the total U.S. commercial finfish fishery, with the Atlantic fishery comprising between 25 and 33% of this total. Currently, most purse seine catch is reduced to meal and oil. Meal is primarily used in animal husbandry for feed, and the oil is used for paints, cosmetics, and food products. A smaller pound net and "snapper rig" boat fishery in the Chesapeake Bay provides crab pot bait. Almost the entire catch along the middle Atlantic Bight and in the Chesapeake Bay goes to one of the two Reedville, Virginia reduction plants. There is also

one plant in Beaufort, North Carolina and two in Canada.

Menhaden are filter-feeding, coastal, euryhaline clupeoids that form dense surface schools. They are principally harvested along the Atlantic coast from New Jersey to North Carolina by purse seine. There is a lesser harvest in the middle Atlantic Bight by pound nets. At one time (mid-1950s), the Atlantic fishery extended from the Bay of Fundy to north Florida with 36 plants operating (Fry 1978).

The menhaden fishery has historically been the largest and oldest fishery dating back to colonial times (Fry 1978; Smith 1991). Menhaden are pursued by vessels which are 50 (snapper rig) to 210 feet long (average 168 feet, 56 m) which use purse seine nets which are 1000-1200 feet (333-365 m) long and 60-90 feet deep (20-30 m). The purse seine has a bar mesh size of 0.75 to 0.88 in (19-22 mm). A vessel consists of a mother ship and two purse boats that carry the net and make the set on the schools.

The purse seine has been the standard gear since the early 1800s. The advent of the hydraulic block in the mid-1950s reduced the size of the labor intensive crews for hand-hauled nets from 22-25 men down to 10-12. Since World War II, spotter planes have been used to locate schools and direct vessels to the fish which reduces steaming time and mitigates the possibility of setting on important food and game fish. After the net is pursed and the fish brought to the bunt, they are pumped into the hold where a recirculating refrigeration system holds the catch at about 33^0 F (0.56 C) until landing.

Menhaden are offloaded at the dock and further processed into meal and oil. In recent years, however, there has been considerable uncertainty about production levels and prices (Hale et al. 1991). Menhaden meal, although widely used by the swine and poultry industry, faces a limited demand. Oil faces strong price competition and market uncertainty.

Because of these concerns, there has been considerable interest by the menhaden industry to produce new value-added food products (e.g., surimi and sausage and meal for use in aquaculture).

METHODOLOGY

Sampling procedures:

Preliminary discussions with members of industry suggested that two sampling strategies were necessary to assess the nature and extent of by-catch in the Atlantic menhaden fishery. First, it would be necessary to sample dockside since this would be the most economically feasible point for state and/or federal government inspectors to sample catch to determine by-catch. Dockside sampling has also been the primary point of inspection for most Northwest Atlantic fisheries. Second, it would be necessary to sample at-sea to more precisely assess by-catch and to compare at-sea estimates to dockside estimates of by-catch. At-sea sampling was also necessary to define the magnitude of release or potential mortality of other by-catch species before landing dockside.

Further conversations with industry and National Marine Fisheries Service (NMFS) officials suggested a need for a purely random sampling strategy. A sampling strategy similar to law enforcement activities in which investigations are unannounced and unplanned was proposed and accepted by industry. A list of project personnel was provided to vessel owners and plant managers which permitted researchers unlimited entrance to plants and vessels for the purpose of inspecting harvests. A similar list was provided to vessel owners for sampling by-catch at sea; to facilitate logistics, however, we gave at least a one day advance notice to vessel owners that research personnel would be on-board.

Sample size:

Sample size or number of samples was determined in an "ad-hoc" manner.

Conventional sampling theory proposes that sample size (n) for assessing percentages or proportions be determined as follows:

$$n \pi \geq 5 \text{ and } n (1-\pi) \geq 5$$

where n is the number of samples and π is percentage or proportion. Management and regulation requires that π be less than or equal to 1 percent. If this were the true mean proportion, a sample size of 500 trips, off-loadings, or inspections would be required to accurately assess by-catch. The same sample size (500) could be obtained by using Chebyshev's Inequality (Bender et al. 1989). However, one percent (π) is a regulated or upper limit, and in reality, is unknown. Moreover, 500 plant and/or vessel inspections would be cost prohibitive.

It was, thus, decided to simply sample as frequently as possible and focus on dockside and on-board activities. In addition, it was concluded by researchers that the random nature of inspections partly mitigated the limited sample size. A total of 45 dockside off-loadings and 43 sets were sampled to assess the nature and extent of by-catch in the Atlantic menhaden fishery. Additional trips and at-sea sets were made, but weather and or inadequate resource conditions prevented samples from being collected (e.g., eight man days were devoted in June to at-sea sampling, but the vessels had to return to port because of bad weather or near zero availability of menhaden).

Unit measure or count of menhaden:

In this study, all counts or references to number of menhaden caught or landed are in terms of standard menhaden. The menhaden industry in the mid-Atlantic area use a

normalization factor to equate one hopper or dump box load of menhaden, which weighs approximately 670 pounds, to 1,000 menhaden (i.e., standard menhaden). Vessel captains similarly estimate the catch of menhaden per set in terms of standard menhaden. Also, it was not practical for researchers to actually count all menhaden caught or offloaded. Last, no sampling for assessing weights of menhaden or by-catch was conducted.

Sampling and data collection:

Dockside sampling

Off-loading and on-board inspections were randomly conducted. For the dockside inspections, researchers went unannounced to the plants and observed off-loadings. Menhaden are pumped from the vessel's hold to a large cylindrical, rotating dewatering tank; menhaden are then dumped into a hopper or box which holds approximately 1000 standard menhaden (670 pounds). The box is weight activated to turn and dump menhaden onto a conveyor which carries them into the plant for processing into meal and fish oil. Using a combination of video recorders, visual inspections, and sampling (randomly removing baskets of fish from the cylinder before they were deposited into the hopper), by-catch was categorized by species and assessed. Tapes from the video recorders were viewed by several researchers to assess by-catch and species composition and to determine whether or not video technology offered a valid means for assessing by-catch.

A total of 57 plant or on-site inspections were made, but only 45 inspections provided useful information. Equipment malfunctions and storms prevented researchers from completing the other 12 inspections. During all inspections, researchers observed fish as they came through the dewatering cylinder. The plants used counters to determine the

number of standard menhaden. Since each box held 1,000 standard menhaden (670 pounds), the counts were easily obtained by determining the difference between the beginning and ending counts of standard fish. By-catch was determined by documenting and counting all the fish or shellfish other than menhaden that came through the dewatering container during off-loading.

The off-loading of menhaden was also monitored by video cameras. Researchers held cameras and filmed several off-loadings. Later, researchers viewed the video films to assess by-catch. Accurate counts of the number of menhaden off-loaded during filming were obtained from the counters. Often, species other than menhaden were severely mutilated and could not be readily identified. In these cases, researchers conducted a Delphi-assessment (expert opinion) to determine the species. Alternatively, researchers collectively reviewed the video films, and by consensus, estimated the species of severely mutilated fish.

During a limited number of off-loadings, researchers also sampled the catch using large steel-handled nets. Each net was capable of holding approximately 100 fish. The net was held under the dewatering container, just above the collection hopper, until it was full of fish. The contents of the net were then dumped into 1.5 bushel baskets, and the number of menhaden and other fish and shellfish were counted. This approach to determining by-catch during off-loading was discontinued, however, because of safety concerns and limited workspace (i.e., there was not enough room to adequately collect samples at the hopper).

At-sea sampling

On-board inspections were less random in that vessel owners required at least a one-day advance notice prior to research teams boarding the vessel. This was necessary for

logistical and insurance reasons. Vessel owners needed to ensure there was enough food and Coast Guard required equipment on-board and that the researchers were properly insured. Researchers could stay on with the vessel, however, for any length of time (e.g., spend the night on the vessel and make the next day's trip). In addition, researchers could change vessels at sea. Thus, possible criticism that the at-sea inspections were not purely random is justified; however, such criticism is strongly mitigated by owners' permission to stay with the vessels or change vessels at sea.

At-sea sampling was usually conducted with a research team of two individuals. Once a vessel captain was aware of a school of menhaden, purse boats and crew were launched. Researchers accompanied the captain and crew in the purse boats and stayed until the menhaden were ready for pumping aboard the large mother vessel. During the entire operation, researchers visually observed and filmed the fish in the net. Once pumping was initiated, researchers returned to the large vessel and sampled the catch by placing 1.5 bushel baskets (a standard fish basket holds approximately 100 pounds of fish or 250 large menhaden) on the grate or just above the fish hold. Researchers attempted to sample no less than 10 baskets per pumping operation and occasionally were able to process up to 20 baskets from a set.

Researchers then examined each basket of fish and menhaden. The total number of menhaden (not number of standard menhaden) in each basket was recorded as was the by-catch. The by-catch and menhaden were also measured for size. Additional information requested by NMFS and industry included the number of marine mammals or turtles caught and/or sighted. Remaining information recorded on log sheets included (1) time of day gear was set, (2) time when pumping was completed, (3) hail or captain's estimate of

number of fish in set, (4) geographic area of catch, and (5) bottom depth. When the basket samples were finished and the vessel stopped pumping menhaden, random sampling of the hold was conducted to further assess the by-catch.

Estimation of by-catch:

Information on by-catch or all animals that occurred in catch other than menhaden, *Brevoortia tyrannus,* sampled at-sea was used to estimate only the at-sea by-catch. Up to twenty baskets were sampled for each set. Information collected from the samples was used to estimate total at-sea by-catch and at-sea by-catch by species relative to the number of menhaden harvested. Depending upon the size of the menhaden and other fish, each 1.5 bushel basket held between 100 and 500 fish or shellfish. Total and species by-catch per set were estimated in integer value by multiplying the percentage of total and species by-catch obtained from the basket samples by the estimated number of standard menhaden harvested by the purse seine during the set. For example, if twenty samples were taken and the ratio of bluefish to menhaden from the sample data was 0.005 and the captain's estimated number of standard menhaden was 1,000,000, the number of bluefish estimated to have been harvested in a set was 5,000 (0.005 x 1,000,000).

Dockside by-catch or by-catch during off-loading was determined by counting the number of animals other than menhaden. The number of by-catch observed was then related to the number of standard menhaden to determine the percent composition and and by-catch. It was, however, necessary to occasionally estimate the species or type of fish or shellfish other than menhaden. Severely mutilated fish or shellfish were identified by reviewing the video films and visually examining the mutilated fish.

ANALYSES AND RESULTS

By-catch and menhaden:

A total of 88 samples were obtained between June and November 1992. Forty-three of the samples were from at-sea sets, and forty-five of the samples were collected dockside (Table 1). A total of 16,146,413 fish were sampled at sea or at the dock; 16,145,000 of the total were standard menhaden and 1,413 fish or shellfish were by-catch. Using the data obtained from the dockside and at-sea samples, by-catch was estimated to equal 6,617 fish; thus, the total number of menhaden and other fish harvested was estimated to equal 16,151,617 fish or shellfish.

Table 1. Monthly number of at-sea and dockside samples, 1992

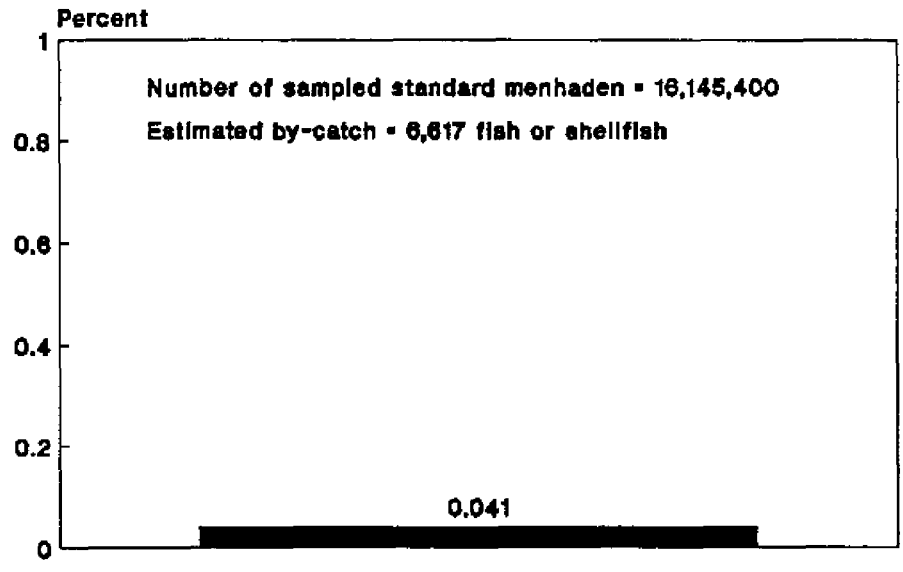
Month	Number of samples*	
	At-sea	Dockside
June	0	3
July	0	8
August	25	11
September	0	4
October	12	7
November	6	12
Total	43	45

*Number of at-sea samples equals number of sets sampled. Number of dockside samples equals number of off-loadings sampled or inspected.

Throughout this report, all references to menhaden and by-catch harvests are in terms of numbers of standard menhaden and fish and shellfish. Dockside harvests were determined by using the counters which indicate number of standard fish assuming that 1,000 standard fish fill up a dump box. Estimates of weight were based on the industry conversion of 1,000 standard fish weigh 670 pounds. Weights of by-catch species were not assessed. At-sea harvests were determined by the captain in terms of numbers of standard menhaden.

Relative to the total harvest, by-catch accounted for only 0.041%. Alternately, for every 10,000 standard menhaden harvested, there were approximately four fish or shellfish of species other than menhaden also harvested. Relative to one unit of by-catch, approximately 2,440 standard menhaden were harvested. During the 1992 menhaden fishing season, by-catch for the mid-Atlantic fleet, particularly the Chesapeake Bay fleet, was extremely low (Figure 1).

Figure 1. Percentage by-catch relative to number of menhaden, 1992



Analysis of each sample indicated that nearly 82% of all dockside samples had by-catch (Figure 2). The range of by-catch observed from dockside sampling was between 0.0 and 0.103% (Table 2). On a monthly basis, however, by-catch ranged from 0.002% to 0.0402% (Figure 3). At-sea sampling indicated that approximately 46.5% of the sets contained by-catch (Figure 4). The percent of sets in which by-catch was caught ranged from 40.00% in August, to 58.33% in October. The range of by-catch observed for the at-sea samples was between 0.0% and 3.37% of the total number of menhaden sampled in a set (Table 3). Relative to the number of menhaden sampled on a monthly basis, at-sea by-catch ranged from a low of 0.075% in November to a high of 0.287% in August (Figure 5).

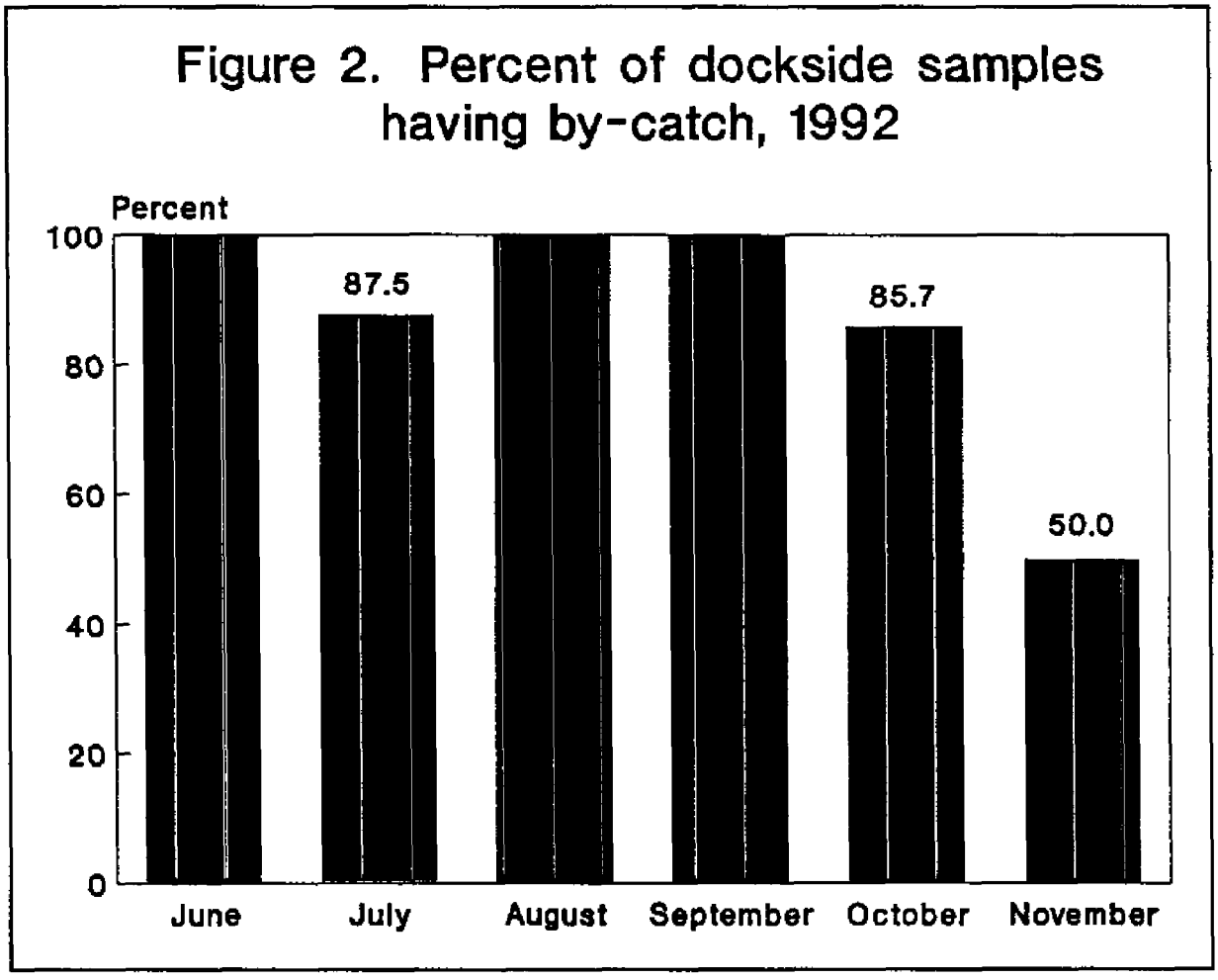


Table 2. Percent by-catch, dockside sampling

Month	Range-percent by-catch per sample
June	0.00-0.01
July	0.00-0.02
August	0.00-0.10
September	0.00-0.01
October	0.00-0.02
November	0.00-0.01

Figure 3. Monthly by-catch determined by dockside samples, 1992

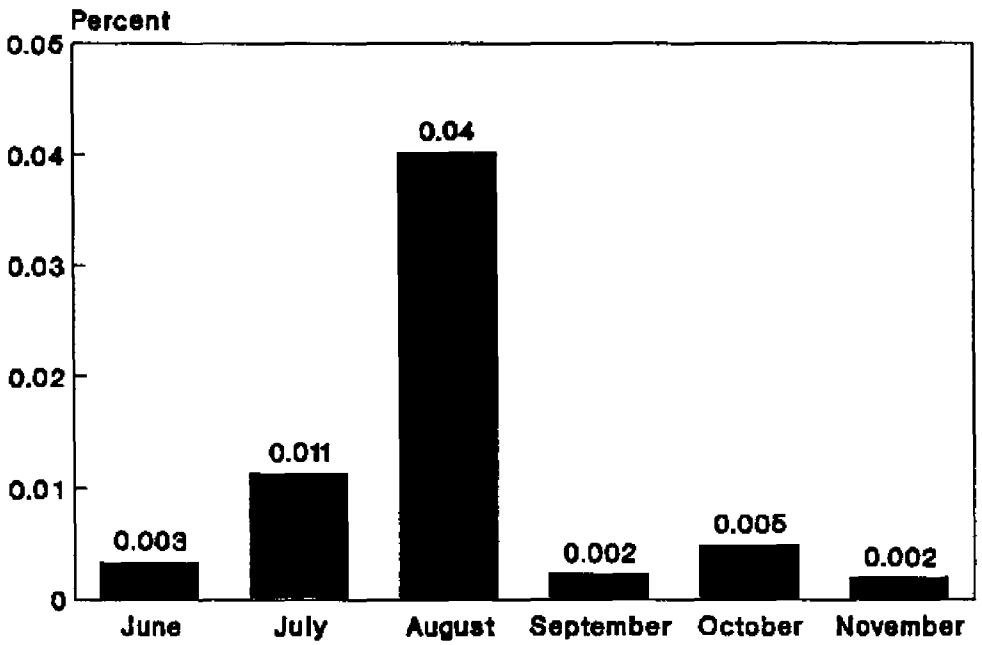
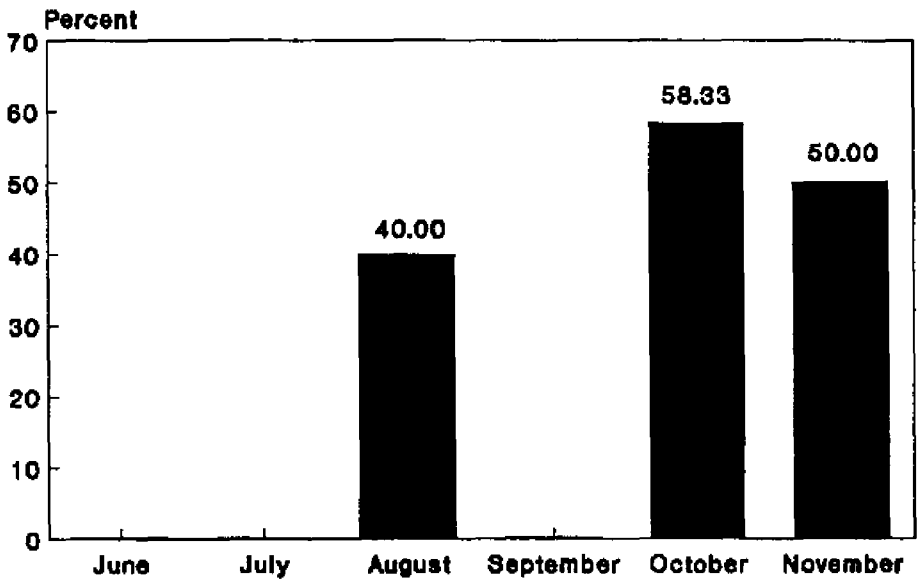


Figure 4. Percent of at-sea samples having by-catch, 1992

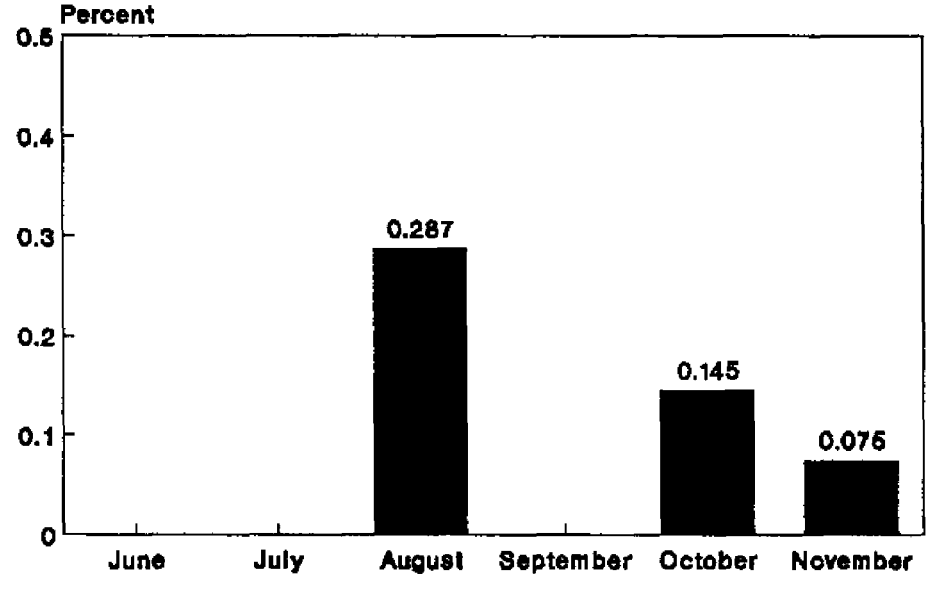


At-sea sampling not conducted during June, July, and September

Table 3. Percent by-catch, at-sea sampling

Month	Range-percent by-catch per set
June	No at-sea samples
July	No at-sea samples
August	0.00-3.67
September	No at-sea samples
October	0.00-1.11
November	0.00-0.74

Figure 5. Monthly by-catch determined by at-sea samples, 1992



By-catch of recreational species:

A total of 43 species other than menhaden were harvested during the by-catch study period (Table 4). Recreational species harvested were bluefish, Atlantic croaker, spot, Spanish mackerel, weakfish/sea trout, striped bass, false albacore, and summer flounder (Table 5). There was an estimated total 3,988 recreational fish harvested relative to the 16,145,000 standard menhaden observed in the samples. Relative to every 10,000 menhaden observed in the samples, there were 2.47 recreational fish harvested. The major recreational by-catch was bluefish; 1,204 bluefish were estimated to have been harvested with the 16,145,000 menhaden. Thus, for every 10,000 menhaden observed in our samples, there were approximately 0.75 bluefish. The second major recreational species was Spanish mackerel. The estimated by-catch of Spanish mackerel was 1,182 individuals; thus, there were 0.73 Spanish mackerel for every 10,000 menhaden observed in the samples. Atlantic croaker, weakfish, and summer flounder were the third, fourth, and fifth major recreational species in terms of numbers (747, 329, and 260 individuals per species, respectively).

There appeared to be a temporal pattern in by-catch and species diversity (Table 6). Bluefish accounted for most of the by-catch in all months except August and October (Figures 6-11). Spanish mackerel dominated the by-catch during August and was followed by bluefish and Atlantic croaker. Striped bass were not harvested until October (one striped bass observed and 8 estimated as being caught) with the largest by-catch of striped bass occurring during November (ten striped bass actually observed and 89 estimated as being harvested). It was estimated that striped bass accounted for 20.4% of total by-catch during November; estimated total by-catch during November, however, was only 437 individual fish or 0.0102% of the total number (4,281,000 menhaden) of fish examined in November.

Table 4. By-catch species harvested during menhaden harvesting, 1992

Species or fish name	
Sandbar shark	*Carcharhinus plumbeus*
Shark	*Carcharhinus sp.*
Smooth dogfish	*Mustelus canis*
Clearnose skate	*Raja eglanteria*
Skate	*Raja*
Cownose ray	*Rhinoptera bonasus*
Sting ray	*Dasyatis sp.*
Butterfly ray	*Gymnura micrura*
Blueback herring	*Alosa aestivalis*
Atlantic thread herring	*Opistonema oglinum*
Channel catfish	*Ictalurus punctatus*
Silver hake	*Merluccius bilinearis*
Hake	*Urophycis sp.*
Oyster toad	*Opsanus tau*
Houndfish	*Tylosurus crocodilus*
Atlantic silverside	*Menidia menidia*
Sea robin	*Prionotus sp.*
Striped bass	*Morone saxatilis*
Black seabass	*Centropristis striata*
Bluefish	*Pomatomus saltatrix*
Cigarfish	*Selar crumenophthalmus*
Silver perch	*Bairdiella chrysoura*
Weakfish	*Cynoscion regalis*
Spot	*Leiostomus xanthurus*
Croaker	*Micropogonius undulatus*
Spanish mackerel	*Scomberomorus maculatus*
Little tunny (false albacore)	*Euthynnus alletteratus*
Harvestfish	*Peprilus alepidotus*
Butterfish	*Peprilus triacanthus*
Summer flounder	*Paralicthys dentatus*
Windowpane	*Scopthalmus aquosus*
Witch flounder	*Glyptocephalus cynglossus*
Winter flounder	*Pleuonectes americanus*
Hogchoker	*Trinectes maculatus*
Conch	*Busycon sp.*
Hard clam	*Merceneria sp.*
Squid	*Loligo pealei*
Horseshoe crab	*Limulus polyphemus*
Shrimp	*Penaeus sp.*
Spider crab	*Libinia sp.*
Ladycrab	*Ovalipes sp.*
Bluecrab	*Callinectes sapidus*

Table 5. By-catch composition during survey[a]

Species/common name	Number of individuals		Number of menhaden per unit by-catch
	Total	Per 10,000 menhaden[b]	
Bluefish	1,206	0.747	13,387
Croaker	747	0.463	21,613
Spot	137	0.085	117,847
Spanish mackerel	1,182	0.732	13,659
Weakfish	329	0.204	49,073
Striped bass	97	0.060	166,493
False albacore	30	0.019	538,167
Flounder	260	0.161	62,096
All other species excluding menhaden	2,629	1.630	6,141
Total fish	6,617	4.101	2,439

[a]By-catch composition assessed using estimated by-catch.

[b]All numbers relative to menhaden are in terms of number of standard menhaden.

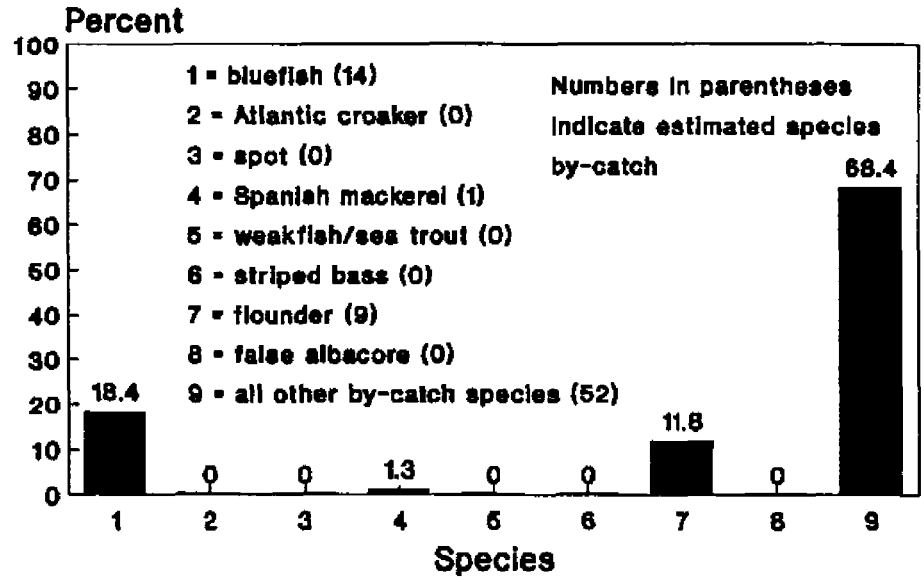
Table 6. Monthly by-catch during 1992 survey

Species/common name	Month					
	June	July	August	September	October	November
	----------Number of individuals in sample[a]----------					
Bluefish	14 [161786][b]	133 [12158]	852 [4072]	36 [64389]	47 [46702]	124 [34524]
Croaker	0	0	653 [5312]	1 [2318000]	89 [24663]	4 [1070250]
Spot	0	0	119 [29151]	0	17 [12912]	1 [4281000]
Spanish mackerel	1 [2265000]	11 [147000]	1167 [2973]	4 [579500]	0	0
Weakfish	0	0	228 [15215]	4 [579500]	87 [25230]	10 [428100]
Striped bass	0	0	0	0	8 [274375]	89 [48101]
Flounder	9 [251667]	1 [1617000]	89 [38978]	1 [2318000]	156 [14071]	4 [1070250]
False albacore	0	0	0	0	11 [199545]	19 [225316]
All other	52 [43558]	37 [43703]	1824 [1902]	8 [289750]	521 [4213]	187 [22893]
Total	76 [29803]	292 [8885]	4932 [703]	53 [43736]	937 [2343]	437 [9796]
Number menhaden in sample--millions	2.265	1.617	3.469	2.318	2.195	4.281

[a]By-catch estimated using sample data; estimated by-catch equals sum of observed dockside by-catch and estimated at-sea by-catch.

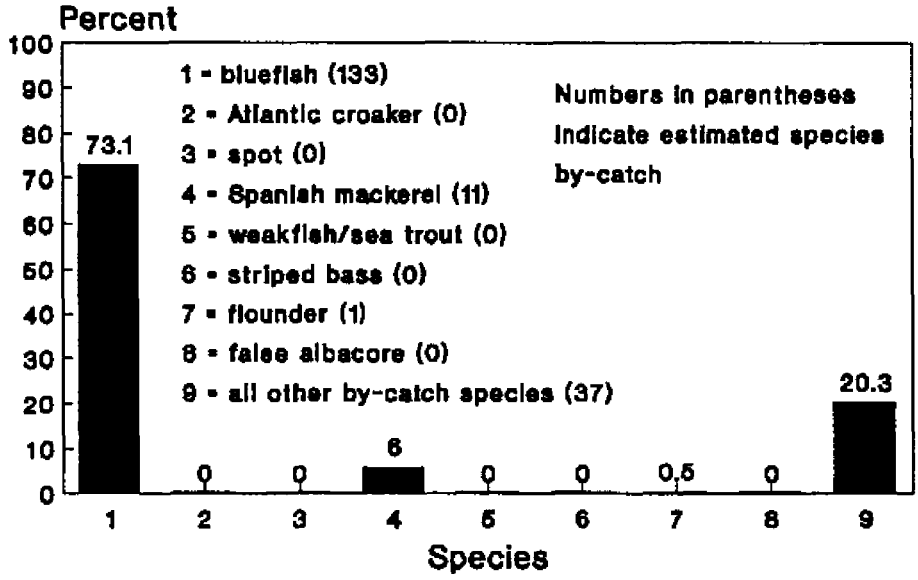
[b]Numbers in brackets indicate the number of standard menhaden caught per unit of by-catch. For example, 14 bluefish were harvested along with 2,265,000 menhaden in June 1992; this equates to one bluefish for every 161,786 menhaden.

Figure 6. Estimated by-catch composition during June, 1992



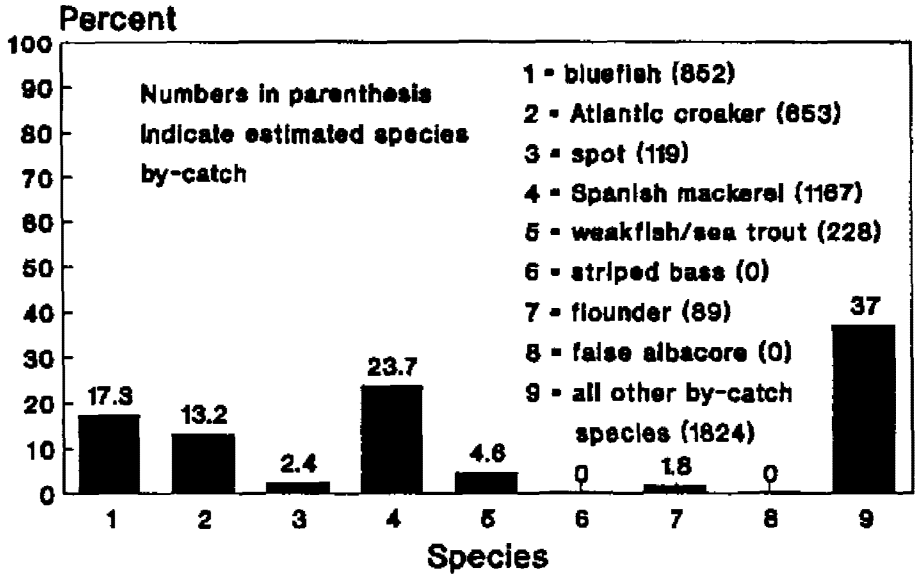
Total number of menhaden = 2,266,000
Total by-catch = 76 fish or shellfish

Figure 7. Estimated by-catch composition during July, 1992



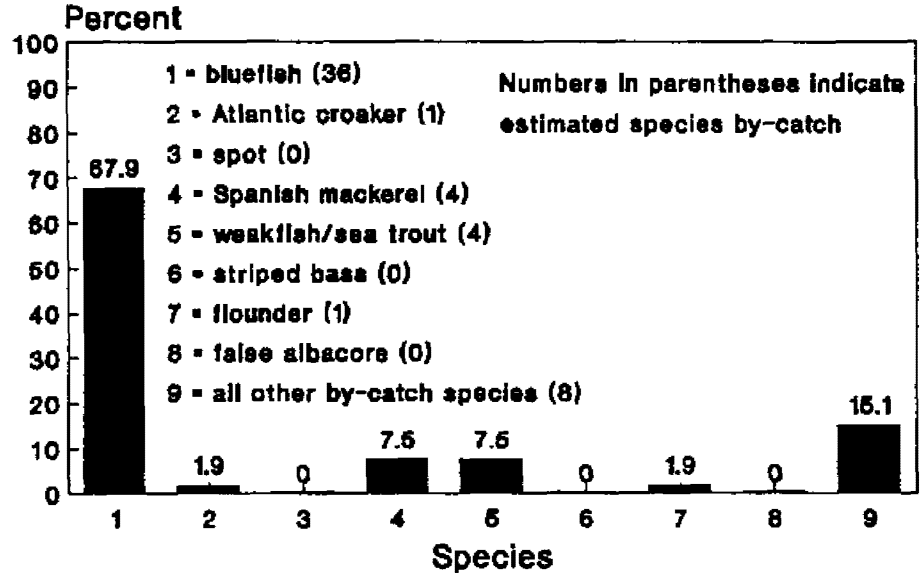
Total number of menhaden = 1,617,000
Total by-catch = 182 fish or shellfish

Figure 8. Estimated by-catch composition during August, 1992



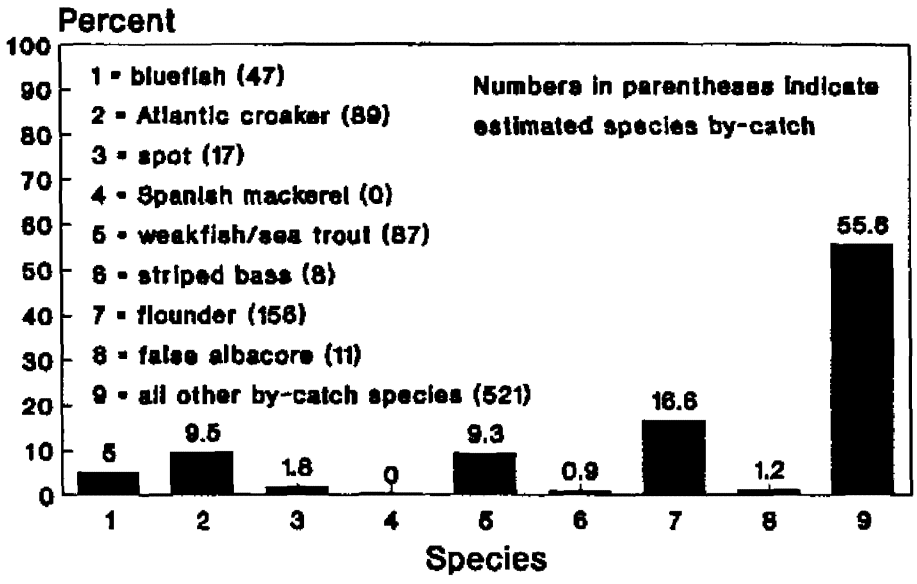
Total number of menhaden = 3,469,000
Total by-catch = 4,932 fish or shellfish

Figure 9. Estimated by-catch composition during September, 1992



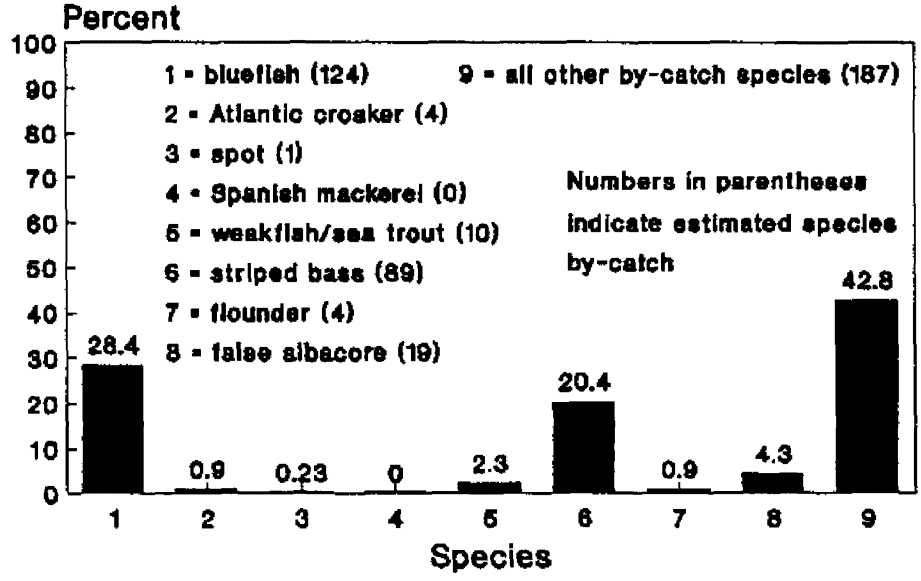
Total number of menhaden = 2,318,000
Total by-catch = 53 fish or shellfish

Figure 10. Estimated by-catch composition during October, 1992



Total number of menhaden = 2,195,000
Total by-catch = 937 fish or shellfish

Figure 11. Estimated by-catch composition during November, 1992



Total number of menhaden = 4,281,000
Total by-catch = 437 fish or shellfish

At-sea vs. dockside sampling:

If dockside inspections yielded results equivalent to at-sea inspections, it would be possible to design a more cost efficient and effective inspection program to assess by-catch. Analysis of the samples containing by-catch revealed that by-catch estimates based on at-sea samples were generally higher than by-catch estimates obtained from dockside samples. An F-test of the equality of the mean proportions for dockside vs. at-sea samples rejected equality at the 5 percent level ($F_{1,87}$ = 12.73). The hypothesis that the dockside by-catch proportion equalled zero was strongly rejected (t_{44} = 5.57). The hypothesis that the by-catch proportion for at-sea samples equalled zero was also strongly rejected (t_{42} = 4.58). The alternative hypothesis that the by-catch proportion exceeded 0.01 was also strongly rejected by a one-tailed t-test. Alternatively, the by-catch proportion was statistically determined to be less than 0.01 (t_{87} = -3.12).

Lilliefors test--the Lilliefors test is similar to the Kolmogorov-Smirnov test for normality but applies to sample data--that the percentage by-catch was normally distributed--a requirement for analysis of variance (ANOVA) and t-tests, however, rejected the null hypothesis (maximum difference = 0.368 vs. critical value at 5% level of significance (LOS) = 0.094). The Lilliefors test statistic value is defined as the greatest absolute difference between hypothesized cumulative distribution function and the sample distribution function evaluated in terms of normalized variates (Lilliefors 1967). Similarly, Bartlett's test for homogeneity of variances for dockside and at-sea samples indicated strong heteroscedasticity--unequal variances between dockside and at-sea samples (chi-square with one degree of freedom (d.f.) = 251.65). Even after numerous transformations of the percentage of by-catch data, heteroscedasticity could not be mitigated. Non-parametric

analogs of ANOVA (Kruskal-Wallis) and independent t-tests (Mann-Whitney U) were used to further examine the equality of mean percentages between dockside and at-sea samples.

The Kruskal-Wallis test strongly rejected the null hypothesis of equality of mean percentage of by-catch between dockside and at-sea samples (chi-square with 1 d.f. = 66.46; critical value = 3.84). A modified Mann-Whitney U test in which mean percentage by-catch for dockside and at-sea samples equalled zero rejected the null hypothesis of equality of mean percentage by-catch (dockside: Z-score = 6.714; at-sea: Z-score = 5.713). Similar tests that the by-catch equalled 0.01 were also rejected by the Mann-Whitney U tests. Statistical and mathematical analyses, thus, suggest that by-catch proportions were well below 1.0% in that portion of the Atlantic menhaden fishery sampled during 1992.

Geographical area differences:

Although samples or area fished could readily be grouped into 41 distinct areas, the data were pooled and examined relative to four groupings: (1) offshore--Virginia and North Carolina, (2) mouth of Chesapeake Bay, (3) Chesapeake Bay, and (4) tributaries or river mouths. Since the data were not normally distributed, however, the standard analysis of variance could not be used to test equality of mean percentage by-catch among the various areas. Therefore, the non-parametric Kruskal-Wallis test was used.

Overall, the null hypothesis that the mean percentage by-catch was equal for the four selected areas could not be rejected by the Kruskal-Wallis (chi-square with 3 d.f. = 6.26 vs. critical value at 5% LOS = 7.81). This does not imply that there are no differences among some of the areas. In order to accept the null hypothesis that there are no differences among the four fishing areas, there must be no differences between any two fishing areas.

Interestingly, differences in mean percentage by-catch were detected between river mouths or tributaries and the other three areas: (1) tributaries vs. offshore--chi-square with 1 d.f. = 4.48; (2) tributaries vs. Chesapeake Bay--chi-square with 1 d.f. = 4.29; (3) tributaries vs. mouth of Chesapeake Bay--chi-square with 1 d.f. = 4.35). The null hypothesis of equality of mean percentage by-catch could not be rejected with respect to the other three fishing areas.

Temporal or seasonal differences in by-catch:

Analysis of the by-catch of recreational species--species identified in tables 5 and 6--by month suggested the possibility of strong seasonality in by-catch. A Kruskal-Wallis test that the mean percentage by-catch was equal for all months could not reject the null hypothesis of equality (chi-square with 5 d.f. = 4.15). The null hypothesis of equality of mean percentage by-catch by month, however, was rejected when analyzed relative to dockside and at-sea samples. The chi-square for the Kruskal-Wallis test for equality relative to dockside samples was 11.94 with 5 degrees of freedom; the chi-square relative to at-sea samples was 0.53 with 2 degrees of freedom.

Further analysis of by-catch by species suggested that the monthly by-catch was different for bluefish and Spanish mackerel. The null hypothesis of monthly equality of mean percentage by-catch could not be rejected for the other species. The same results were obtained for the dockside samples; that is, monthly mean percentage by-catch of bluefish and Spanish mackerel were different by month. Examination of the at-sea by-catch suggested that the monthly mean percentage by-catch was different only for striped bass (chi-square with 3 d.f. = 8.48 vs. critical value of 5.99 at 5% level of significance).

Problems and limitations of analysis:

Two major problems of statistical analysis with the data were zero values and percentage values. The percent by-catch was bounded between 0 and 100.00%, and thus, was censored (i.e., data were restricted to a lower and/or upper bound). In this case, the percentage by-catch cannot be normally distributed, and conventional parametric tests based on the normal distribution are not valid. The non-parametric tests used in this study do not require the by-catch data to be normally distributed, and thus, offer a valid method of analzing the data collected for this study.

An alternative parametric approach is Tobin's (1958) model which specifically recognizes censored dependent variables. An analysis of variance equivalent approach given censored data and non normality of the distribution could possibly be developed. Development of the algorithm, however, is thought to be well beyond the scope of this project. A simple Tobin model in which percentage of by-catch between dockside and at-sea samples was examined suggested no difference in mean values; the ANOVA and Kruskal-Wallis tests both rejected equality of mean values. Similarly, a test of monthly equality of mean percentage by-catch indicated that by-catch was different only in August.

SUMMARY AND CONCLUSIONS

Results of this study indicated that by-catch in the Atlantic menhaden fishery in the Chesapeake Bay and mid-Atlantic coastal area was well below the legal limit (1%) in terms of weight or number of fish during the 1992 study period. A total of 16,145,400 standard menhaden (10.8 million pounds) were sampled either at the dock or on-board commercial menhaden fishing vessels. A total of 1,413 fish or shellfish other than menhaden were observed in the actual harvest. Using dockside and at-sea sample information, however, by-catch was estimated to equal 6,617 individuals. Statistical examination of by-catch during off-loading suggested that the mean proportion of by-catch was not statistically equal to zero; it was, however, well below 1.0 percent. A similar examination of by-catch during harvesting rejected the hypotheses that the proportion of by-catch equalled zero or one percent. By-catch was determined to equal approximately 0.041% (0.04097% of the total catch or 0.04098% of the total menhaden catch) and was statistically less than 1.0%.

By-catch of major recreational species in descending order of number of by-catch caught--bluefish (1,206), Spanish mackerel (1,182), Atlantic croaker (747), weakfish (329), flounder (260), spot (137), striped bass (97), and false albacore (30)--accounted for 0.025% of the total catch. Alternatively, recreational species accounted for approximately 60.2% of the total by-catch. In order of number caught, bluefish accounted for 1,206 of the estimated 6,617 fish or shellfish harvested as by-catch; this equates to one bluefish for every 13,387 menhaden. Spanish mackerel was the second major recreational species harvested; a total of 1,182 Spanish mackerel were harvested with the 16.1 million menhaden. Relative to the harvest of menhaden, one Spanish mackerel was harvested for every 13,659 menhaden. Striped bass, a major game fish in the Chesapeake Bay area, ranked seventh

in terms of by-catch. A total of 97 striped bass were estimated as being harvested; thus, for every 166,493 menhaden harvested, one striped bass was harvested. Harvests of striped bass were returned to the water by vessel crew regardless of their condition; the mortality on those bass returned alive could be not estimated.

Most by-catch relative to the number of menhaden harvested occurred during August. A total of 43 different types of fish, other than menhaden, were harvested during the study period. By-catch accounted for 0.14% of the total catch during August. The month of October had the second highest by-catch relative to total catch and accounted for 0.04% of the total harvest. By-catch of the eight recreational species listed in tables 5 and 6 during August accounted for 0.09% of the total number of menhaden observed in dockside and at-sea samples. Bluefish was the major recreational species harvested with menhaden in all months except August and November; Spanish mackerel was the dominant recreational species harvested during August. Striped bass were not harvested until October. One striped bass was observed in October, and 10 striped bass were observed during November. The estimated number of striped bass harvested in October and November were 8 and 89; the corresponding number of standard menhaden observed during harvesting operations were 2.2 and 4.3 million fish, respectively.

Interestingly, 11 and 19 false albacore were harvested offshore of North Carolina during October and November. All 30 false albacore were harvested during offshore menhaden fishing. Given the size and speed of false albacore, their capture as by-catch was not expected. Their capture as by-catch raises the important issue of whether or not sampling should have been increased for offshore operations and off of North Carolina. The total number of samples from North Carolina offshore areas was 8. Available data

were inadequate to address whether or not offshore areas of North Carolina should have been sampled more frequently in order to assess the by-catch for North Carolina areas. Given that red drum, bluefish, Spanish mackerel, porposes, and sea turtles frequent the North Carolina offshore areas, increased at-sea sampling of North Carolina offshore areas would have certaintly benefitted this study.

During the course of the study, no marine mammals or other protected species were ever harvested or even observed. This was an important observation since the National Marine Fisheries Service has responsibility for administering a protected species program. It also was an important observation for industry since many fisheries are subject to regulations which require turtle excluder devices. Results from this study suggest the Atlantic menhaden industry in the mid-Atlantic region did not capture any marine mammals, sea turtles, or protected species during 1992.

Evaluation of at-sea and dockside samples indicated that the most accurate assessment of by-catch must be done at-sea. There was too much of a discrepancy between dockside and at-sea counts of by-catch; at-sea by-catch was typically higher. Moreover, dockside sampling does not provide as accurate information on fish harvested and discarded as available from at-sea sampling. Dockside sampling, even if done according to proper statistical criteria, would still not likely provide accurate information on actual by-catch (fish or all animals other than menhaden harvested during fishing activities) particularly larger animals such as sharks or rays. This is partly because of the fact that as fish exit the de-watering tumbler, they are often many layers deep and much by-catch passes unobserved. Dockside sampling, therefore, while cost effective, does not appear to offer an accurate approach for determining by-catch.

Another aspect of the project was the evaluation of using video technology to assess by-catch. Unfortunately, current video technology did not appear to offer a valid approach for accurately assessing by-catch. It was difficult to review the film and determine the species and number of by-catch. Moreover, counts of total menhaden still had to be maintained to assess by-catch relative to number of menhaden harvested. Video technology was useful, however, for identifying the species of severely mutilated fish or shellfish.

It is important to stress, however, that these conclusions, as well as other results presented in this report, were based on a very limited sample and only for one year--1992. By-catch profiles and percentages could very well be quite different given different relative abundances of species, and different relative abundances could change the level and composition of by-catch.

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