S E D A R

Southeast Data, Assessment, and Review

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Commercial Harvest and Catch-at-Age
for Atlantic Menhaden

Prepared by
Joseph W. Smith and Douglas S. Vaughan
NOAA Fisheries
Beaufort, North Carolina

Jeffrey Brust
New Jersey Division of Fish and Game
Trenton, New Jersey

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SEDAR
The South Atlantic Fishery Management Council
4055 Faber Place #201
North Charleston, SC 29405
(843) 571-4366

3.0 Commercial Fisheries Background

The commercial fisheries for Atlantic menhaden consist primarily of directed purse-seine fisheries for reduction and bait, and are nearly the exclusive sources of fishery-dependent data for the stock. As reduction landings have declined in recent years, menhaden landings for bait have become relatively more important to the coastwide total landings of menhaden. A mixed species aggregate by-catch of menhaden from pound nets, gill nets, and trawls also exists in several states, however, the landings are minor compared to the purse-seine fisheries.

Landings at the menhaden reduction plants have been reported since 1940 and biostatistical samples of the catches have been continuously collected since 1955. A chronology of menhaden plant activity since 1955 is shown in **Table 3.1**. As the directed bait fishery for menhaden has grown in recent years, greater emphasis has been placed on acquiring more representative port samples and more accurate landings records from this segment of the fishery (**Figure 3.1**). Deck logbooks (Captain's Daily Fishing Reports, or CDFRs) maintained by menhaden reduction vessels have helped reduce some sampling biases inherent in harvesting menhaden on distant fishing grounds. Recreational fishermen also catch Atlantic menhaden as bait for various game fish; however, the quantities removed are estimated to be minimal.

3.1 Reduction Fishery

The reduction fishery for Atlantic menhaden employs purse-seine gear to encircle schools of menhaden. Two purse boats (ca. 40 ft long), each holding one-half of the seine, are deployed from a large carrier vessel (ca. 160-200 ft long; also called a 'steamer'). A pilot in a spotter aircraft directs the purse boats via radio to the fish schools and assists in setting the net. The fish are 'hardened' into the bunt of the net, and then pumped onboard the steamer. The contemporary purse-seine fleet averages about 5 sets per fishing day (Smith 1999). At the end of the fishing trip, the catch is pumped at dockside into the fish factory, where it is reduced into the three main processed products of the menhaden industry - fish meal, fish oil, and fish solubles.

Prior to World War II, most menhaden was dried and sold as 'fish scrap' for fertilizer. By the early 1950s, the demand for fish meal as an ingredient in poultry feeds increased as the 'fryer' chicken industry expanded. During the latter half of the twentieth century, menhaden meal also became an integral component in swine and ruminant feeds. By the 1990s, menhaden meal was being milled in greater quantities into aquaculture feeds. Historically, most menhaden oil was exported to Europe where it was processed into cooking oil or margarines. Since the late 1990s, greater quantities of menhaden oil, a high-grade source of omega-3 fatty acids, are being utilized by the pharmaceutical and processed-food industries of the U.S.

Fishery-dependent data for the Atlantic menhaden reduction fishery are maintained by NOAA Fisheries at the Center for Coastal Fisheries and Habitat Research in Beaufort, NC (Beaufort Laboratory) in three large data sets. Commercial catch and effort data (**Table 3.2**) for the reduction fishery are available from 1940 through 2008. Contemporary landings data are supplied to the Beaufort Laboratory by the menhaden industry on a monthly basis; catches are

enumerated as daily vessel unloads. The biostatistical data, or port samples, for length and weight at-age are available from 1955 through 2008, and represent one of the longest and most complete time series of fishery data sets in the nation. The CDFRs (daily logbooks) itemize purse-seine set locations and estimated catch, and vessel compliance is 100%. CDFR data for the Atlantic menhaden fleet are available for 1985-2008.

3.1.1 Reduction Fishery Overview

Some fishing for Atlantic menhaden has occurred since colonial times, but the use of purse-seine gear began in New England about 1850 (Ahrenholz et al. 1987). No longer bound to shore-based seining sites, the purse-seine fishery spread south to the Mid-Atlantic states and the Carolinas by the late 1800s. Purse-seine landings reached their zenith in the 1950s, and peak landings of 712,100 metric tons occurred in 1956; extant menhaden factories at the time, over 20 (ASMFC 2004a), ranged from northern Florida to southern Maine (**Table 3.1**). In the 1960s, the Atlantic menhaden stock contracted geographically, and many of the fish factories north of Chesapeake Bay closed because of a scarcity of fish (Nicholson 1975).

During the 1970s and 1980s, the menhaden population began to expand primarily because of a series of above average year classes entering the fishery. Adult menhaden were again abundant in the northern half of their range, that is, Long Island Sound north to the southern Gulf of Maine. By the mid-1970s, reduction factories in Rhode Island, Massachusetts, and Maine began processing menhaden again (**Table 3.1**). In 1987, a reduction plant in New Brunswick, Canada, processed menhaden harvested in southern Maine, but transported by steamer to Canada. Beginning in 1988, Maine entered into an Internal Waters Processing venture (IWP) with the Soviet Union which brought up to three foreign factory ships into Maine territorial waters (< 3 miles from the coast). American vessels harvested the menhaden and unloaded the catch for processing on the factory ships. By 1989 all shore-side reduction plants in New England had closed mainly because of odor abatement issues with local municipalities. A second Canadian plant in Nova Scotia also processed Atlantic menhaden caught in southern Maine in 1992-93. The Russian-Maine IWP and the Canadian plants last processed menhaden during summer 1993.

During the 1990s the Atlantic menhaden stock contracted again (as in the 1960s) mostly due to a series of poor to average year classes. Fish became scarce again north of Long Island Sound. After 1993, only three factories remained in the fishery, two factories in Reedville, VA, and one factory in Beaufort, NC. Virginia vessels (about 18-20) ranged north to New Jersey and south to about Cape Hatteras, NC, while the North Carolina vessels (generally two) fished mostly in North Carolina waters.

Major changes in the industry began following the 1997 fishing season, when the two reduction plants operating in Reedville, VA, consolidated into a single company and a single factory; this significantly reduced effort and overall production capacity. Seven of the 20 vessels operating out of Reedville, VA, were removed from the fleet prior to the 1998 fishing year and 3 more vessels were removed prior to the 2000 fishing year, reducing the Virginia fleet to 10 vessels during 2000 to 2009 (although an eleventh vessel at Reedville fished sparingly during fall 2005). Up to three purse-seine vessel for bait in Northern Neck, VA, during recent years unloaded their

catch sporadically at the Reedville fish factory for reduction when bait markets were 'soft' or individual fish were too small for bait.

Another major event within the industry occurred in winter 2004-2005 when the fish factory at Beaufort, NC, closed permanently, and the property was sold to developers. Thus, beginning in 2005 the lone, surviving menhaden plant was in Reedville, VA, with about ten vessels.

Summer 2005 was noteworthy in that it was the first time in twelve years (since 1993 when the IWP last operated) that adult Atlantic menhaden were abundant north of Long Island Sound. Several New England states recorded significant menhaden-for-bait landings for the first time in over a decade. This trend in an abundance of adult menhaden in New England continued through 2008.

The regulatory trend of Atlantic coastal states relative to reduction purse-seine fishing for menhaden has been one of progressive area closures. Since New Jersey closed its territorial sea to reduction purse-seine vessels in 2002, the Atlantic menhaden reduction fishery has essentially become a two-state fishery. Within the geographic range of the current menhaden reduction fleet, Virginia and North Carolina are the only states which permit menhaden reduction purse-seine fishing. Nevertheless, in 2008 the North Carolina legislature approved a bill prohibiting purse seining for menhaden along the beaches of Brunswick County, the southernmost county on the North Carolina coast. The Virginia fleet catches Atlantic menhaden off the coasts of Maryland, Delaware, and New Jersey, however, these catches are beyond three miles from shore and in the U.S. EEZ where there are no restrictions on catch.

Beginning in 2006, the ASMFC (Addendum III of the Atlantic menhaden FMP) approved a 5-year annual 'cap' (2006-2010) of 109,020 mt on removals of Atlantic menhaden for reduction from Chesapeake Bay. Within a given year, there are penalties for an overage, and allowances for an underage. Ostensibly, the cap was invoked to prevent expansion of the fishery and to allow time for scientific studies to address research priorities.

3.1.2 Reduction Fishery Landings

Landings of Atlantic menhaden for reduction are reported to the Beaufort Laboratory monthly during the fishing year. Daily vessel unloads are provided in thousands of standard fish (1,000 standard fish = 670 lbs), which are converted to kilograms. Between 2006 and 2008 the reduction fleet (ca. 10 vessels) unloaded an average of 685 times during each fishing year; the average unload per vessel was 232 mt.

Landings and nominal fishing effort (vessel-weeks, measured as number of weeks a vessel unloaded at least one time during the fishing year) are available since 1940 (**Table 3.2**). Landings rose during the 1940s (from 167,000 to 376,000 t), peaked during the late 1950s (> 600,000 t for four of five years), and then declined to low levels during the 1960s (from 576,000 t in 1961 to 162,000 t in 1969). During the 1970s the stock rebuilt (landings rose from 250,000 t in 1971 to 376,000 t in 1979) and then maintained intermediate levels during the 1980s (varying

between 238,000 t in 1986 when fish meal prices were extremely low to 418,600 t in 1983). Landings during the 1990s declined from 401,200 t in 1990 to 171,200 t in 1999.

By 1998, the fishery had contracted to only two factories, one in VA and one in NC. Landings dipped to 167,200 t in 2000, rose to 233,700 t in 2001, and then varied annually from 174,000 t to 166,100 to 183,400 t through 2004. Landings during 2000-04 when the fishery was relatively stable with two plants and about twelve vessels averaged 184,900 t. During 2005 to 2008 only the factory in Virginia operated and landings ranged 141,100 mt (2008) to 174,500 mt (2007), and averaged 155,000 mt. Reduction landings in 2008 accounted for 75% of total coastwide landings of Atlantic menhaden (bait and reduction combined); this is down from 80% in 2007 and 86% in 2006.

During the 1980s, the menhaden industry suggested that a "topping off" bias occurred in the NOAA Fisheries' sampling routine. Virginia vessels, returning from more northerly waters with presumably larger and older fish, often made one final purse-seine set on relatively smaller and younger fish in Chesapeake Bay to "top off" the fish hold. Since port agents sample the top of the hold and hence the final set of the trip, larger and older fish could have been under-represented in the catch-at-age matrix. Annual CDFR data sets for 1985-2008 were used to better apportion weekly-plant catches by fishing area and to correct for this bias. Coastwide, only minor differences were found in catch-at-age estimates used for management. Thus, based on temporal and areal distribution of current and historical port samples for the reduction fishery, and the complete accounting of landings by the menhaden companies, biases in the reduction fishery sampling data set are believed to be minimal.

Smith (1999) summarized the distribution of Atlantic menhaden purse-seine catches and sets during 1985-1996 using the CDFR data sets for the Virginia and North Carolina vessels. He found that on average the fleet (up to 22 vessels) made 10,488 sets annually. Virginia vessels made at least one set on 67-83% of the available fishing days between May and December. In most years, five was the median number of sets attempted each fishing day. Median catch per set ranged from 15-30 t annually. Spotter aircraft assisted in 83% of the sets. Regionally, median catch per set was: 24 t off Rhode Island, New York, New Jersey and Delaware; 23 t off the ocean beaches of Virginia; 18 t in the Virginia portion of Chesapeake Bay; 26 t off North Carolina in summer; and 38 t off North Carolina in the fall fishery.

In recent years, median catches in Chesapeake Bay have been near equivalent at 21 mt in 2006, and 22 mt in 2007 and 23 mt in 2008. Between 2000 to 2005 when the reduction fishery contracted to only one fish plant and about ten vessels in Virginia, removals from Chesapeake Bay by the reduction fleet averaged 104,400 t annually, a 28% decline versus 1990-99 when removals from the Bay averaged 145,700 t per year.

3.1.3 Age and Length Composition

Biological sampling for the menhaden purse-seine fishery is based on a two-stage cluster design and it is conducted over the range of the fishery, both temporally and geographically (Chester 1984). The number of fish sampled in the first cluster was reduced during the early 1970s from

20 fish to 10 fish to increase sampling of the second cluster (number of purse-seine sets). Port agents randomly select vessels and at dockside retrieve a bucket of fish (first cluster) from the top of the vessel's fish hold. The sample is assumed to represent fish from the last purse-seine set of the day, not the entire boat load or trip. The agent ascertains from the crew the location and date of the last set. From the bucket the agent randomly selects ten fish (second cluster), which are measured (fork length in mm), weighed (grams), and have scales removed for ageing. June and Roithmayr (1960) performed detailed examinations (validation and verification) of Atlantic menhaden scales and determined that rings on the scales are reliable age marks (more discussion in S20DW04).

Detailed sampling of the reduction fishery permits landings in biomass to be converted to landings in numbers at age. For each port/week/area caught, biostatistical sampling provides an estimate of mean weight and the age distribution of fish caught. Hence, dividing landings for that port/week/area caught by the mean weight of fish allows the numbers of fish landed to be estimated. The age proportion then allows numbers at age to be estimated. Adjustments in these estimates (using CDFRs) are made to account for potential bias resulting from "topping off" by vessels returning to Chesapeake Bay from outside and taking a final set before offloading (Chester 1984; Smith 1999b). Developing the catch matrix at the port/week/area caught level of stratification provides for considerably greater precision than is typical for most assessments.

About 2,650 Atlantic menhaden from the reduction fishery have been processed annually for size and age composition over the past three fishing seasons, 2006-08 (**Table 3.3**). In comparing menhaden sampling intensity to the rule-of-thumb criteria used by the Northeast Fisheries Science Center (e.g. <200 t/100n), this sampling level might be considered low, although the results of Chester (1984) suggest this sampling level is relatively high.

In two of the past three years, age-2 Atlantic menhaden have comprised 60% or more of the total numbers of fish landed (**Table 3.4**). In 2006 the age composition of the coastwide landings for reduction was 1% age-0's, 40% age-1's, 40% age-2's, and 19% age-3+'s; in 2007, it was <1% age-0's, 26% age-1's, 65% age-2's, and 8% age-3+'s; and in 2008, it was 1% age-0's, 9% age-1's, 68% age-2's, and 22% age-3+'s. Overall mean weights of Atlantic menhaden for reduction in port samples for 2006 through 2008 were 225 g, 196 g, and 246 g, respectively.

3.2 Bait Fishery

Atlantic menhaden are harvested for bait in almost all Atlantic coast states and are used for bait in crab pots, lobster pots, and hook and line fisheries (both sport and commercial, often as ground chum). A specialized use involves live menhaden as bait for coastal pelagic fishes (ASMFC 2001); however, no data are available to quantify these landings, which are usually taken by cast net or beach seine for personal bait or supplied to tournaments. Information on the harvest and use of menhaden for bait is often difficult to obtain because of the nature of the bait fisheries and the various data collection systems. Bait harvest comes from directed fisheries, primarily small purse seines, pound nets, and gill nets, and by-catch in various food-fish fisheries, such as pound nets, haul seines, and trawls.

Since the mid-1990s the Atlantic Menhaden Technical Committee (AMTC), and its predecessor the Atlantic Menhaden Advisory Committee (AMAC), recognized the increasing importance of landings of Atlantic menhaden for bait. Consequently, the AMTC has strived to better quantify bait landings through better reporting and to characterize bait landings through better port sampling information. The AMTC has determined that accurate bait landings are only available since 1985. The AMTC continues to develop and update the reported annual coastal bait landings for all gear types.

3.2.1 Bait Fishery Overview

Commercial landings of menhaden for bait occur in almost every Atlantic coast state. The bait fishery utilizes a wide variety of gear and fishing techniques. Landings come from both directed menhaden fisheries, which make up the majority of the bait landings, and from non-directed, by-catch fisheries.

As mentioned earlier, the presumed growth of the Atlantic coast bait fishery must be tempered by the knowledge that systems for reporting bait landings have historically been incomplete, particularly for Atlantic menhaden. In most cases, recent landings estimates are more accurate, although for some states bait landings may still be underestimated. The nature of the fishery and its unregulated marketing are causes of the under-reporting problem. There are some well-documented, large-scale, directed bait fisheries for menhaden using gears such as purse seines, pound nets, and gill nets. There are also many small-scale bait fisheries and by-catch fisheries whose catch may be under-reported. Menhaden taken as by-catch in other commercial fisheries is often reported as "bait" together with other fish species. Some "over-the-side" sale of menhaden for bait by commercial fishermen may go unreported. Common practices such as utilizing menhaden for bait or chum in sport fishing tournaments is difficult to estimate when quantity sales are made to individual marinas and fishing clubs (ASMFC 2001).

Despite problems associated with estimating menhaden bait landings, data collection has improved in many areas. Some states license directed bait fisheries and require detailed landings records. Catch-per-unit-effort (CPUE) data, pounds caught per hour set, and pounds caught per yard of net set are also reported for directed gill net fisheries in some states.

In New England, purse-seine landings in Maine, Massachusetts, and Rhode Island account for the majority of the recorded bait landings. An ocean trap net fishery has historically operated off Rhode Island and Massachusetts. In New Hampshire and Connecticut, smaller directed gill net fisheries are well-regulated and monitored. The bulk of menhaden landings for bait in New England are utilized in the lobster fishery.

New Jersey dominates current menhaden bait landings among the Mid-Atlantic states. Within New Jersey, purse-seine gear accounts for over 95% of bait landings. New Jersey requires reports of catch by fishing area for licensed bait purse-seine vessels. Historically, pound nets and gill nets also contributed to bait landings in New York and New Jersey. Delaware closely regulates its directed gill net fishery, obtaining detailed catch/effort data each year (ASMFC 2001).

Virginia snapper rigs (small purse seines) dominate (about 85%) the reported menhaden bait landings in Chesapeake Bay, as documented by the Captain's Daily Fishing Reports beginning in 1998. Pound net landings contribute significantly in Maryland, Virginia, and the Potomac River. Most of the catch is used in the blue crab pot fishery (ASMFC 2001).

Bait harvests in the South Atlantic were historically dominated by landings in Florida and North Carolina. Some landings in North Carolina are reported directly, while the rest are estimated from fishery-dependent sampling. The principal use for menhaden as bait in North Carolina is in the blue crab pot fishery. South Carolina and Georgia have no directed menhaden fisheries; shrimp trawl by-catch and cast nets supply menhaden to crab potters and sport fishermen in those states. Florida's East coast had substantial menhaden landings for bait from gill nets and purse seines prior to the implementation of a net ban in 1995 (ASMFC 2001).

3.2.2 Bait Landings

Coastwide bait landings of Atlantic menhaden have gradually increased from 1985 to present (**Table 3.2**). During 1985 to 1989 bait landings averaged 30,485 mt, and landings peaked at 36,257 mt in 1988. During the 1990s bait landings averaged 32,425 mt, with peak landings of 39,194 mt in 1998. Between 2000 to present average bait landings for the coast increased again to 35,967 mt. After falling to 26,768 mt in 2006, bait landings rebounded to 44,563 mt in 2007, and rose further to peak landings for the time series of 46,674 mt in 2008.

In recent years (2006-2008) bait landings have averaged 20% of the total coastwide Atlantic menhaden landings (including landings for reduction) (**Figure 3.1**). This is up from an average of 11% of total landings for the period 1985-2000. The relative increase of bait as a percent of coastal landings since the late 1990s is attributed to better data collection in the Virginia 'snapper rig' bait seine fishery, and the decline in coastal reduction landings because of plant closures.

Bait landings during 1985 to 1993 were widely distributed along the coast with major contributions from Maine, Massachusetts, Rhode Island, New Jersey, the PRFC, Virginia, North Carolina, and Florida (**Figure 3.2**). During the mid-1990s contributions from the New England states and Florida fell sharply. The decline in landings from New England waters was because of the scarcity of fish from about Long Island Sound and north after 1993; the decline in landings in Florida was no doubt due to the state's 'net ban' in 1995. From about 1998 to present coastwide bait landings have been dominated by contributions from two areas, namely, New Jersey and Chesapeake Bay; within the latter area, landings in Virginia dominate over those from Maryland and the PRFC. Thus, bait landings in Chesapeake Bay (all gears combined) beginning in 1998 accounted for on average 63% of coastwide bait landings. Bait landings in New Jersey for the same time period accounted on average for 32% of coastwide bait landings.

In terms of gear, on average purse seines accounted for 78% of all coastwide bait landings in recent years (2001-2008). Purse-seine fisheries for bait operate predominately in New Jersey and Virginia, with recent contributions from Narragansett Bay (Rhode Island and Massachusetts) and Maine (2008). A small purse-seine fishery for bait existed in North Carolina, but it ceased

operation after 2003. Within Virginia in recent years (2000-2008), purse seines on average accounted for 87% of the bait landings by gear; likewise in New Jersey, on average purse seines accounted for 97% of that state's bait landings by gear (2000-2008).

Pound net and small scale directed gill net fisheries for menhaden as bait exist in many states. These fisheries account for the majority of the *remaining* bait landings coastwide. Additionally, menhaden for bait are taken as an aggregate by-catch in other coastal states by a variety of gears such as trawls, haul seines, traps, and cast nets.

To better document menhaden bait landings by purse seines in Virginia (snapper rigs), the AMAC requested that Virginia bait vessels voluntarily complete CDFRs during 1995-2001. With the adoption of Amendment 1 to the FMP, Virginia snapper rigs, beginning in 2002, were required to report their daily catches on CDFR forms, which are compiled at the Beaufort Laboratory. Bait vessels in New Jersey comply with Amendment 1 by completing daily logs documenting the amount and location of menhaden harvested to the NJ Division of Fish and Wildlife. The former bait purse-seine fishery in North Carolina reported daily catch activity on a state trip ticket to the NC Division of Marine Fisheries. Purse-seine vessels operating Narragansett report their daily catches to the RI Department of Environmental Management; similarly, purse-seine vessels operating in Maine waters report catches to the ME Department of Marine Resources. Recently, bait landings are again expanding in the New England area.

In the 2006 Atlantic Menhaden Assessment Update, concern was raised about unreported landings from Virginia bait purse seines during 1993-1997. As an alternate data input for subsequent model runs, Virginia bait landings for 1993-1997 were linearly interpolated from estimated values for 1992 and 1998. Thus, a second set of bait landings (alternate) was developed for analysis.

Staff at the Beaufort Laboratory recently 'discovered' daily catch records (= CDFRs) which were completed by two of the three or four Virginia 'snapper rigs' operating in 1995-1997. The data were probably overlooked because the entire 'snapper rig' fleet had not yet (not until 1998) enrolled in the voluntary CDFR reporting program to document their daily landings. For this assessment a preferred set of Virginia bait landings for 1995, 1996, and 1997 incorporates:

- reported landings by two vessels for all three years,
- average landings of a third vessel for 1999 and 2000, years when it joined the voluntary reporting system for all three years, and
- estimated landings for a fourth vessel, which only operated in 1995, based on reported landings of a similar-sized vessel which did report in 1995.

Landings for 1993 and 1994 are linearly interpolated from estimated values in 1992 and 1995.

3.2.3 Age and Length Composition

Prior to about 2006, biological sampling of bait landings had mostly been focused on directed-bait, purse-seine vessels in North Carolina, Virginia, and New Jersey. In recent years additional effort has been made to acquire port samples from bait purse seines and pound nets in Narragansett Bay and purse seines in southern Maine (**Table 3.5**). Protocols for acquiring size-at-age data from the bait fisheries are similar to sampling procedures for the reduction fishery. In Virginia, a federal port agent meets bait vessels at dockside and then process samples for size and age composition; samples from pound nets are made at dockside. In New Jersey most menhaden bait samples are acquired and frozen by the bait companies. New Jersey Fish and Wildlife personnel batch process the bait samples for length and weight; scale samples are aged at the Beaufort Laboratory. Likewise in Rhode Island, Massachusetts, and Maine, state fisheries personnel acquire bait port samples at dockside, process specimens for length and weight, then they ship scale samples to the Beaufort Laboratory. Sampling for bait has been at a similar level to that of the reduction fleet for North Carolina, Virginia, and New Jersey. Sampling intensity has increased recently in Massachusetts, Rhode Island and, Maine.

Sampling of the bait fishery for size and age has generally improved since 1988, especially beginning in 1994 when the AMAC emphasized greater biological sampling of the bait fishery (**Table 3.5**). Because of the limited age composition data, characterizing the age distribution of the removals by the bait fishery has been done at the region/year level, rather than port/week/area fished used for the reduction fishery. Four regions are defined as follows: (1) New England (Connecticut and north); (2) Mid-Atlantic (coastal Maryland, and Delaware through New York); (3) Chesapeake Bay (including coastal waters of Virginia); and (4) South Atlantic (North Carolina to Florida). Recently, landings have been primarily from the Mid-Atlantic and Chesapeake Bay regions (**Figure 3.3**). When the number of samples for a given region and year was less than 50, data were pooled across the years available and substituted for that year. For the New England region, data for 1986-2008 were pooled and used for individual years 1986-1993 and 1996-2006. Data for 1985 was kept separate because these were particularly small fish. For the Mid-Atlantic region, data for 1994-2008 were pooled and substituted for individual years 1985-1993 and 2004-2005. For the Chesapeake Bay region, data for 1992-2008 were pooled and substituted for individual years 1985-1994. For the South Atlantic region, three temporal periods were used to pool data: (1) 1985-1989, (2) 1990-1996, and (3) 1997-2008. Years within the respective temporal periods for which substitution was necessary were 1988-1990, 1992, 1996, 1999-2001, and 2003-2008. The resultant catch-at-age matrix for the bait fishery is shown in **Table 3.6**. So as not to completely ignore the small amount of recreational catches (see next section), the catch matrix was inflated to reflect these additional landings. The inflation was based on a regional basis.

From 1985-2000, 75% of the bait landings were age-2 and -3 menhaden (45% and 30%, respectively), with ages-1 and -4 significantly contributing to the landings (11% and 13%, respectively). Recently (2001-2008), age-2 and -3 menhaden comprised over 84% of the bait landings (54% and 31%, respectively), with age-1's comprising 8% and age-4's comprising 7%. Lower percentages for age-3 menhaden were obtained for the reduction fishery, ranging between 8% for 1985-2000 and 15% for 2001-2008.

3.3 Recreational Catches (MRFSS), 1981-2008

It was brought to our attention recently that the Marine Recreational Fisheries Statistics Survey (MRFSS) contained estimated Atlantic menhaden catches. These were downloaded from

http://www.st.nmfs.noaa.gov/st1/recreational/queries/index.html

using the Custom Query option.

Estimated recreational catches are reported as number of fish harvested (Type A+B1) and released alive (Type B2) (**Tables 3.7 and 3.8**, respectively). The fundamental cell structure for estimating recreational catches is by state [Maine – Florida], mode of fishing [beach/bank, man made, shore, private/rental, charter], fishing area [inland, ocean (<=3mi), ocean (>3mi)], wave [six 2-month periods]. To determine total harvest, an estimate of release mortality to apply to the B2 caught fish is necessary. Under the assumption that many of these recreationally caught fish was by castnet, the judgment of the data workshop participants was that 50% was a reasonable value. Based on this value, the total number of fish dying due recreational fishing (A+B1+0.5*B2) is summarized in **Table 3.9**.

There are additional complications for estimating total biomass of fish dying due to recreational fishing. Because observed fish weights at this basic cell level are not always available for converting landings in numbers to landings in weight, or sample sizes are very small resulting in spurious estimates, reporting harvest (A+B1) in weight typically underestimates the actual harvest weight. Also, catches of released alive (B2) fish are only available in numbers. To provide estimates of harvest (Type A+B1) in weight, the catch records are retained at the basic cell level for which both harvest in numbers and harvest in weights are available. These landings are then pooled by region (NE, MA, SA) and the ratio used to obtain an average weight by region. Because it is remarkable that anglers would release menhaden, and the likelihood of menhaden surviving is negligible, we make the assumption that the size (mean weight) of the B2 caught fish is similar to that of the A+B1 fish and combine them in calculating our harvest in weight. Thus, the average weight was applied by region to total harvest (A+B1+0.5*B2) in numbers to obtain harvest in weight (**Table 3.10**).

To put these removals into perspective, reduction landings have been on the order of 200,000 mt, bait landings around 30,000 to 40,000 mt, and recreational landings on the order of 300-400 mt. In general, the recreational landings represent less than about 1% of the combined bait and reduction landings, and at most 3% in 2006.

For handling this source of mortality in our models, the decision of the data workshop participants was to combine the recreational landings with bait landings. In addition, the bait catch-at-age matrix will be expanded to reflect these additional landings in numbers.

3.4 Atlantic Menhaden Effort

Because of the lack of an adult abundance index, the last peer review panel (ASMFC 2004) provided the following recommendations:

• *Evaluate commercial purse seine fishery effort (vessel/weeks) series as a possible tuning index in the model. Evaluate any measure of effort contained in this or other data series.*

• *Evaluate the data collected in the Captain's Daily Fishing Reports for an adult abundance index. If these data are not useful, explore the utility of a commercial fishery-based index, developed jointly with the fishermen, for future assessments.*

This section is intended to begin that process. In general, fishery-dependent indices of abundance are viewed with suspicion, particularly for purse-seine fisheries (Clark and Mangel 1979, Condrey 1984). In particular, the catchability coefficient for menhaden fisheries has been demonstrated to be inversely related to population abundance (Vaughan 1987, Vaughan and Smith 1988, Vaughan et al. 1996, 2000). Any attempt to incorporate menhaden CPUE into the model structure will need to acknowledge this relationship. Recently, a special workshop of SEDAR was held to address the issue of time-varying catchability, and a report (currently in draft form) has been developed. Recent papers by Wilberg and Bence (2006) and Wilberg et al. (*in review*) address this issue.

3.4.1 Nominal Measures of Fishing Effort from the Reduction Fleet

3.4.1.1 Effort Based on Vessel-Week, 1940-2008

Historic catch summations and estimates of fishing effort in the menhaden purse-seine fishery for reduction are based on company records of individual vessel unloads. At dockside, menhaden are hydraulically pumped from the carrier vessel, or 'steamer', into a rotating hopper device. By convention and throughout the industry, each segment of the hopper volumetrically holds 1,000 'standard' fish. The actual number of fish of course varies with the size of the fish, but each measure of fish is estimated to weigh 670 pounds (June and Reintjes 1976). Companies report daily vessel unloads in terms of 1,000 of 'standard' fish, which are converted to kilograms.

Normally, menhaden vessels unload their catches daily; however, trips of 2-3 days are common. The menhaden plant records, while showing the date and amount of fish unloaded per vessel, do not list number of days fished, nor days when the catch is zero. Logbooks were placed on menhaden vessels during the late 1950s and early 1960s to try and capture better information on 'fishing' and 'non-fishing' days at sea (Roithmayr 1960), but compliance was incomplete (Nicholson 1971). Thus, through about the 1970s there was no satisfactory way to acquire a complete at-sea history of each vessel.

Considering that menhaden vessels generally operate continuously over the course of a fishing season and fish every day that weather permits, Nicholson (1971) argued that the vessel-week (one vessel fishing at least one day of a given week) was a satisfactory unit of nominal fishing effort for the Atlantic menhaden purse-seine fishery. Thus, a vessel unloading a catch at least

one time during a given week was assign one vessel-week of effort. Vessel-weeks for all vessels in the fleet are calculated across all months of operation, and then summed for an estimate of annual nominal fishing effort for the fishery. These data are available for 1940-2008 (**Table 3.11**).

Similar trends in menhaden reduction landings and nominal effort (vessel-weeks) has been noted (**Figure 3.4**). A significant linear regression is estimated (adjusted $R^2 = 0.65$) as:

$$L = 146.61 + 0.154\ E + \text{error},$$

where L is menhaden reduction landings in 1000 metric tons, and E is nominal fishing effort in vessel-weeks (**Figure 3.5**).

1. Effort Based on Trip, 1955-2008

Detailed catch data are available from the menhaden reduction fishery since 1955, representing almost 180,000 trips. In addition to landings, variables included in these files are offload date (year, month, and day), plant, and vessel. Location of fishing beyond plant location is not available on these records. To perform a more detailed analysis (e.g., general linear model) of these data, more detailed information on fishing location was thought useful. To accomplish this task, the landings record files were merged with the biostatistical sampling files at the trip level. Biostatistical samples are obtained from the top of the vessel hold, representing the location of the final set. These samples have been collected using a two-stage sampling framework since 1955 (Chester 1984). Information from this latter data set included not only fish length, weight and age, but also fishing location by general area (South Atlantic, Chesapeake Bay, Middle Atlantic, and New England) and by latitude (34^o to 44^o North in units of 10' arc). The merged data set contained almost 30,000 trips, or about 17% of all trips made between 1955 and 2008. Sample sizes are summarized by year and area in **Table 3.12**.

First, a simple annual landings per trip was calculated for both the complete landings file and for the merged subset file (**Figure 3.6**). Temporally, within-year factors were based on either month or season (Mar-May, Jun-Aug, Sep-Nov, and Dec-Feb) based on the fishing year of March 1 – February 28. Geographic area was based on either area or more finely on latitude. Separate GLMs were run using either the coarse level (area and season) or fine level (latitude and month). Furthermore, separate GLMS were run assuming either normal error (untransformed) or lognormal error (natural log transform). These analyses were run with PROC GLM in SAS and annual trends were obtained from the LSMEANS option. For the GLM runs on the lognormal catch per trip, the annual results from the LSMEANS option were retransformed back to normal space by applying the exp of LSMEANS plus bias corrections (RMSE/2). The results using "coarse" input data were compared to the averages (**Figure 3.6**). All factors were found to be highly significant. Overall, variance explained by the various GLMs ranged between 34% and 47%, with higher R^2 values for the finer input data.

Estimates of nominal fishing effort for Atlantic menhaden reduction fleet for 1955-2008 are compared (**Figure 3.7**). Measures of nominal effort for this comparison include: (1) vessel-week, (2) trips (all landings data), and (3) GLM LSMEANS (additive model) based on subset of trips. All effort estimates are standardized by dividing by respective value in 1955. The trends noted include a rapid drop in effort during the 1960s, a period of poor recruitment and low stock abundance. Effort temporarily stabilized during the 1970s, as the stock was considered to be rebuilding. Declines in the 1980s are associated with low meal prices, and in 1986 one of the Reedville, VA, plants did not open for economic reasons.

3.4.1.3 Effort Based on Sets, 1985-2008 (CDFRs)

Beginning in the late 1970s, the menhaden industry, state fisheries agencies, and the NMFS entered into a joint program called the Captains Daily Fishing Reports, or CDFRs, to better document menhaden catch and fishing effort. For each fishing day, captains are asked to specify, among other things, time and location of each purse-seine set, estimated catch, and distance from shore. Since the mid-1980s, compliance by menhaden fleets in Virginia and North Carolina has been almost 100%. CDFR data sets for fishing years 1985 through 2008 have been computerized at the NMFS Beaufort Laboratory. Smith (1999) summarized CDFR catch and effort information for fishing years 1985-1996.

CDFR catch records for fishing years 1985-2008 were concatenated into one large data set containing over 190,000 records of purse-seine sets by the Virginia and North Carolina menhaden fleets. Variables in the file include plant, vessel, set date (year, month, and day), set start and set finish times, fishing location, and an at-sea estimate of catch in metric tons. Analyses of catch per set were calculated in various ways. First, mean annual catch per set was calculated for all sets (**Table 3.13**). A pair of GLM analyses were also conducted assuming either normal or lognormal error. The GLMs used the following class variables as factors: year, plant, month, area, duration, and vessel. An index of annual catch per set was obtained using LSMEANS as in the analyses for catch per trip. All results show a peak in 1986 when one of the two plants in the Chesapeake Bay did not operate because of low fish meal prices.

We scaled the different CPUE indices by dividing by their respective time series means for 1985-2008. We compare between the observed CPUE in **Figure 3.8.** In general, similar patterns were obtained from the different approaches to estimating fishery-dependent catch per effort from the menhaden reduction fishery. Finally we compare the nominal effort obtained from these approaches (**Figure 3.9**) for the period 1985-2008. All three approaches for estimating nominal effort (vessel-week, trips, sets) show similar patterns for this recent period. Following a period of low effort and low meal prices during the mid-1980s, effort peaked about 1990-1991, and has subsequently declined since then. Although we do not suggest that declining effort since 1990 implies declining fishing mortality, we note that the decline in fishing mortality found in past assessments can be explained in part by this decline in effort.

3.4.2 Other Approaches

Atran and Loesch (1986) analyzed weekly variations in catchability coefficients for purposes of examining short-term fluctuations in stock abundance of Atlantic menhaden. Culquichicon (1994) investigated Captain's Daily Fishing Reports from the gulf menhaden reduction fishery "to test the hypothesis that the ratio of searching time to total time available for fishing is a good index of stock abundance". She estimated this ratio at about 0.8, and it varied without trend for the study years, 1979-1991.

In an effort to explore additional indices of abundance for Atlantic menhaden, Captains Daily Fishing Reports (CDFRs) were used to develop an index of abundance for age-1 menhaden specifically for Chesapeake Bay. CDFRs are available for the Virginia fleet of menhaden vessels from 1985-2008. The index was computed by dividing the estimated number of age-1 fish caught in the Chesapeake Bay Area from the catch-at-age matrix (in millions of fish; area includes some ocean waters of Virginia also) by a unit of fishing effort, namely, the number of annual purse-seine sets made in Chesapeake Bay (from the CDFR data bases); the index was multiplied by 100 to raise the index to the unit's level or greater. Results are shown in **Table 3.14** and **Figure 3.10**. Estimated numbers of age-0 menhaden in the population at the start of each fishing season 1984-2004 (from Table 6.4 in the 2006 Assessment Update [ASMFC 2006]) were advance one year and graphed against the index (**Figure 3.11**), which correlated well with an $R^2 = 0.90$ when age-0 data from the terminal assessment year 2006 were dropped from the analysis.

Finally, within the Atlantic Menhaden Technical Committee, a Cooperative Research Subcommittee was formed to foster cooperative studies among the menhaden reduction and bait fisheries and state and federal scientists. At the Subcommittee's meeting in May 2008, the NMFS Beaufort Laboratory and Omega Protein, Inc., agreed to work together to implement a weekly aerial survey (utilizing menhaden spotter pilots) which would report menhaden abundance observations during the 2008 fishing season. Further elaboration on this developing project can be found in the **Appendix** to this report.

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Table 3.1. Years of activity for individual menhaden reduction plants along the U.S. Atlantic coast, 1955-2009.

	Plant																																			Total	Number
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	32	33	34	35	36	Plants	Vessels
1955	+	+	+	+	+	+		+		+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+										23	150
1956	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+											24	149
1957	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+										25	144
1958	+	+	+	+	+			+	+	+	+	+	+	+	+	+	+	+		+	+		+	+	+	+										22	130
1959	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+		+	+		+	+	+	+										23	144
1960	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+		+			+		+											20	115
1961	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+		+			+		+											20	117
1962	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+			+			+		+											19	112
1963	+	+	+	+	+			+	+	+	+	+	+	+	+	+	+	+		+																17	112
1964	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+		+																18	111
1965	+	+		+	+			+		+	+	+	+	+		+	+	+	+	+							+	+								17	84
1966	+	+		+	+		+	+	+	+	+	+	+	+	+	+	+		+	+							+	+	+							20	76
1967		+		+			+	+	+	+	+	+	+	+	+	+	+		+	+							+	+	+							18	64
1968	+	+		+			+			+	+	+	+	+	+	+	+		+	+							+	+	+							17	59
1969	+	+		+			+			+		+	+	+	+	+	+			+							+	+	+							15	51
1970		+					+			+		+	+	+	+	+	+			+			+		+		+	+	+							15	54
1971		+					+			+		+	+	+	+	+	+			+			+		+		+	+								14	51
1972		+					+			+			+	+			+			+			+		+		+	+								11	51
1973		+					+			+			+	+			+			+		+	+		+			+								11	58
1974		+					+			+			+	+			+			+			+		+			+								10	63
1975		+					+			+			+	+			+			+		+	+		+			+		+						12	61
1976		+					+			+			+	+			+			+			+		+			+		+						11	62
1977		+					+			+			+	+			+			+		+	+		+			+		+						12	64
1978		+					+			+			+	+			+			+		+	+		+			+		+						12	53
1979		+					+			+			+	+			+			+		+	+		+			+		+						12	54
1980		+					+			+			+	+			+			+		+	+					+		+						11	51
1981		+					+			+			+	+			+			+		+	+					+		+						11	57
1982							+			+			+	+			+			+		+	+					+		+						10	47
1983							+			+			+	+			+			+			+					+		+						9	41
1984							+			+			+	+						+			+					+		+						8	38
1985							+			+			+							+								+		+						6	24
1986							+			+			+							+								+		+						6	16
1987							+			+			+							+										+	+					6	23
1988							+			+			+																	+	+	+				6	30
1989							+			+			+																		+	+				5	37
1990							+			+			+																		+	+				5	35
1991							+			+			+																		+	+				5	37
1992							+			+			+																		+	+	+	+	+	8	37
1993							+			+			+																		+	+		+	+	7	31
1994							+			+			+																							3	20
1995							+			+			+																							3	20
1996							+			+			+																							3	21
1997							+			+			+																							3	23
1998										+			+																							2	15
1999										+			+																							2	15
2000										+			+																							2	12
2001										+			+																							2	12
2002										+			+																							2	12
2003										+			+																							2	12
2004										+			+																							2	12
2005										+																										1	11
2006										+																										1	10
2007										+																										1	10
2008										+																										1	10
2009										+																										1	10

Table 3.1. (*continued*)

Port	Plant	Name	Location
3	1	Atlantic Processing Co.	Amagansett, NY
4	2	J. Howard Smith (Seacoast Products)	Port Monmouth, NJ
4	3	Fish Products Co.	Tuckerton, NJ
8	4	New Jersey Menhaden Products Co.	Wildwood, NJ
0	5	Fish Products Co. (Seacoast Products Co.)	Lewes, DE
0	6	Consolidated Fisheries	Lewes, DE
5	7	AMPRO (Standard Products Co.)	Reedville, VA
5	8	McNeal-Edwards (Standard Products Co.)	Reedville, VA
5	9	Menhaden Co. (Standard Products Co.)	Reedville, VA
5	10	Omega Protein (Zapata Haynie Co.)	Reedville, VA
5	11	Standard Products Co.	White Stone, VA
6	12	Fish Meal Co.	Beaufort, NC
6	13	Beaufort Fisheries, Inc.	Beaufort, NC
6	14	Standard Products Co.	Beaufort, NC
6	15	Standard Products Co.	Morehead City, NC
6	16	Haynie Products, Inc.	Morehead City, NC
7	17	Standard Products Co.	Southport, NC
7	18	Southport Fisheries Menhaden	Southport, NC
9	19	Quinn Menhaden Fisheries, Inc.	Fernandina Beach, FL
9	20	Nassau Oil and Fertilizer Co.	Fernandina Beach, FL
9	21	Mayport Fisheries	Mayport, FL
1	22	Maine Marine Products (Pine State Products)	Portland, ME
2	23	Lipman Marine Products	Gloucester, MA
		(Gloucester Marine Protein)	
2	24	Gloucester Dehydration Co.	Gloucester, MA
11	25	Point Judith By Products Co.	Point Judith, RI
9	26	Quinn Fisheries	Younges Island, SC
5	27	Haynie Products (Cockerall's Ice & Seafood)	Reedville, VA
6	28	Sea and Sound Processing Co.	Beaufort, NC
12	29	Cape Charles Processing Co.	Cape Charles, VA
13	30	Sea Pro, Inc.	Rockland, ME
15	32	Connor Bros.	New Brunswick, Canada
14	33	Riga (IWP)	Maine
14	34	Vares (IWP)	Maine
14	35	Dauriya (IWP)	Maine
15	36	Comeau	Nova Scotia, Canada

Table 3.2. Atlantic menhaden landings and effort (vessel-weeks) of from the reduction purse-seine fishery, 1940-2008, landings from the bait fisheries, 1985-2008, landings estimated from the recreational fishery (MRFSS), 1981-2008, and total landings for all fisheries. Recreational landings represent removals of A+B1+50%B2 by weight.

	Reduction Fishery		Bait Fishery	Recreational Fishery	Total Landings
Year	Landings (1000 t)	Effort (v-w)	Landings (1000 t)	Catches (1000 t)	(1000 t)
1940	217.7	967			217.7
1941	277.9	1291			277.9
1942	167.2	991			167.2
1943	237.2	889			237.2
1944	257.9	1167			257.9
1945	295.9	1271			295.9
1946	362.4	1365			362.4
1947	378.3	1582			378.3
1948	346.5	1781			346.5
1949	363.8	2076			363.8
1950	297.2	1650			297.2
1951	361.4	1686			361.4
1952	409.9	1653			409.9
1953	593.2	1972			593.2
1954	608.1	2094			608.1
1955	641.4	2748			641.4
1956	712.1	2878			712.1
1957	602.8	2775			602.8
1958	510.0	2343			510.0
1959	659.1	2847			659.1
1960	529.8	2097			529.8
1961	575.9	2371			575.9
1962	537.7	2351			537.7
1963	346.9	2331			346.9
1964	269.2	1807			269.2
1965	273.4	1805			273.4
1966	219.6	1386			219.6
1967	193.5	1316			193.5
1968	234.8	1209			234.8
1969	161.6	995			161.6
1970	259.4	906			259.4
1971	250.3	897			250.3
1972	365.9	973			365.9
1973	346.9	1099			346.9
1974	292.2	1145			292.2
1975	250.2	1218			250.2

Table 3.2. (*continued*)

	Reduction Fishery		Bait Fishery	Recreational Fishery	Total Landings
Year	Landings (1000 t)	Effort (v-w)	Landings (1000 t)	Catches (1000 t)	(1000 t)
1976	340.5	1163			340.5
1977	341.1	1239			341.1
1978	344.1	1210			344.1
1979	375.7	1198			375.7
1980	401.5	1158			401.5
1981	381.3	1133		0.12	381.4
1982	382.4	948		0.13	382.5
1983	418.6	995		0.12	418.7
1984	326.3	892		0.15	326.4
1985	306.7	577	26.7	0.16	333.5
1986	238.0	377	28.0	0.35	266.3
1987	327.0	531	30.6	0.25	357.9
1988	309.3	604	36.3	0.31	345.9
1989	322.0	725	31.0	0.15	353.2
1990	401.2	826	30.8	0.17	432.2
1991	381.4	926	36.2	0.38	418.0
1992	297.6	794	39.0	0.52	337.2
1993	320.6	626	42.8	0.19	363.6
1994	260.0	573	39.1	0.12	299.3
1995	339.9	600	42.4	0.24	382.5
1996	292.9	528	35.3	0.09	328.3
1997	259.1	618	36.5	0.09	295.7
1998	245.9	437	39.4	0.08	285.3
1999	171.2	382	36.2	0.23	207.6
2000	167.2	311	35.3	0.07	202.6
2001	233.7	334	36.3	0.13	270.1
2002	174.0	318	37.1	0.19	211.2
2003	166.1	302	33.8	0.21	200.2
2004	183.4	345	35.5	0.36	219.2
2005	146.9	291	38.8	0.13	185.9
2006	157.4	322	26.5	0.40	184.3
2007	174.5	333	42.8	0.34	217.6
2008	141.1	262	47.4	0.37	188.8

Table 3.3. Sample size (n), landings in numbers of fish, landings in biomass (C), sampling 'intensity' (landings in metric tons per 100 fish measured), and mean weight of fish landed from the Atlantic menhaden reduction fishery, 1955-2005.

Year	Sample Size (n)	Landings (millions)	Landings (1000 mt)	Intensity (C/100n)	Mean Weight (g)
1955	16037	3118.4	641.4	3999.5	205.7
1956	19873	3564.8	712.1	3583.3	199.8
1957	19674	3511.7	602.8	3063.9	171.7
1958	15315	2719.2	510.0	3330.1	187.6
1959	17935	5353.6	659.1	3674.9	123.1
1960	13505	2775.1	529.8	3923.0	190.9
1961	13184	2598.3	575.9	4368.2	221.6
1962	15771	2099.9	537.7	3409.4	256.1
1963	13001	1764.5	346.9	2668.3	196.6
1964	10438	1729.1	269.2	2579.0	155.7
1965	19518	1519.5	273.4	1400.8	179.9
1966	15633	1340.6	219.6	1404.7	163.8
1967	15426	984.2	193.5	1254.4	196.6
1968	26830	1148.0	234.8	875.1	204.5
1969	15114	868.2	161.6	1069.2	186.1
1970	8426	1403.0	259.4	3078.6	184.9
1971	8269	969.1	250.3	3027.0	258.3
1972	6552	1713.9	365.9	5584.6	213.5
1973	6351	1843.4	346.9	5462.1	188.2
1974	5421	1990.6	292.2	5390.1	146.8
1975	7278	2162.3	250.2	3437.8	115.7
1976	6725	3283.5	340.5	5063.2	103.7
1977	7276	3673.7	341.1	4688.0	92.8
1978	7094	3085.2	344.1	4850.6	111.5
1979	6365	3870.1	375.7	5902.6	97.1
1980	7291	3332.3	401.5	5506.8	120.5
1981	9201	3984.0	381.3	4144.1	95.7
1982	9066	3175.7	382.4	4218.0	120.4
1983	11533	3942.1	418.6	3629.6	106.2
1984	11689	3548.0	326.3	2791.5	92.0
1985	8498	3025.3	306.7	3609.1	101.4
1986	5828	1912.4	238.0	4083.7	124.5
1987	7618	2315.2	327.0	4292.5	141.2
1988	7349	2158.0	309.3	4208.7	143.3
1989	7027	2630.5	322.0	4582.3	122.4

Table 3.3. (*continued*)

Year	Sample Size (n)	Landings (millions)	Landings (1000 mt)	Intensity (C/100n)	Mean Weight (g)
1990	6838	2157.9	401.2	5867.2	185.9
1991	7770	3166.6	381.4	4908.6	120.4
1992	5680	2052.5	297.6	5239.4	145.0
1993	5488	1594.0	320.6	5841.8	201.1
1994	5278	1492.0	260.0	4926.1	174.3
1995	4996	1643.3	339.9	6803.4	206.8
1996	4628	1091.9	292.9	6328.9	268.2
1997	4465	995.9	259.1	5802.9	260.2
1998	4558	1007.5	245.9	5394.9	244.1
1999	4279	1056.3	171.2	4000.9	162.1
2000	3669	657.4	167.2	4557.1	254.3
2001	5012	669.2	233.7	4662.8	349.2
2002	4370	803.1	174.0	3981.7	216.7
2003	3945	698.3	166.1	4210.3	237.9
2004	4600	978.0	183.4	3987.0	187.5
2005	3940	648.5	146.9	3727.4	226.4
2006	4209	754.0	157.4	3739.6	208.8
2007	5320	932.6	174.5	3280.1	187.1
2008	4438	577.4	141.1	3179.4	244.4

Table 3.4. Estimated reduction landings of Atlantic menhaden in numbers by age (in millions), 1955-2005.

Year	0	1	2	3	4	5	6	7	8
1955	761.01	674.15	1057.68	267.31	307.21	38.07	10.53	1.84	0.64
1956	36.37	2073.26	902.72	319.60	44.78	150.68	28.70	6.72	1.99
1957	299.58	1599.98	1361.77	96.73	70.80	40.52	36.93	4.26	1.10
1958	106.06	858.16	1635.35	72.05	17.25	15.94	9.09	4.88	0.43
1959	11.40	4038.72	851.29	388.27	33.41	11.87	12.36	4.55	1.77
1960	72.17	281.01	2208.63	76.37	102.20	23.77	7.95	2.36	0.65
1961	0.25	832.42	503.60	1209.57	19.18	29.38	2.86	0.81	0.24
1962	51.58	514.11	834.52	217.25	423.37	30.75	24.60	2.98	0.70
1963	96.89	724.23	709.20	122.53	44.97	52.38	10.42	3.33	0.56
1964	302.59	703.95	604.98	83.50	17.94	7.85	6.62	1.31	0.32
1965	259.12	745.21	421.40	77.76	12.17	1.81	1.22	0.75	0.07
1966	349.45	550.82	404.14	31.70	3.89	0.36	0.11	0.11	0.04
1967	6.95	633.20	265.67	72.78	5.09	0.49	0.01	0.00	0.00
1968	154.26	377.36	538.95	65.69	10.68	0.98	0.06	0.00	0.00
1969	158.13	372.33	284.31	47.81	5.44	0.15	0.01	0.00	0.00
1970	21.42	870.85	473.92	32.63	4.02	0.11	0.00	0.00	0.00
1971	72.85	263.29	524.32	88.29	17.84	2.51	0.00	0.00	0.00
1972	50.16	981.27	488.47	173.06	19.12	1.86	0.00	0.00	0.00
1973	55.98	588.47	1152.94	38.63	7.00	0.34	0.00	0.00	0.00
1974	315.55	636.68	985.97	48.59	2.49	1.35	0.00	0.00	0.00
1975	298.64	719.96	1086.53	50.24	6.63	0.20	0.10	0.00	0.00
1976	274.23	1611.96	1341.09	47.97	7.95	0.28	0.00	0.00	0.00
1977	484.62	1004.54	2081.77	83.46	17.80	1.41	0.11	0.00	0.00
1978	457.41	664.09	1670.91	258.12	31.19	3.48	0.00	0.00	0.00
1979	1492.46	623.14	1603.29	127.93	21.76	1.47	0.09	0.00	0.00
1980	88.29	1478.09	1458.23	222.71	69.23	14.36	1.43	0.00	0.00
1981	1187.57	698.66	1811.46	222.20	47.47	15.37	1.27	0.00	0.00
1982	114.12	919.44	1739.55	379.67	16.33	5.78	0.53	0.32	0.00
1983	964.41	517.22	2293.06	114.35	47.37	5.01	0.23	0.00	0.46
1984	1294.22	1024.17	892.09	271.50	50.34	15.21	0.51	0.00	0.00
1985	637.19	1075.85	1224.62	44.06	35.63	6.25	1.68	0.00	0.00
1986	98.39	224.21	1523.13	49.07	10.47	6.08	1.06	0.00	0.00
1987	42.87	504.70	1587.66	151.88	25.17	2.19	0.70	0.00	0.00
1988	338.82	282.65	1157.65	301.37	69.79	7.11	0.33	0.25	0.00
1989	149.72	1154.59	1158.54	108.36	47.47	11.63	0.21	0.00	0.00

Table 3.4. (*continued*)

Year	0	1	2	3	4	5	6	7	8
1990	308.07	132.80	1553.12	108.96	42.18	12.34	0.43	0.00	0.00
1991	881.77	1033.94	946.07	253.98	37.95	10.70	2.03	0.13	0.00
1992	399.65	727.22	795.44	66.06	51.30	10.89	1.39	0.51	0.00
1993	67.91	379.02	983.07	148.90	10.91	3.88	0.30	0.00	0.00
1994	88.61	274.51	888.86	165.07	67.24	7.52	0.23	0.00	0.00
1995	56.76	533.65	671.85	309.13	67.53	4.36	0.00	0.00	0.00
1996	33.72	209.14	679.13	138.95	28.96	2.04	0.00	0.00	0.00
1997	25.22	246.91	424.54	237.43	51.59	8.97	1.21	0.00	0.00
1998	72.84	184.99	540.56	126.32	72.98	9.00	0.76	0.00	0.00
1999	193.87	301.12	450.82	81.84	25.00	3.24	0.36	0.00	0.00
2000	77.75	114.15	340.62	111.89	11.06	1.94	0.00	0.00	0.00
2001	22.97	43.52	369.48	217.60	14.93	0.67	0.00	0.00	0.00
2002	178.19	211.74	259.79	135.80	17.05	0.48	0.00	0.00	0.00
2003	60.74	127.51	447.28	53.76	7.79	0.93	0.27	0.00	0.00
2004	17.97	213.95	652.09	75.70	17.41	0.90	0.00	0.00	0.00
2005	12.10	78.86	382.89	154.19	18.68	1.82	0.00	0.00	0.00
2006	9.16	298.91	300.13	121.65	23.62	0.48	0.00	0.00	0.00
2007	1.14	239.20	609.24	69.43	12.97	0.68	0.00	0.00	0.00
2008	7.90	52.37	394.87	106.64	14.65	1.03	0.00	0.00	0.00

Table 3.5. Number of fish sampled from Atlantic menhaden landed for bait, 1985-2008.

	Purse Seine				Poundnet				Totals		
Year	NE	MA	CB	SA	NE	MA	CB	SA	Purse Seine	Poundnet	Grand
1985	600	0	0	170	0	0	0	30	770	30	800
1986	40	0	0	340	0	0	0	40	380	40	420
1987	0	0	0	220	0	0	0	0	220	0	220
1988	0	0	0	10	0	0	0	0	10	0	10
1989	20	0	0	10	0	0	0	0	30	0	30
1990	0	0	0	10	0	0	10	0	10	10	20
1991	0	0	0	78	0	0	0	0	78	0	78
1992	0	0	30	40	0	0	0	0	70	0	70
1993	29	0	10	130	0	0	0	0	169	0	169
1994	80	320	0	139	0	0	10	0	539	10	549
1995	130	59	96	77	0	0	0	0	362	0	362
1996	15	187	137	18	0	0	0	0	357	0	357
1997	0	110	136	67	0	0	100	0	313	100	413
1998	0	225	295	106	0	0	0	10	626	10	636
1999	0	192	299	47	0	0	0	0	538	0	538
2000	0	273	231	39	0	0	0	0	543	0	543
2001	0	677	275	10	0	0	0	0	962	0	962
2002	0	155	471	76	0	0	0	0	702	0	702
2003	0	108	309	10	0	0	0	0	427	0	427
2004	0	28	326	0	0	0	0	0	354	0	354
2005	0	4	318	0	0	0	0	0	322	0	322
2006	28	223	203	0	0	10	20	0	454	30	484
2007	122	477	374	0	190	10	80	0	973	280	1253
2008	199	329	314	0	140	50	80	0	842	270	1112
Total	663	3367	3824	1597	330	70	300	80	10051	780	10831

Table 3.6. Atlantic menhaden catch in numbers (in millions) at age from the bait fishery, 1985-2008. Includes adjustment to include recreational landings (MRFSS).

Year	0	1	2	3	4	5	6	Total
1985	0.3	8.8	67.6	19.4	6.4	1.1	0.2	103.8
1986	0.2	5.1	40.9	34.8	12.8	1.2	0.2	95.2
1987	0.2	5.0	50.5	34.9	13.0	1.2	0.2	104.9
1988	0.2	6.1	49.6	45.4	17.4	1.6	0.2	120.6
1989	0.3	7.8	59.9	32.8	10.9	1.1	0.1	112.8
1990	0.4	23.6	47.3	34.1	12.4	1.3	0.2	119.3
1991	0.2	15.9	53.2	43.8	16.5	1.7	0.2	131.6
1992	0.4	20.6	48.6	47.3	17.6	1.9	0.3	136.7
1993	0.8	23.9	43.9	49.7	17.9	1.9	0.3	138.4
1994	0.3	12.5	60.2	36.7	17.8	2.4	0.2	130.1
1995	0.0	41.6	44.9	50.7	26.1	0.1	0.0	163.5
1996	0.0	2.9	61.7	28.6	6.8	0.2	0.0	100.4
1997	0.0	5.1	39.0	31.6	20.4	5.5	1.1	102.6
1998	3.2	5.0	44.9	31.5	21.2	3.5	0.7	110.0
1999	0.2	5.2	75.3	30.9	14.1	1.8	0.3	127.8
2000	0.6	18.8	65.5	20.6	8.1	1.0	0.3	114.9
2001	0.2	4.7	55.4	37.4	4.5	0.6	0.1	103.0
2002	0.0	2.5	16.8	44.5	18.7	2.6	0.1	85.3
2003	0.5	9.1	69.8	24.0	4.8	0.2	0.0	108.4
2004	0.0	7.8	88.2	31.0	8.0	0.9	0.1	136.0
2005	0.0	1.6	55.7	53.2	7.0	0.9	0.1	118.4
2006	0.0	18.4	39.8	29.7	5.7	0.2	0.0	93.8
2007	0.0	36.5	116.1	34.1	8.1	0.5	0.1	195.3
2008	0.0	3.5	96.1	53.2	11.1	1.3	0.0	165.3

Table 3.7. Recreational harvest (Type A+B1) in numbers of Atlantic menhaden in the recreational fishery by region (New England, Middle Atlantic, and South Atlantic states), 1981-2008.

Year	MA	NE	SA	Overall
1981	117,956	248,063	77,841	443,860
1982	3,362	218,032	546,378	767,772
1983	26,032	175,877	382,532	584,441
1984	315,659	101,280	259,740	676,679
1985	266,892	227,163	101,708	595,763
1986	736,270	557,216	13,463	1,306,949
1987	365,505	463,769	142,009	971,283
1988	892,561	252,017	280,734	1,425,312
1989	192,874	258,202	182,656	633,732
1990	234,233	250,854	343,572	828,659
1991	856,362	374,939	390,179	1,621,480
1992	288,409	1,098,239	1,266,056	2,652,704
1993	268,991	354,035	84,018	707,044
1994	222,664	133,236	279,251	635,151
1995	777,497	142,589	85,271	1,005,357
1996	50,411	181,925	297,758	530,094
1997	227,652	98,780	135,071	461,503
1998	54,784	187,576	78,272	320,632
1999	742,075	54,578	289,447	1,086,100
2000	47,275	131,385	99,969	278,629
2001	147,773	17,388	985,208	1,150,369
2002	200,812	233,814	515,634	950,260
2003	217,044	21,153	1,669,518	1,907,715
2004	88,731	44,850	1,138,636	1,272,217
2005	144,656	42,526	952,714	1,139,896
2006	821,451	58,421	1,582,632	2,462,504
2007	322,704	329,903	1,407,367	2,059,974
2008	921,417	345,909	571,790	1,839,116

Note: Preliminary data for 2008.

Table 3.8. Recreational released alive (Type B2) in numbers of Atlantic menhaden in the recreational fishery by region (New England, Middle Atlantic, and South Atlantic states), 1981-2008. Final column divides numbers released alive divided by numbers harvested.

Year	MA	NE	SA	Overall
1981	0	14,269	71,401	85,670
1982	9,314	0	378,801	388,115
1983	539	5,314	805,522	811,375
1984	44,583	5,435	534,244	584,262
1985	46,767	8,020	338,916	393,703
1986	30,881	3,372	97,582	131,835
1987	36,935	6,102	58,806	101,843
1988	29,642	22,082	41,840	93,564
1989	11,980	10,676	162,419	185,075
1990	43,490	27,470	108,289	179,249
1991	265,965	66,990	22,600	355,555
1992	697	96,997	22,737	120,431
1993	13,642	27,527	177,890	219,059
1994	12,424	18,771	4,116	35,311
1995	99,622	17,829	9,124	126,575
1996	2,082	3,139	391	5,612
1997	1,458	861	6,164	8,483
1998	3,208	3,628	10,219	17,055
1999	1,119	51,974	369,179	422,272
2000	57,935	0	81,725	139,660
2001	714	1,276	413,751	415,741
2002	91,224	18,222	387,997	497,443
2003	17,352	0	613,070	630,422
2004	2,040,891	5,569	316,253	2,362,713
2005	8,557	5,943	351,737	366,237
2006	321,391	71,738	773,188	1,166,317
2007	331,594	9,447	325,870	666,911
2008	29,723	19,262	20,124	69,109

Note: Preliminary data for 2008.

Table 3.9. Total catch (A+B1+0.5*B2) in numbers of Atlantic menhaden in the recreational fishery (MRFSS) by region (New England, Middle Atlantic, and South Atlantic states), 1981-2008.

Year	MA	NE	SA	Overall
1981	117,956	255,198	113,542	486,695
1982	8,019	218,032	735,779	961,830
1983	26,302	178,534	785,293	990,129
1984	337,951	103,998	526,862	968,810
1985	290,276	231,173	271,166	792,615
1986	751,711	558,902	62,254	1,372,867
1987	383,973	466,820	171,412	1,022,205
1988	907,382	263,058	301,654	1,472,094
1989	198,864	263,540	263,866	726,270
1990	255,978	264,589	397,717	918,284
1991	989,345	408,434	401,479	1,799,258
1992	288,758	1,146,738	1,277,425	2,712,920
1993	275,812	367,799	172,963	816,574
1994	228,876	142,622	281,309	652,807
1995	827,308	151,504	89,833	1,068,645
1996	51,452	183,495	297,954	532,900
1997	228,381	99,211	138,153	465,745
1998	56,388	189,390	83,382	329,160
1999	742,635	80,565	474,037	1,297,236
2000	76,243	131,385	140,832	348,459
2001	148,130	18,026	1,192,084	1,358,240
2002	246,424	242,925	709,633	1,198,982
2003	225,720	21,153	1,976,053	2,222,926
2004	1,109,177	47,635	1,296,763	2,453,574
2005	148,935	45,498	1,128,583	1,323,015
2006	982,147	94,290	1,969,226	3,045,663
2007	488,501	334,627	1,570,302	2,393,430
2008	936,279	355,540	581,852	1,873,671

Note: Preliminary data for 2008.

Table 3.10. Total catch (A+B1+0.5*B2) in weight (1000 metric tons) of Atlantic menhaden in the recreational fishery (MRFSS) by region (New England, Middle Atlantic, and South Atlantic states), 1981-2008.

Year	MA	NE	SA	Total
1981	0.0265	0.0798	0.0088	0.1150
1982	0.0018	0.0682	0.0567	0.1267
1983	0.0059	0.0558	0.0605	0.1223
1984	0.0759	0.0325	0.0406	0.1491
1985	0.0652	0.0723	0.0209	0.1584
1986	0.1689	0.1747	0.0048	0.3484
1987	0.0863	0.1459	0.0132	0.2454
1988	0.2039	0.0822	0.0233	0.3094
1989	0.0447	0.0824	0.0203	0.1474
1990	0.0575	0.0827	0.0307	0.1709
1991	0.2223	0.1277	0.0309	0.3809
1992	0.0649	0.3585	0.0985	0.5218
1993	0.0620	0.1150	0.0133	0.1903
1994	0.0514	0.0446	0.0217	0.1177
1995	0.1859	0.0474	0.0069	0.2402
1996	0.0116	0.0574	0.0230	0.0919
1997	0.0513	0.0310	0.0106	0.0930
1998	0.0127	0.0592	0.0064	0.0783
1999	0.1669	0.0252	0.0365	0.2286
2000	0.0171	0.0411	0.0109	0.0691
2001	0.0333	0.0056	0.0919	0.1308
2002	0.0554	0.0759	0.0547	0.1860
2003	0.0507	0.0066	0.1523	0.2097
2004	0.2492	0.0149	0.1000	0.3641
2005	0.0335	0.0142	0.0870	0.1347
2006	0.2207	0.0295	0.1518	0.4019
2007	0.1098	0.1046	0.1210	0.3354
2008	0.2104	0.1112	0.0449	0.3664

Note: Preliminary data for 2008.

Table 3.11. Menhaden reduction landings (1000 mt), nominal effort (vessel-week), and LPUE (landings per vessel-week), 1940-2008.

	Reduction Fishery		
Year	Landings (1000 t)	Effort (v-w)	LPUE
1940	217.7	967	0.225
1941	277.9	1291	0.215
1942	167.2	991	0.169
1943	237.2	889	0.267
1944	257.9	1167	0.221
1945	295.9	1271	0.233
1946	362.4	1365	0.265
1947	378.3	1582	0.239
1948	346.5	1781	0.195
1949	363.8	2076	0.175
1950	297.2	1650	0.180
1951	361.4	1686	0.214
1952	409.9	1653	0.248
1953	593.2	1972	0.301
1954	608.1	2094	0.290
1955	641.4	2748	0.233
1956	712.1	2878	0.247
1957	602.8	2775	0.217
1958	510.0	2343	0.218
1959	659.1	2847	0.232
1960	529.8	2097	0.253
1961	575.9	2371	0.243
1962	537.7	2351	0.229
1963	346.9	2331	0.149
1964	269.2	1807	0.149
1965	273.4	1805	0.151
1966	219.6	1386	0.158
1967	193.5	1316	0.147
1968	234.8	1209	0.194
1969	161.6	995	0.162
1970	259.4	906	0.286
1971	250.3	897	0.279
1972	365.9	973	0.376
1973	346.9	1099	0.316
1974	292.2	1145	0.255
1975	250.2	1218	0.205

Table 3.11. (*continued*)

	Reduction Fishery		
Year	Landings (1000 t)	Effort (v-w)	LPUE
1976	340.5	1163	0.293
1977	341.1	1239	0.275
1978	344.1	1210	0.284
1979	375.7	1198	0.314
1980	401.5	1158	0.347
1981	381.3	1133	0.337
1982	382.4	948	0.403
1983	418.6	995	0.421
1984	326.3	892	0.366
1985	306.7	577	0.532
1986	238.0	377	0.631
1987	327.0	531	0.616
1988	309.3	604	0.512
1989	322.0	725	0.444
1990	401.2	826	0.486
1991	381.4	926	0.412
1992	297.6	794	0.375
1993	320.6	626	0.512
1994	260.0	573	0.454
1995	339.9	600	0.567
1996	292.9	528	0.555
1997	259.1	618	0.419
1998	245.9	437	0.563
1999	171.2	382	0.448
2000	167.2	311	0.538
2001	233.7	334	0.700
2002	174.0	318	0.547
2003	166.1	302	0.550
2004	183.4	345	0.532
2005	146.9	291	0.505
2006	157.4	322	0.489
2007	174.5	333	0.524
2008	141.1	262	0.539

Table 3.12. Number of fishing trips by the Atlantic menhaden reduction fleet, 1955-2008. Approximately 17% of all trips (179,891) were matched with corresponding biostatistical samples (29,626), and hence fishing location was available.

	All Data			Subsetted Data			Sampling
Year	N	Catch (mt)	SE (C MT)	N	Catch (mt)	SE (Catch)	Fraction
1955	8978	160.6	1.39	668	179.9	5.67	0.074
1956	9912	161.5	1.38	806	178.4	5.23	0.081
1957	9403	144.1	1.24	809	161.2	4.55	0.086
1958	7828	146.5	1.36	706	158.6	5.04	0.090
1959	9969	148.6	1.17	874	167.3	4.26	0.088
1960	7611	156.5	1.36	635	179.6	5.57	0.083
1961	8428	153.6	1.38	605	173.4	5.59	0.072
1962	8015	151.0	1.43	736	162.8	5.12	0.092
1963	7232	107.8	1.20	598	110.8	4.46	0.083
1964	5742	105.4	1.37	482	112.9	5.34	0.084
1965	5659	108.6	1.39	898	104.5	3.22	0.159
1966	4525	109.1	1.84	708	108.3	4.49	0.156
1967	3968	109.6	1.90	661	111.3	4.54	0.167
1968	3729	141.5	2.25	885	152.0	4.77	0.237
1969	2837	128.0	2.59	701	111.2	5.06	0.247
1970	3099	187.3	2.70	415	223.6	7.63	0.134
1971	3016	185.7	2.78	385	208.4	8.41	0.128
1972	3181	257.4	3.32	631	271.3	6.93	0.198
1973	3652	212.6	3.08	577	223.4	8.30	0.158
1974	3338	195.9	3.31	479	199.4	9.93	0.143
1975	3500	160.0	2.79	648	187.5	8.29	0.185
1976	3450	220.9	3.85	574	279.8	12.07	0.166
1977	3416	223.5	3.61	635	248.6	9.28	0.186
1978	3365	228.8	3.92	664	263.1	10.12	0.197
1979	3266	257.4	4.30	582	300.7	12.27	0.178
1980	3198	281.0	4.48	656	309.7	11.77	0.205
1981	2970	287.3	5.18	811	270.5	10.12	0.273
1982	2933	291.8	4.90	829	306.5	9.66	0.283
1983	2666	351.4	5.84	952	298.6	9.06	0.357
1984	2349	310.8	6.13	982	273.9	8.77	0.418
1985	1261	544.2	9.36	505	503.2	14.47	0.400
1986	933	570.8	11.00	379	387.4	18.03	0.406
1987	1252	584.3	9.24	574	543.4	13.69	0.458
1988	1525	453.8	8.17	567	434.1	11.55	0.372
1989	1775	406.0	7.35	587	424.8	11.33	0.331

Table 3.12. (*continued*)

	All Data			Subsetted Data			Sampling
Year	N	Catch (mt)	SE (C MT)	N	Catch (mt)	SE (Catch)	Fraction
1990	2201	407.9	6.77	624	389.4	11.06	0.284
1991	2250	379.3	6.23	660	415.0	11.41	0.293
1992	1716	388.1	7.34	445	435.0	14.33	0.259
1993	1489	481.8	8.53	423	506.7	16.04	0.284
1994	1339	434.5	8.65	377	518.3	17.22	0.282
1995	1431	531.6	9.43	361	600.8	19.42	0.252
1996	1399	468.5	9.04	350	578.8	19.17	0.250
1997	1499	386.9	8.11	347	487.0	18.73	0.231
1998	999	550.9	11.09	282	599.7	19.62	0.282
1999	895	428.0	10.27	297	528.6	18.68	0.332
2000	690	542.4	13.76	209	560.2	24.87	0.303
2001	836	625.7	12.69	285	644.4	20.40	0.341
2002	783	497.5	12.09	247	531.1	21.02	0.315
2003	777	478.4	11.62	282	508.9	18.78	0.363
2004	807	508.5	11.34	318	498.2	17.05	0.394
2005	745	441.1	9.80	295	463.8	15.10	0.396
2006	684	514.9	12.21	208	445.4	18.88	0.304
2007	803	486.2	10.48	279	452.8	14.48	0.347
2008	567	557.0	12.37	133	468.9	21.89	0.235

Table 3.13. Sample size (number of sets), mean catch per set (mt), and standard error of mean catch per set made by the Virginia and North Carolina reduction fleet, 1985-2008.

Year	N	Catch (mt)	Std Err
1985	10587	26.25	0.26
1986	5313	41.09	0.53
1987	9208	32.59	0.32
1988	9523	26.70	0.28
1989	10925	25.67	0.26
1990	12061	26.81	0.26
1991	13113	23.95	0.24
1992	11590	22.98	0.24
1993	9620	31.27	0.33
1994	10850	24.19	0.27
1995	11158	31.12	0.33
1996	9612	30.38	0.32
1997	10548	26.10	0.32
1998	7491	32.97	0.44
1999	6400	27.27	0.39
2000	4739	36.34	0.57
2001	5665	41.01	0.56
2002	4910	36.37	0.59
2003	4565	36.93	0.61
2004	5551	33.36	0.44
2005	5103	29.16	0.35
2006	3953	41.71	0.66
2007	4698	38.99	0.56
2008	3467	42.68	0.75

Table 3.14 Data used to develop index of abundance for age-1 menhaden in Chesapeake Bay, and estimated number of age-0 menhaden at start of a given fishing season (from ASMFC 2006) advance one year.

Year	No. of purse-seine sets in Ches Bay	No. of age-1 menhaden caught in Ches Bay 'area' (area 3) in millions of fish	Index of abundance for age-1 menhaden in Ches Bay [(No. age-1's caught/no. of purse-seine sets)*100]	Estimated no. of age-0's (billions) in population at start of fishing season, advanced one yr [from 2006 assessment]
1985	6248	647.6	10.36	30.79
1986	3931	154.4	3.93	25.32
1987	6494	324	4.99	18.44
1988	6746	90.5	1.34	13.8
1989	7555	887.2	11.74	27.27
1990	7484	91.2	1.22	10.5
1991	8220	545.9	6.64	19.04
1992	7245	592.7	8.18	22.48
1993	6368	225.6	3.54	18.24
1994	7220	92.2	1.28	12.64
1995	6506	368.4	5.66	16.9
1996	6391	58.9	0.92	9.35
1997	7706	12	0.16	9.04
1998	5483	87.5	1.60	7.91
1999	5459	73.1	1.34	10.29
2000	3274	39.6	1.21	10.12
2001	4231	21.3	0.50	5.53
2002	3796	81.4	2.14	9.32
2003	4050	93.8	2.32	14.85
2004	3811	61.7	1.62	12.72
2005	3901	18.1	0.46	5.44
2006	2316	252.4	10.90	8.81
2007	3077	231.8	7.53	
2008	2693	51.8	1.92	

Figure 3.1. Landings from the reduction purse seine fishery (1940-2008) and bait fishery (1985-2008) for Atlantic menhaden. Recreational catches (1981-2008) are not included because they are two-orders of magnitude smaller than the bait landings.

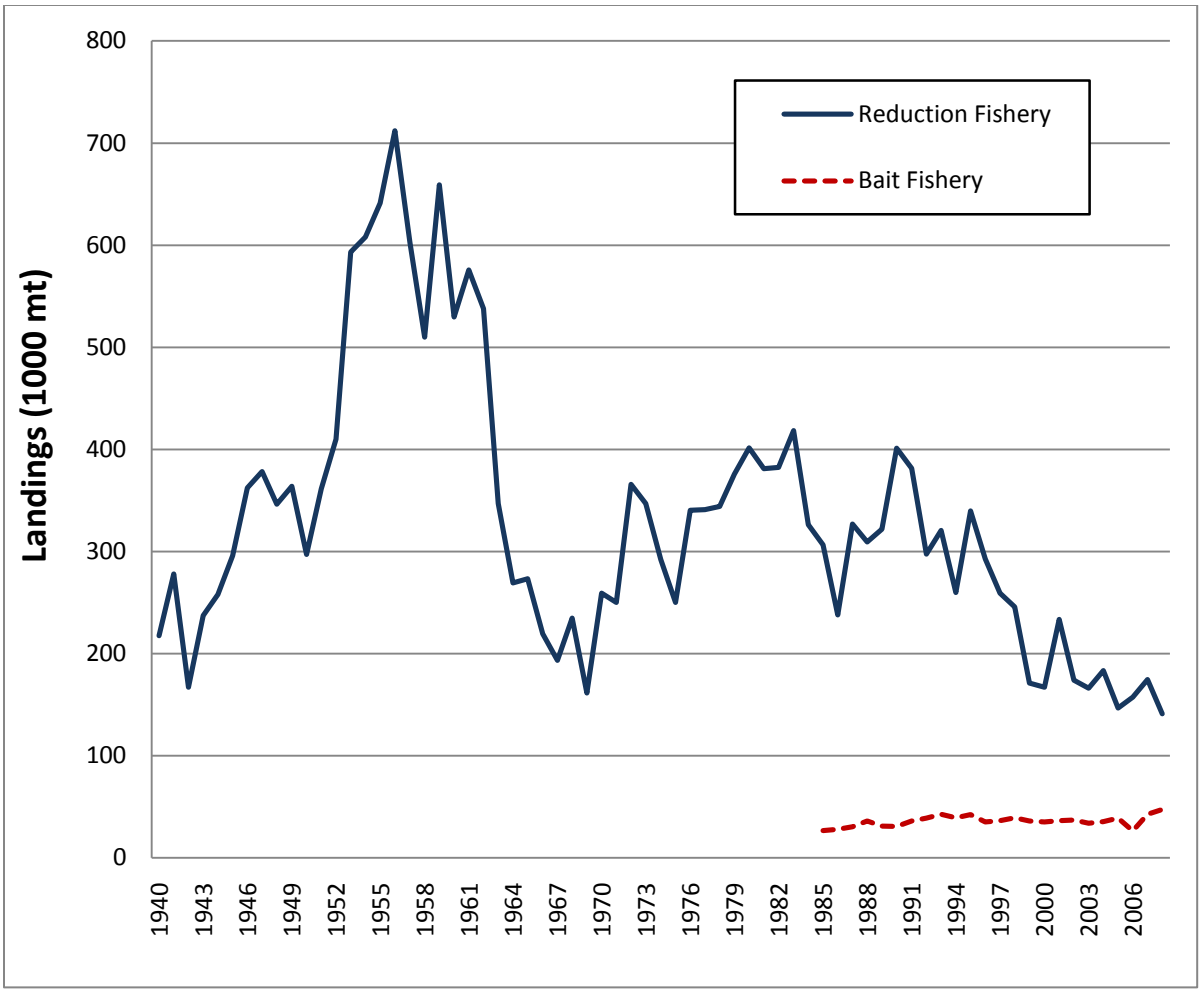


Figure 3.2. Comparison of mean landings by state from the bait fishery for Atlantic menhaden, 1985-2000 and 2001-2005.

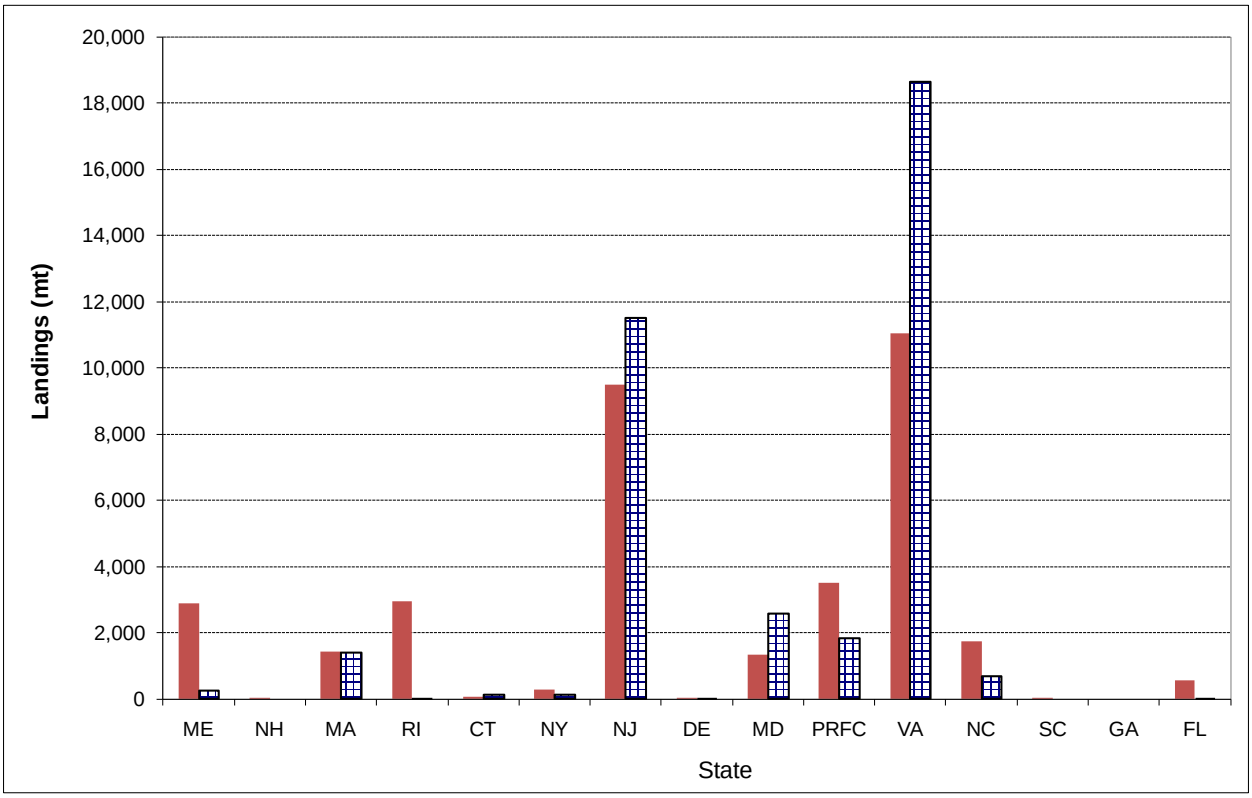


Figure 3.3. Atlantic menhaden bait landings (1000 metric tons) by region, 1985-2008.

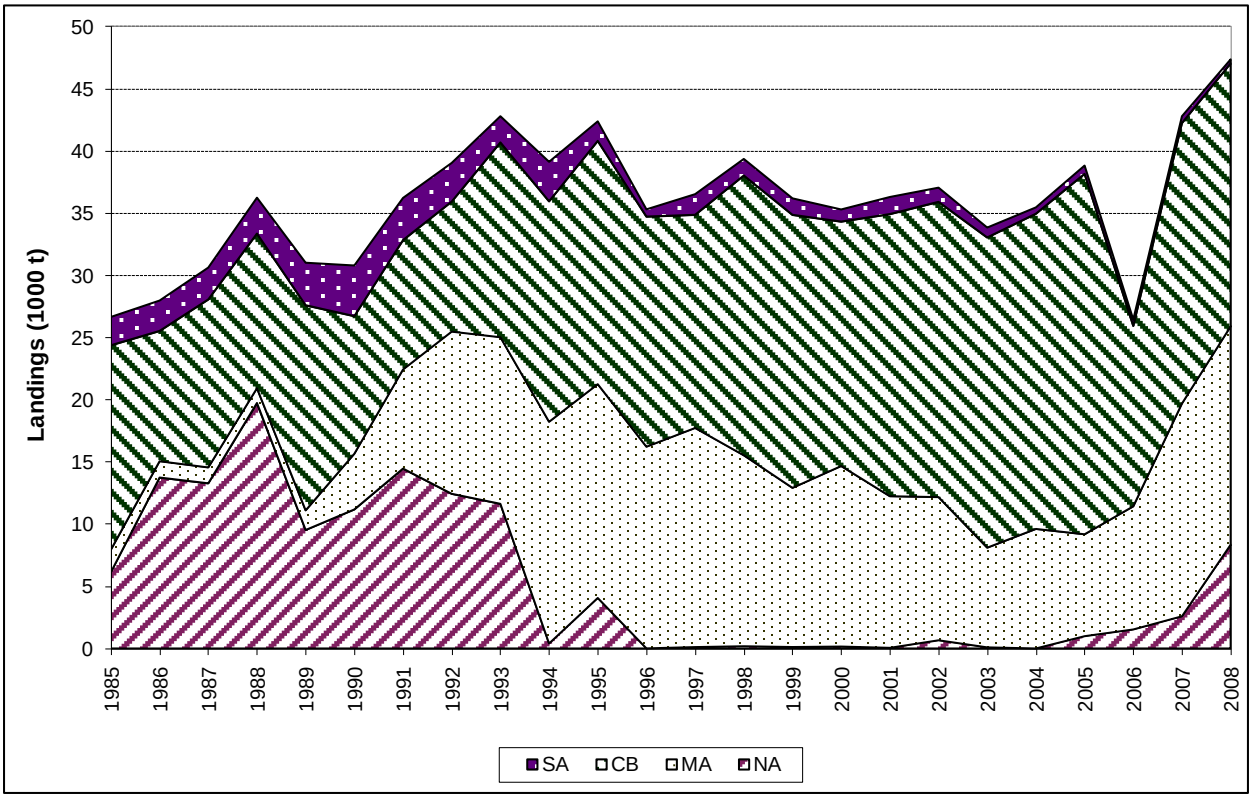


Figure 3.4. Annual values of menhaden reduction landings (1000 mt) and nominal effort (vessel-week), 1940-2008.

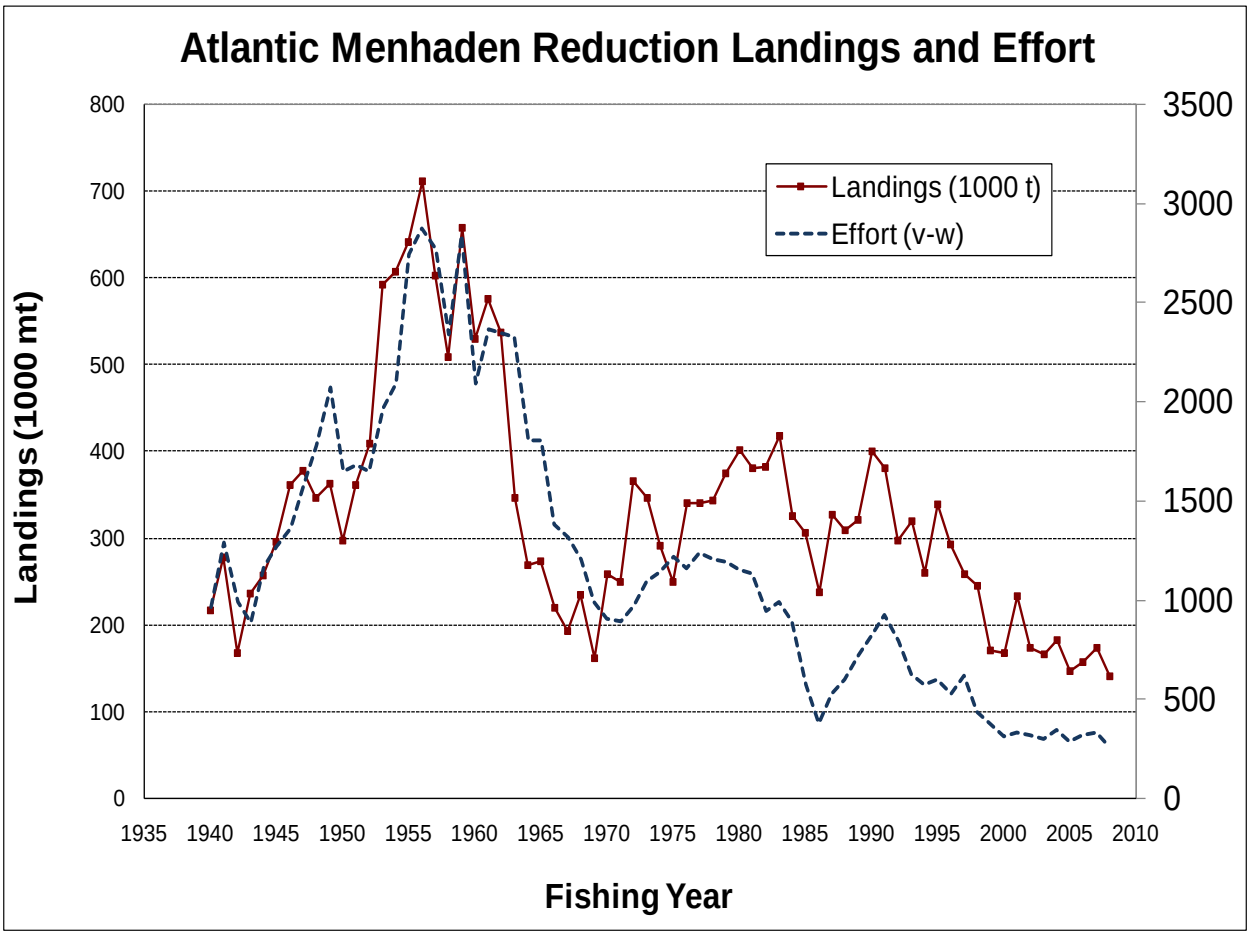


Figure 3.5. Relationship between menhaden reduction landings (1000 mt) and nominal fishing effort (vessel week), 1940-2008.

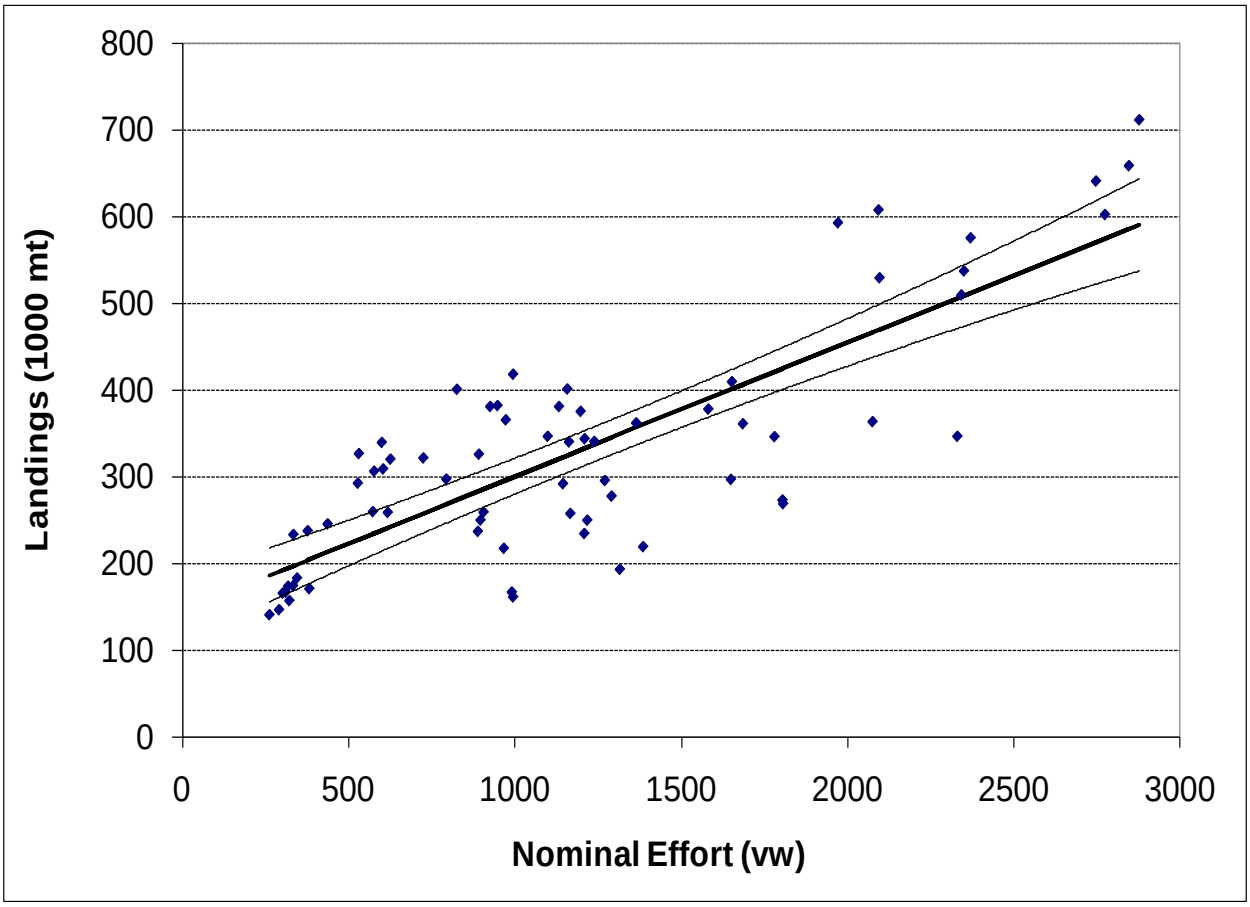


Figure 3.6. Comparison of catch per trip from all Atlantic menhaden reduction trips, subset sampled in biostatistical program (merged data), and LSMEANS from initial GLM runs based on coarse (area/season) input data with either normal or lognormal error structure.

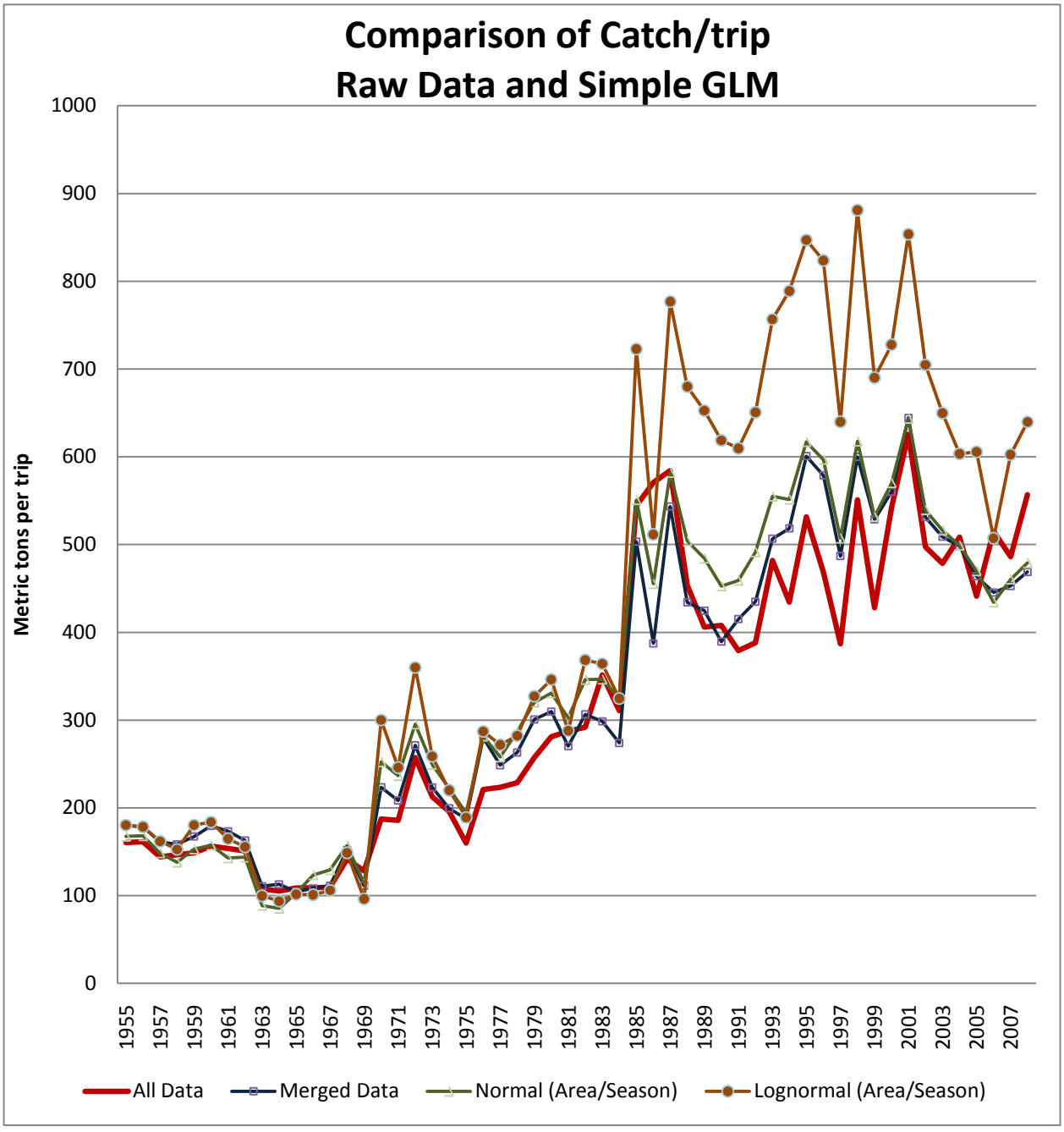


Figure 3.7. Comparison of nominal fishing effort for Atlantic menhaden reduction fleet, 1955-2008. Effort compared includes: (1) vessel-week, (2) trips (all landings data), and (3) GLM LSMEANS (additive model) based on subset of trips. All effort estimates are standardized by dividing by respective value in 1955.

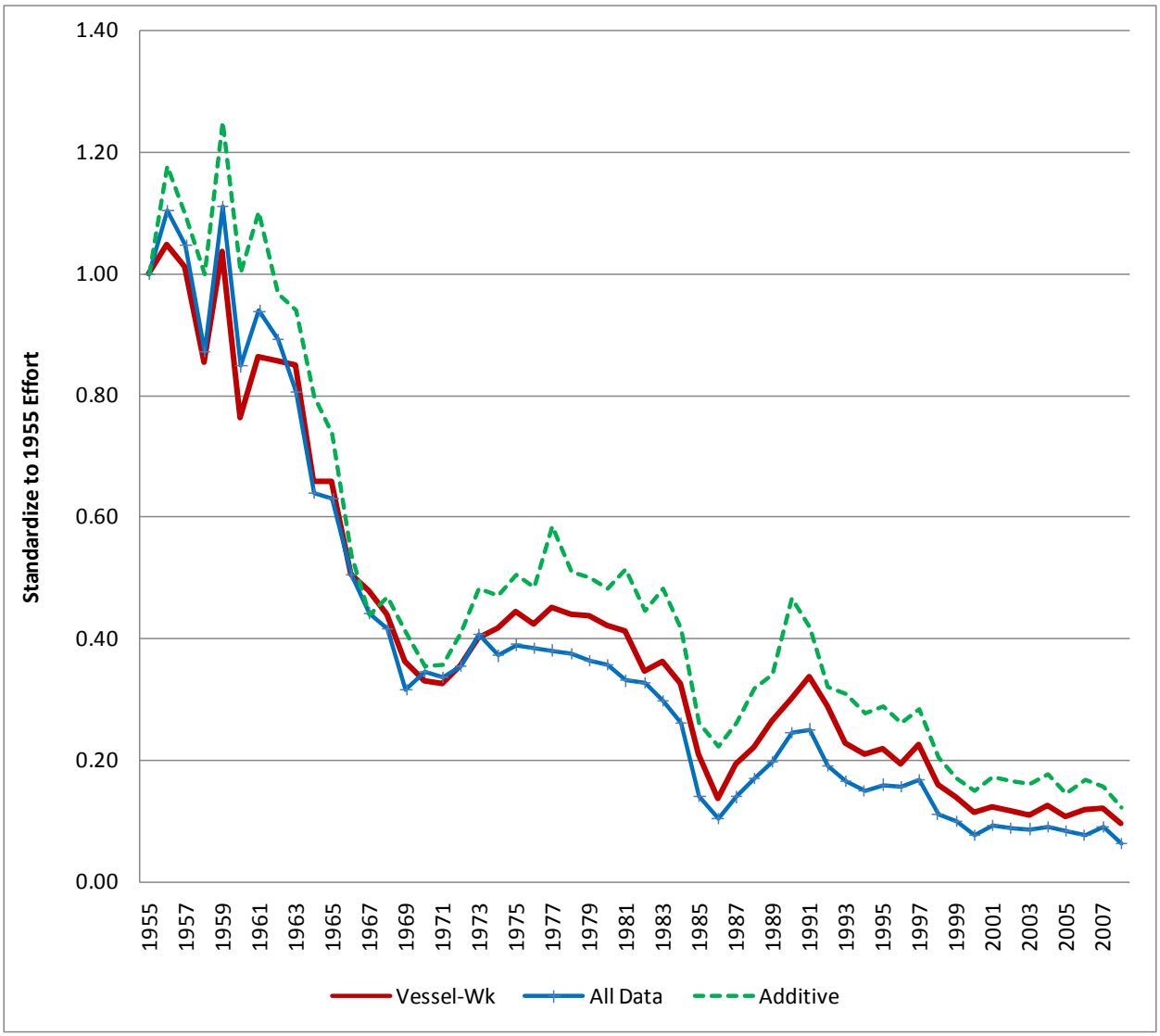


Figure 3.8. Comparison of calculated averages for CPUE across different measures of fishing effort, including landings per vessel week, landings per trip and catch per set.

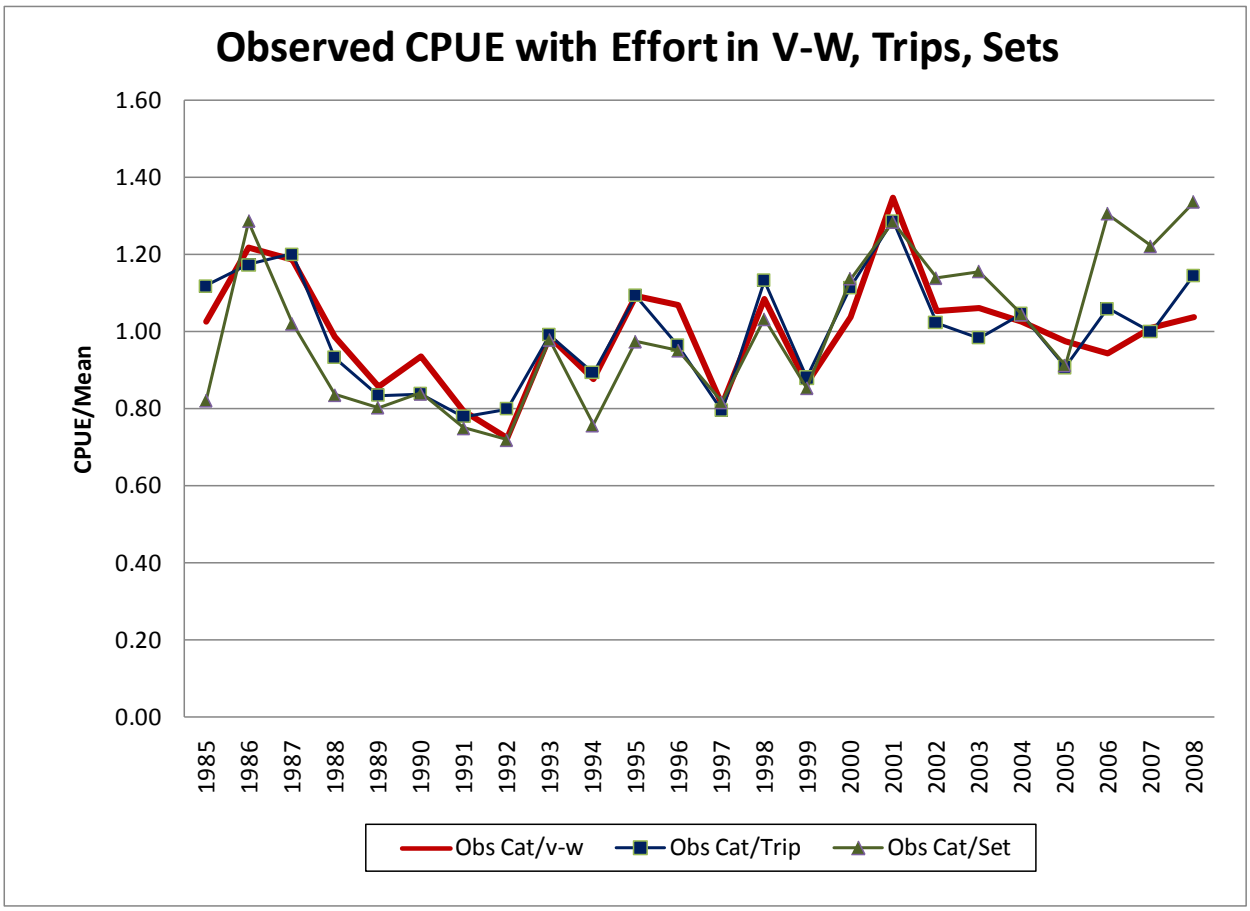


Figure 3.9. Comparison of nominal fishing effort for Atlantic menhaden reduction fleet, 1985-2008. Effort compared includes: (1) vessel-week, (2) trips (all landings data), and (3) purse-seine sets from VA and NC reduction plants. All effort estimates are standardized by dividing by respective value in 1985.

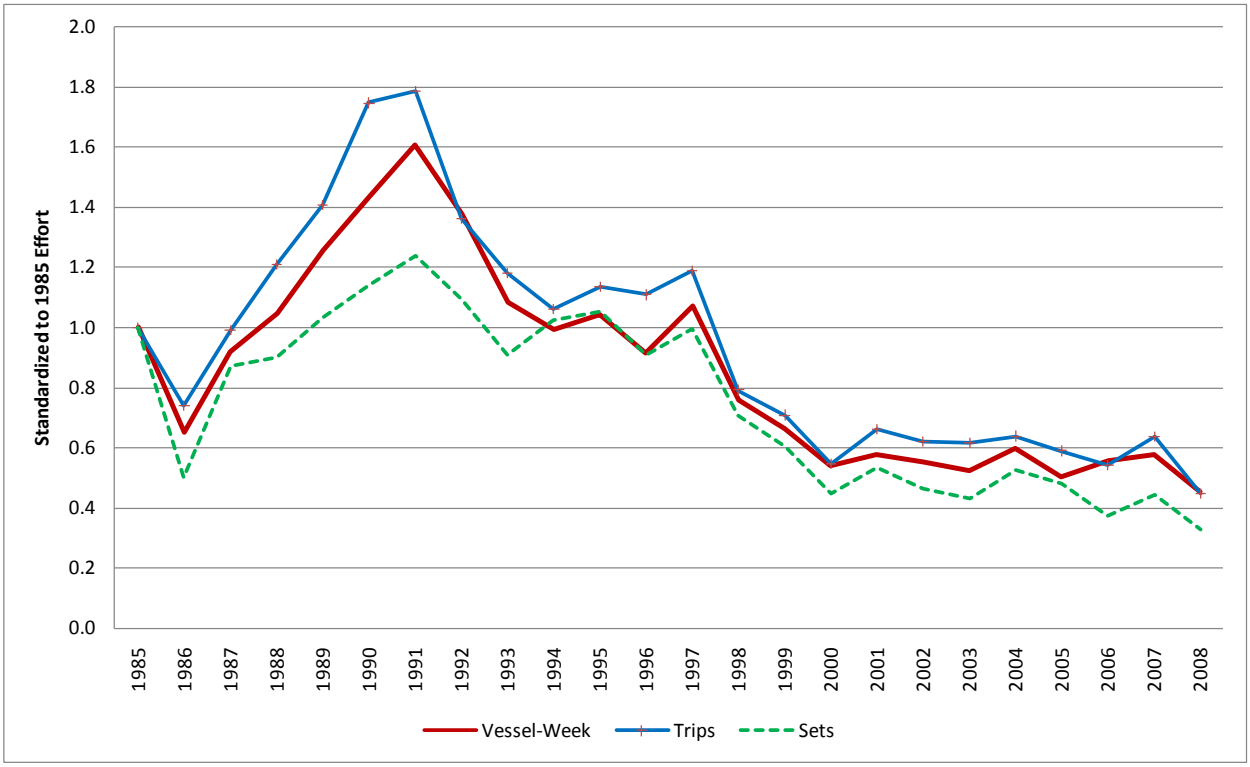


Figure 3.10. Index of abundance for age-1 menhaden in Chesapeake Bay [(No. age-1's caught/no. of purse-seine sets)*100].

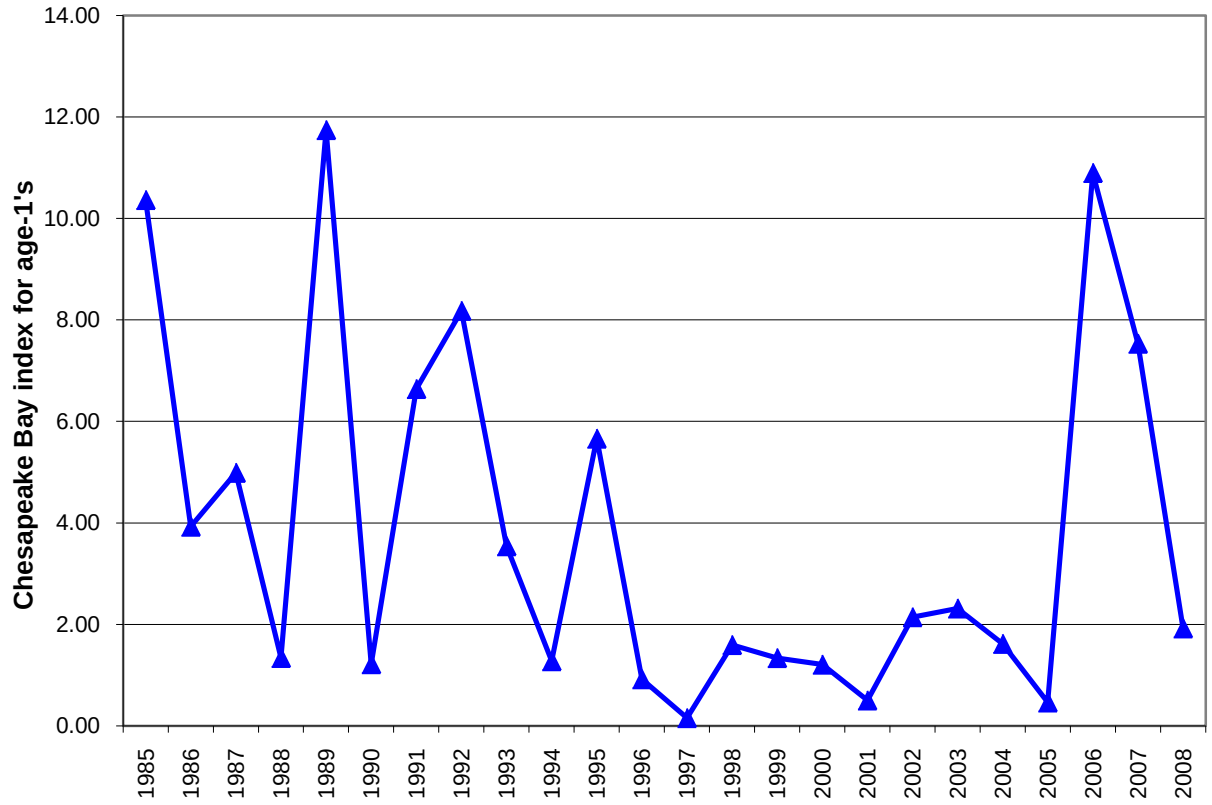
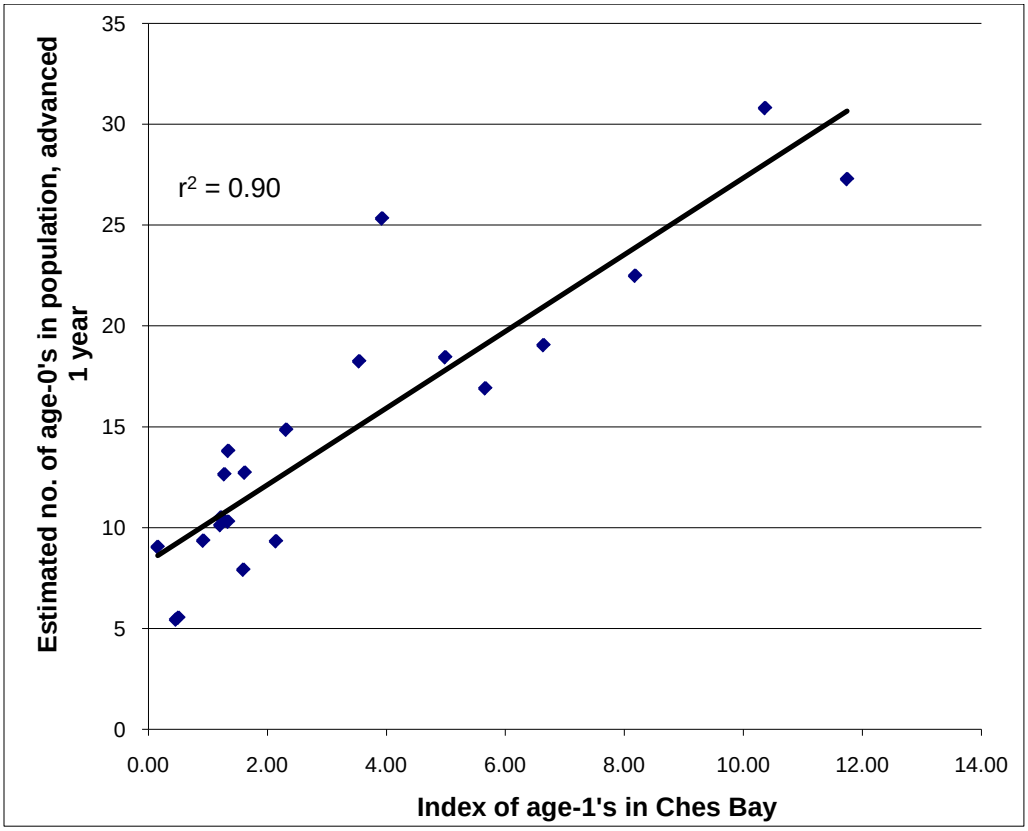


Figure 3.11. Estimated no. of age-0's in population at start of fishing season, advanced one yr [from 2006 assessment], less 2006 data.



Appendix

Spotter Pilot Log Book Survey

Within the Atlantic Menhaden Technical Committee, a Cooperative Research Subcommittee was formed to foster cooperative studies among the menhaden reduction and bait fisheries and state and federal scientists. At the Subcommittee's meeting in May 2008, the NMFS Beaufort Laboratory and Omega Protein, Inc., agreed to work together to implement a weekly aerial survey (utilizing menhaden spotter pilots) which would report menhaden abundance observations during the 2008 fishing season. Each Sunday during the fishing season several of Omega's spotter pilots scout for menhaden schools in Chesapeake Bay (Virginia portion only) and in ocean waters from Virginia to New Jersey. The pilots fill out 'fish reports' with number of schools, estimated numbers of fish (in thousands of standard fish), and location of the schools. Omega's Chief Pilot compiled and transferred 'fish report' information to a chart, which was then mailed to the NMFS Beaufort Laboratory weekly.

Rhode Island's Department of Environmental Management and a spotter pilot for a bait fishing company (Ark Bait Co.) agreed to implement a similar survey that recorded menhaden abundance observations throughout Narragansett Bay. The pilot in Rhode Island compiled data on number of schools and estimates of fish (in pounds) within pre-determined areas of Narragansett Bay, then forwarded weekly data sheets to the RI DEM.

An index of relative abundance for menhaden was adapted from methodology in the literature (Squire 1972) used for spotter pilot data from the California sardine fishery. The modified methodology was applied to data collected in 2008 from the menhaden fisheries. An additional data set from 2006 was available from the Virginia spotter pilots. The methodology appears to produce useful information for spatially tracking relative abundance of Atlantic menhaden. The Subcommittee determined that if the survey design and index methodology are found to be defensible, they will not be useful until at least five years of data are collected.

The Subcommittee discussed several improvements that could be made to the survey. One improvement important for scientific defensibility is the addition of a measure of effort, that is, area covered per flight. Industry representatives agreed to investigate if electronic downloads of flight paths are feasible for the 2009 fishing season.

An additional improvement discussed was expanding the coverage of the spotter survey beyond the coverage during the 2008 season. The spotter pilot from Rhode Island has offered to record observations farther south to the New Jersey coast. Omega's pilots currently fly as far north as Atlantic City, NJ. Coverage for the 2009 season should span from Chesapeake Bay to Narragansett Bay, including coverage for northern New Jersey and into Long Island Sound.