S E D A R

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Harvest, Effort, and Catch-at-Age
for Gulf Menhaden

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Data Sources

The commercial fishery for gulf menhaden consists primarily of a directed purse-seine fishery for *Brevoortia patronus* for reduction purposes, which is nearly the exclusive source of fishery-dependent data for the stock. Purse-seine fisheries for gulf menhaden for bait were active off the west coast of Florida and Louisiana during the 1980s through about 2000, but landings for bait were minor compared to the reduction fishery. A mixed-species aggregate by-catch of gulf menhaden mostly from gill nets and trawls also exists in several states, but again, the landings are minor compared to the reduction fishery. Recreational fishermen catch gulf menhaden as bait for various game fish; however, the quantities removed are considered negligible.

Landings processed by the gulf menhaden reduction plants have been reported to the National Marine Fisheries Service (NMFS) since 1964. A chronology of gulf menhaden plant activity since 1964 is shown in **Table 1**. Federal scientists were given access to historical records of gulf menhaden companies, and thus were able to reconstruct catch and nominal fishing effort by the various menhaden factories back to the mid-1940s. These data are thought to be complete back to 1948. Biostatistical samples of the catches have been continuously collected since 1964. Deck logbooks (Captain's Daily Fishing Reports, or CDFRs) maintained by menhaden reduction vessels have better defined removals by area and have given insights into alternate measures of nominal fishing effort.

Reduction Fishery

The reduction fishery for gulf menhaden is a daytime fishery, which 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 directing the purse boat crews to set 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 4-5 sets per fishing day and median catch size per set is about 17 to 22 mt (Smith et al. 2002). At the end of the fishing trip, which is often a multi-day trip, the catch is pumped at dockside into the fish factory. Then, the catch 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, processed-food, and aquaculture industries of the U.S.

Fishery-dependent data for the gulf menhaden reduction fishery are maintained at the NMFS Beaufort Laboratory in three large data sets. Commercial catch and effort data (**Table 2**) for the reduction fishery are available from 1948 through 2010. 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 1964 through 2010, 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%. Annual CDFR data sets for the gulf menhaden fleet are available from 1983 to 2010.

Reduction Fishery Overview

Much of the information on the development of the gulf menhaden fishery during the 20th century is addressed in the document S27DW04. The overview here deals with the fishery since about the 2000 fishing season.

The gulf menhaden purse-seine fishery is almost exclusively a single species fishery for gulf menhaden, *B. patronus*. Small and relatively insignificant amounts of other menhaden species, i.e., yellowfin menhaden, *B. smithi,* or finescale menhaden, *B. gunteri,* may be incidentally harvested as these species may overlap with *B. patronus* at the extreme east and west ranges of the gulf menhaden fishery (Ahrenholz 1991). Occasionally, vessels in the menhaden fishery make directed purse-seine sets on schools of Atlantic thread herring, *Opisthonema oglinum*. This occurs primarily in the central portion of the northern Gulf of Mexico by vessels fishing from the port of Empire, Louisiana.

Four extant fish factories existed on the U.S. Gulf coast from 2000 through 2010. Of these four factories, three are owned by Omega Protein, Inc. (at Moss Point, Mississippi, and Abbeville and Cameron, Louisiana) and one is owned by Daybrook Fisheries, Inc. (at Empire, Louisiana).

Through the past decade, the number of gulf menhaden vessels gradually declined from 47 in 2000 to 41 in 2006. Since 2006, the fleet has been reasonably stable at 41 vessels.

A recent innovation to the gulf menhaden fleet (since about 2000) has been the use of carry vessels or 'run boats'. These are former menhaden steamers that are not involved with setting the net. Rather, they rendezvous with regular steamers on the fishing grounds, pump fish from the fish holds of the steamers into their own fish hold, then transport accumulated catches back to the fish factory. Run boats have been used most successfully at Moss Point, where on average about two of these vessels have operated each fishing season in recent years.

Reduction Fishery Landings

Nicholson (1978) suggested that the "modern" gulf menhaden fishery began just after World War II; he documented that 103,000 mt of gulf menhaden were landed in 1948 at ports in Florida, Mississippi, Louisiana, and Texas. He noted that landings were incomplete for 1946 and 1947 (see Table 3 in Nicholson 1978). Chapoton (1970, 1971) reviewed the history and status of the fishery from 1946 to 1970. He cited a general trend toward greater landings over the 25-year period. This upward trend in landings continued during the 1980s culminating with six consecutive years of landings over 800,000 mt (1982 through 1987) and record landings of 982,800 mt in 1984 (Smith et al. 1987, Smith 1991). The historical pattern in landings and corresponding nominal fishing effort (discussed later) are shown in **Figure 1**.

Consolidation within the menhaden industry (plant closures and fewer vessels), weak product prices, and weather were the major contributing factors to declining landings during the 1990s; annual landings during the decade averaged 552,000 mt per year and ranged from 421,400 mt in 1992 (Hurricane Andrew) to 761,600 mt in 1994. During 2000 to 2010, landings averaged 479,600 mt annually, a decline of 13% from the average of the previous decade. Nevertheless, landings since 2000 have been less variable than during the 1990s ranging from 379,700 mt in 2010 (Deep Water Horizon Oil Spill) to 579,300 mt in 2000.

Tropical weather systems in the northern Gulf have played a major role in depressing landings in recent years. In 2004 (468,700 mt), the gulf menhaden fleet lost considerable fishing time because of Hurricanes Charley and Ivan. In 2005 (433,800 mt), Hurricanes Katrina and Rita severely damaged all four menhaden plants and a number of vessels, shortening the fishing season for most of the factories. In 2008 (425,400 mt), Hurricane Ike delivered significant damage to the two plants in western Louisiana. Moreover, in 2010 (379,700 mt), the Deep Water Horizon Oil Spill forced major closures to traditional menhaden fishing grounds.

Since 1964, the menhaden fishery in the northern Gulf of Mexico has reported gulf menhaden landings for reduction during the fishing year directly to the Beaufort Laboratory on a monthly basis (**Table 2**). Daily vessel unloads are provided in thousands of standard fish (1,000 standard fish = 670 lbs), which are converted to kilograms. Between 2008 and 2010 the reduction fleet (ca. 41 vessels) unloaded an average of 1,977 times during each fishing year; the average unload per vessel was 214 mt.

Age and Size Composition

Biological sampling for the menhaden purse-seine fishery is based on a two-stage cluster design and 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. Nicholson and Schaaf (1978) performed detailed examinations of gulf menhaden scales and determined that rings on the scales are reliable age marks (see S27DW02).

The original premises of the gulf menhaden port sampling routines remained relatively unchanged for over thirty years; namely, sampling is based on a two-stage design (above) and port agents, who were employed by the NMFS, collected and processed the fish samples. Prior to about 1995, NMFS agents were hired as temporary Federal workers on an intermittent basis, that is, they (mostly undergraduate or graduate students) were employed during the fishing season to collect and process gulf menhaden from about May through October. In about 1994, the Federal government abolished most temporary positions, and the NMFS was no longer able to hire seasonal port agents.

Beginning in about 1995, the solution to acquiring gulf menhaden port samples without temporary Federal hires became two-faceted. First, dockside personnel at each fish factory in Louisiana were identified and asked to acquire a target number of fish samples each week of the fishing season; factory personnel are paid a nominal fee per sample. Samples are labeled with date, vessel, and catch location, then frozen in a chest freezer. Second, between about 1995 and 2003 Gulf States Marine Fisheries Commission (GSMFC) wrote "independent contracts" to temporary employees who retrieved frozen samples at the fish factories, then processed the fish samples for size and age composition, mailing data and scale samples to the NMFS Beaufort Laboratory. Beginning in 2004 to present, Louisiana Department of Wildlife and Fisheries has been assigned the contracts to process the fish samples from Empire, Abbeville, and Cameron. Port samples from Moss Point, Mississippi, since about 1995 have been acquire and processed by an employee of the NMFS Pascagoula Laboratory. In recent years, the task of processing the samples from Moss Point has been performed by an independent contractor through GSMFC. Over the past fifteen years, supervision of port sampling efforts has remained under the direction of the NMFS Beaufort Laboratory.

Detailed sampling of the reduction fishery permits landings in biomass to be converted to landings in numbers at age. For each port/week caught, biostatistical sampling provides an estimate of mean weight and the age distribution of fish caught. Hence, dividing landings for that port/week 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. Developing the catch matrix at the port/week caught-level of stratification provides for considerably greater precision than is typical for most assessments.

About 4,800 gulf menhaden from the reduction fishery have been processed annually for size and age composition over the past three fishing seasons, 2008-10 (**Table 3**). In comparing menhaden sampling intensity to the old rule-of-thumb criteria once 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. Because of these high numbers of fish sampled, and the two-stage sampling procedure, we also provide the number of sets sampled by the port samplers. Number of sets, was favored over number of fish,

in the recent Atlantic menhaden stock assessment (ASMFC 2010 - SEDAR 20) and in the most recent gulf menhaden assessment (Vaughan et al. 2007).

Over the 47-year period that the NMFS has collected fishery-dependent data from the gulf menhaden fishery (1964-2010), age-2 fish have been increasingly represented in the catch-at-age matrices (**Figure 2**). Indeed, age-2 gulf menhaden represented 73% of the total numbers-at–age in the catch-at-age matrix for 2009. Reasons for the increase in age-2 fish in the landings over time, and the subsequent decline of age-1 fish, are not well understood. Surely, recruitment success of juveniles into estuarine areas, which are believed to be largely driven by environmental factors, plays a major role. However, several additional hypotheses have been proposed (at the GMAC meeting in Orange Beach, AL, in March 2010) such as: 1) contraction of the fishery over time from the extremes of the species' range (Texas and Florida, where smaller and younger fish are more abundant) towards the center of the species' range (Louisiana and Mississippi); 2) re-distribution over time of age-1 fish toward more "inside" waters (where they become unavailable to the fishery) due to marsh habitat loss across the Gulf (this is somewhat supported by data from systematic gill net surveys in Louisiana and Texas); and, 3) a "corralling-effect" in which hypoxic waters of the Gulf may have on the distribution of gulf menhaden (Smith 2000).

Methodology for estimating catch in numbers at age from the fishery has been used consistently over time (Nelson and Ahrenholz 1986, Vaughan 1987, Vaughan et al. 1996, 2000, 2007). Catch in numbers at age are developed by week and port based on the detailed port sampling and weekly catch records. In two of the past three years, age-2 gulf menhaden have comprised 68% (2008) and 73% (2009) of the total numbers of fish landed (**Table 4**). However, in 2010 the age composition of the coastwide landings was more evenly distributed with 49% of the catch age-1s and 41% age-2s. Mean fork lengths of age-1 gulf menhaden sampled over the past three years have been 157, 165, and 153 mm, respectively; mean weights of age-1 fish have been 78, 90, and 73 grams. Mean fork lengths of age-2 gulf menhaden sampled over the past three years have been 183, 184, and 181 mm, respectively; mean weights of age-2 fish have been 129, 125, and 121 grams.

Bait Fishery

The bait fishery for menhaden has historically accounted for only a minute portion of the total landings of gulf menhaden (see S27DW04). Until the mid-1980s, the bait purse-seine fishery for gulf menhaden occurred almost exclusively in Florida. Louisiana and Alabama began landing menhaden for bait in 1984, and Louisiana's landings increased substantially through the mid to late 1980s. Through the 1990s, two companies in Morgan City and Cameron, Louisiana, were responsible for a majority of the gulf menhaden landings for bait in the central northern Gulf. Bait landings of gulf menhaden have declined substantially in the past decade.

Bait Fishery Overview

Although little published information exists on menhaden bait fisheries (Smith and O'Bier 2011), the majority of gulf menhaden harvested for bait in the northern Gulf of Mexico probably are used as bait in the blue crab trap fishery and the crawfish fishery. Some bait is sold fresh at dockside; however, most is probably frozen and trucked throughout the Gulf region. Menhaden are also used commercially by long-line and hook and line fishermen as bait and chum for red snapper, grouper, and other reef fishes. In the recreational fishery, menhaden are used for bait and chum by sport fishermen and the charter boat industry.

Bait Landings

Historically, Florida and Louisiana have been the main participants in the gulf menhaden bait fisheries. Purse-seine landings of gulf menhaden for bait in Florida increased substantially during the mid-1980s, peaked in about 1990, declined to lower levels in the 1990s, and have shown a steady downward trend since 2000 (**Table 2**). During the peak years, Florida bait landings were concentrated in Tampa Bay and off the Panhandle region. Closure of Tampa Bay to purse-seine fishing by about 1991-92 and the Florida Net Ban in 1995 (prohibiting purse-seine gear in state waters) no doubt were reasons for the decline in landings.

Purse-seine landings of gulf menhaden for bait in Louisiana increased significantly in the late 1980s when two companies began using surplus reduction fishery steamers to harvest gulf menhaden in the northern Gulf near Morgan City and Cameron (**Table 2**). The operation in Cameron was closed in 2000. The company in Morgan City closed in 2007; consequently, gulf menhaden landings for bait in Louisiana declined sharply.

To fill in for missing values in the earliest years and the latest year, average values were substituted. In particular, values were obtained for 1948-1949 by averaging the following ten years (1950-1959) while the value for 2010 was obtained by averaging the previous 5 years (2005-2009). The small amount of bait landings was combined with reduction landings to produce a single landings stream for 1948-2010 and a single catch at age matrix for use in stock assessment models for 1964-2010 (**Table 5**).

Recreational Catches (MRFSS)

Recreational landings for 1981-2009 are also summarized in **Table 2** (see S27DW04). Similar to filling in missing values for matching landings from reduction fishery for 1948-2010, average values were obtained from 1981-1990 for the earlier years 1946-1980 and average values for 2005-2009 for 2010. The combined landings by bait and recreational fisheries are compared with those by the reduction fishery in **Figure 3**. This small amount of recreational catches was combined with reduction and bait landings to produce a single catch at age matrix for use in stock assessment models (**Table 5**). Specifically, the total landings in weight based on all three fisheries were divided by the reduction landings to calculate an annual expansion factor. This expansion factor was multiplied by the catch at age matrix in **Table 4**.

Gulf Menhaden Effort

Background on units of observed fishing effort in the menhaden purse-seine fisheries

Often, menhaden vessels unload their catches daily, although, 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, or days when the catch was zero. Logbooks were placed on Atlantic menhaden vessels during the late 1950s and early 1960s to try and capture better information on 'fishing' and 'non-fishing' days at sea (Roithmayr 1963), but compliance was incomplete (Nicholson 1971). Similar attempts to maintain logbooks on gulf menhaden vessels (1964-1969) also met with mixed results (Nicholson 1978). Thus, through about the 1970s there was no satisfactory way to acquire a complete at-sea history of each menhaden 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 assigned one vessel-week of effort. Vessel-weeks for all vessels in the Atlantic fleet are calculated across all months of operation, and then summed for an estimate of annual nominal or observed fishing effort for the fishery. For the gulf menhaden fishery, Chapoton (1971) noted that fish catching ability is more directly related to size of the vessel and its fish hold capacity. Thus, the vessel-ton-week (one vessel fishing at least one day of a given week times its net tonnage) is used as a measure of nominal fishing effort for the gulf menhaden fishery, as it better accounts for efficiencies among different sized vessels (**Figure 1**). Similar to Atlantic menhaden, the correlation between landings and nominal fishing effort (vessel-ton-week) is significantly ($r^2 = 0.79$ for 1948-2010). The regression of landings on nominal effort is presented with observed values in **Figure 4**.

As a rule, estimates of nominal fishing effort have only been used by the Menhaden Program at the NMFS Beaufort Laboratory for forecasting annual catches for the gulf and Atlantic menhaden fisheries. In a general predictive sense, the amount of nominal fishing effort expended is a good indicator of the amount of fish that may be removed from the stock in a given year. Estimates of nominal fishing effort have not been used in menhaden stock assessments for reasons outlined below.

CPUEs for the menhaden fisheries

In a general sense for many fisheries, catch-per-unit-effort (CPUE), is used as an index of abundance, where, a proportional change in CPUE is expected to represent the same proportional change in stock size. However, for purse-seine fisheries it has been demonstrated that CPUE and nominal or observed fishing effort are poor measures of population abundance (Clark and Mangel 1979), which is especially true for those fisheries that utilize spotter aircraft. Thus, we have been wary of using fishery-dependent CPUEs as a measure of population abundance for the

menhaden fisheries. For reference purposes, CPUEs in total landings divided by vessel-ton-weeks for the gulf menhaden fishery for 1955-2010, are shown in **Figure 1**.

Alternate measures of nominal fishing effort in the gulf menhaden fishery

In fall 2007, the Gulf Menhaden Advisory Committee (GMAC) requested that the NMFS Beaufort Laboratory explore alternate units of nominal fishing effort for the gulf menhaden fishery that might replace the traditional effort unit, the vessel-ton-week, for predicting annual menhaden forecasts. Since annual CDFR data sets are available electronically for most years with 100% compliance beginning in 1983 (except 1992, 1993, and 2005), we explored two potential alternate units of nominal fishing effort: 1) total number of purse-seine sets, and 2) total number of fishing days when at least one purse-seine set was made. Results were presented to the GMAC at Galveston, TX, in March 2008, and are updated here with data through 2010 (**Table 6**). Some conclusions of this exercise were that:

1) total number of sets and number of days with >=1 purse-seine set were closely correlated with the traditional unit of observed effort, vessel-ton-weeks, and

2) vessel-ton-weeks were adequate for current use in NMFS landings forecast models.

During the Data Workshop portion of SEDAR20 for Atlantic menhaden (ASMFC 2010), we investigated using catch per trip as an alternate unit of CPUE for the Atlantic menhaden purse-seine fishery. Here, we explored the use of catch per fishing trip as a unit of CPUE for the gulf fishery. Catch per trip was calculated simply as the total annual landings of gulf menhaden for reduction divided by the number of times gulf menhaden vessels unloaded during the fishing season (unload events for 1983 and 1984 are incomplete). Surprisingly, catch per trip for the gulf fleet has risen steadily from the mid-1980s to present (**Table 7**). Reasons for this increase are probably: 1) longer trip duration, hence greater volumes of fish at each unloading, 2) as older vessels are retired, newer vessels in the fleet have greater fish hold capacities, and 3) improved efficiencies within the fleet, notably use of stern ramps or similar devices by most vessels to launch and retrieve the purse boats, permitting greater number of sets per fishing day (NMFS Beaufort Lab., unpublished data).

These three measures of nominal fishing effort were scaled to the terminal year (2010) for comparison purposes in **Figure 5**. Similarly, catch per unit effort based on these three measures of nominal fishing effort are compared in **Figure 6**. From about 1980 onwards, similar trends are found for all three measures. However for the period from 1964 to about 1980, there are differences found between vessel-ton-week and trips as measures of fishing effort. Changes in fleet characteristics since about the 1980s may explain this divergence. As older and smaller vessels were phased out of the gulf menhaden fleet during the 1970s and early 1980s, newer vessels with larger fish holds and greater net tonnages joined the fleet (net tonnage is a calculation of the volume of cargo space within a ship). Vessels with larger fish hold capacities presumably can stay on the fishing grounds longer and necessarily make fewer trips in a given fishing year. Table 8 illustrates this trend toward greater mean vessel net tonnage in the gulf

menhaden fleet over the past forty years. Indeed, mean net tonnage of the fleet has increased over 100 net tons since 1970.

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Table 1. Years of activity for individual menhaden reduction plants along the U.S. Gulf of Mexico coast, 1964-2011.

	Plant																	Total
Year	54	55	56	57	58	59	60	61	62	63	64	65	68	69	70	71	72	Plants
1964	1	1	1	1	1	1	1		1	1	1	1						11
1965	1	1	1	1	1		1		1	1		1	1	1	1			12
1966	1	1	1	1	1		1	1	1	1	1	1	1	1				13
1967	1	1	1	1	1		1		1	1	1	1	1	1		1		13
1968	1	1	1	1	1		1	1	1	1	1	1	1	1		1		14
1969	1	1	1	1	1			1	1	1	1	1	1	1		1		13
1970	1	1	1	1	1		1		1	1	1	1	1	1		1		13
1971	1	1	1	1	1		1		1	1	1	1	1	1		1		13
1972	1	1	1	1	1				1	1	1		1	1		1		11
1973		1	1	1	1				1	1	1		1	1		1		10
1974		1	1	1	1				1	1	1		1	1		1		10
1975	1	1	1	1	1				1	1	1		1	1		1		11
1976	1	1	1	1	1				1	1	1		1	1		1		11
1977	1	1	1	1	1				1	1	1		1	1		1		11
1978	1	1	1	1	1				1	1	1		1	1		1		11
1979	1	1	1	1	1				1	1	1		1	1		1		11
1980	1	1	1	1	1				1	1	1		1	1		1		11
1981	1	1	1	1	1				1	1	1		1	1		1		11
1982	1	1	1	1	1				1	1	1		1	1		1		11
1983	1	1	1	1	1				1	1	1		1	1		1		11
1984	1	1	1	1	1				1	1	1		1	1		1		11
1985		1	1	1							1		1	1		1		7
1986		1	1	1	1						1		1	1		1		8
1987		1	1	1	1						1		1	1		1		8
1988		1	1	1	1						1		1	1		1		8
1989		1	1	1	1						1		1	1		1	1	9
1990		1	1	1	1						1		1	1		1	1	9
1991			1	1	1								1	1		1	1	7
1992			1		1								1	1		1	1	6
1993			1		1								1	1		1	1	6
1994			1		1								1	1		1	1	6
1995			1		1								1	1		1	1	6

Table 1. (cont.)

	Plant																	Total
Year	**54**	**55**	**56**	**57**	**58**	**59**	**60**	**61**	**62**	**63**	**64**	**65**	**68**	**69**	**70**	**71**	**72**	**Plants**
1996			1		1								1			1	1	5
1997			1		1								1			1	1	5
1998			1		1								1			1	1	5
1999			1		1								1			1	1	5
2000			1		1								1			1		4
2001			1		1								1			1		4
2002			1		1								1			1		4
2003			1		1								1			1		4
2004			1		1								1			1		4
2005			1		1								1			1		4
2006			1		1								1			1		4
2007			1		1								1			1		4
2008			1		1								1			1		4
2009			1		1								1			1		4
2010			1		1								1			1		4
2011			1		1								1			1		4

Table 1. (*cont.*)

Plant	Name	Location
54	Fish Meal Company	Moss Point, Miss
55	Standard Product Company	Moss Point, Miss
56	Haynie Products Company	Moss Point, Miss
57	Empire Menhaden Company	Empire, LA
58	Quinn Menhaden Fisheries	Empire, LA
59	Fish Meal & Oil Company (Bennett)	Dulac, LA
60	Quinn Menhaden Fisheries	Dulac, LA
61	Smith Meal Company	Apalachicola, FL
62	Fish Meal Company	Morgan City, LA
63	Gulf Menhaden Company	Cameron, LA
64	Louisiana Menhaden Company	Cameron, LA
65	Texas Menhaden Company	Sabine Pass, TX
68	Seacoast Products	Intracoastal City, LA
69	Terrebonne Menhaden Company	Dulac, LA
70	Florida Reduction Plant	Dulac, LA
71	Ocean Protein, Inc.	Cameron, LA
72	Gulf Protein	Morgan City, LA

Table 2. Gulf menhaden landings, effort (vessel-ton-weeks, vtw), and CPUE from the reduction purse-seine fishery, 1948-2010, landings from the bait fisheries, 1950-2009, landings estimated from the recreational fishery (MRFSS), 1981-2009, and combined landings for all fisheries. Recreational landings represent removals of A+B1+B2 by weight. Average values used for shaded areas: subsequent 10-yr average for early years, and prior 5-yr average for 2010.

	Reduction Fishery			Bait Fishery	Recreational Fishery	Combined
Year	Landings (1000 mt)	Effort (vtw)	CPE	Landings (1000 mt)	Catches (1000 mt)	Landings (1000 mt)
1948	74.6	40.7	1.833	0.009	0.153	74.8
1949	107.4	66.2	1.622	0.009	0.153	107.6
1950	147.2	82.2	1.791	0.000	0.153	147.4
1951	154.8	94.2	1.643	0.003	0.153	155.0
1952	227.1	113.3	2.004	0.004	0.153	227.3
1953	195.7	104.7	1.869	0.001	0.153	195.9
1954	181.2	113.0	1.604	0.001	0.152	181.4
1955	213.3	122.9	1.736	0.011	0.152	213.5
1956	244.0	155.1	1.573	0.014	0.152	244.2
1957	159.3	155.2	1.026	0.003	0.152	159.5
1958	196.2	202.8	0.967	0.040	0.152	196.4
1959	325.9	205.8	1.584	0.009	0.153	326.1
1960	376.8	211.7	1.780	0.005	0.154	377.0
1961	455.9	241.6	1.887	0.011	0.154	456.1
1962	479.0	289.0	1.657	0.009	0.154	479.2
1963	437.5	277.3	1.578	0.020	0.152	437.7
1964	407.8	272.9	1.494	0.038	0.149	408.0
1965	461.2	335.6	1.374	0.196	0.149	461.5
1966	357.6	381.3	0.938	0.254	0.150	358.0
1967	316.1	404.7	0.781	0.058	0.152	316.3
1968	371.9	382.8	0.972	0.207	0.156	372.3
1969	521.5	411.0	1.269	0.137	0.161	521.8
1970	545.9	400.0	1.365	0.280	0.166	546.3
1971	728.5	472.9	1.540	0.366	0.154	729.0
1972	501.9	447.5	1.122	0.292	0.145	502.3
1973	486.4	426.2	1.141	0.446	0.134	487.0
1974	587.4	485.5	1.210	0.319	0.122	587.8
1975	542.6	538.0	1.009	0.211	0.152	543.0
1976	561.2	575.8	0.975	0.328	0.162	561.7
1977	447.1	532.7	0.839	0.298	0.166	447.6
1978	820.0	574.3	1.428	0.404	0.195	820.6
1979	777.9	533.9	1.457	1.727	0.218	779.8
1980	701.3	627.6	1.117	0.999	0.210	702.5

Table 2. (cont.)

Year	Reduction Fishery Landings (1000 mt)	Reduction Fishery Effort (vtw)	CPE	Bait Fishery Landings (1000 mt)	Recreational Fishery Catches (1000 mt)	Combined Landings (1000 mt)
1981	552.6	623.0	0.887	1.074	0.038	553.7
1982	853.9	653.8	1.306	1.577	0.054	855.5
1983	923.5	655.8	1.408	1.739	0.024	925.3
1984	982.8	645.9	1.522	2.317	0.005	985.1
1985	881.1	560.6	1.572	2.998	0.449	884.5
1986	822.1	606.5	1.355	8.521	0.258	830.9
1987	894.2	604.2	1.480	17.261	0.209	911.7
1988	623.7	594.1	1.050	16.019	0.488	640.2
1989	569.6	555.3	1.026	13.503	0.440	583.5
1990	528.3	563.1	0.938	11.085	0.135	539.5
1991	544.3	472.3	1.152	8.629	0.051	553.0
1992	421.4	408.0	1.033	11.269	0.138	432.8
1993	539.2	455.2	1.185	12.182	0.170	551.6
1994	761.6	472.0	1.614	13.135	0.189	774.9
1995	463.9	417.0	1.112	8.068	0.056	472.0
1996	479.4	451.7	1.061	12.270	0.082	491.8
1997	611.2	430.2	1.421	11.927	0.020	623.1
1998	486.2	409.3	1.188	0.914	0.047	487.2
1999	684.3	414.5	1.651	1.025	0.051	685.4
2000	579.3	417.6	1.387	0.788	0.207	580.3
2001	521.3	400.6	1.301	0.751	0.048	522.1
2002	574.5	386.7	1.486	0.472	0.108	575.1
2003	517.1	363.2	1.424	0.489	0.118	517.7
2004	468.7	390.5	1.200	0.421	0.064	469.2
2005	433.8	326.0	1.331	0.281	0.048	434.1
2006	464.4	367.2	1.265	0.174	0.055	464.6
2007	453.8	369.2	1.229	0.251	0.030	454.1
2008	425.4	355.8	1.196	0.139	0.028	425.6
2009	457.5	377.8	1.211	0.128	0.061	457.7
2010	379.7	320.3	1.185	0.195	0.044	379.9

Table 3. Sample size as number of fish (N Fish) and number of sets (N Sets), landings in numbers and biomass of fish, and mean weight of fish landed from the gulf menhaden reduction fishery, 1964-2010.

Year	Sample Size (N Fish)	Sample Size (N Sets)	Landings		Mean Weight (g)
			(millions)	(1000 mt)	
1964	12260	625	4949.6	407.8	82.4
1965	15185	790	6232.4	461.2	74.0
1966	12429	640	4244.1	357.6	84.3
1967	14065	721	4640.8	316.1	68.1
1968	15273	795	4579.5	371.9	81.2
1969	14764	759	7413.8	521.5	70.3
1970	10402	527	5646.1	545.9	96.7
1971	7654	393	7924.1	728.5	91.9
1972	9886	998	4893.0	501.9	102.6
1973	8953	896	4290.8	486.4	113.4
1974	10086	1009	5378.9	587.4	109.2
1975	9527	953	4510.5	542.6	120.3
1976	13389	1355	6169.3	561.2	91.0
1977	14897	1492	6107.7	447.1	73.2
1978	12944	1300	9587.4	820.0	85.5
1979	11121	1163	7922.4	777.9	98.2
1980	9883	1014	7220.4	701.3	97.1
1981	10273	1042	7539.1	552.6	73.3
1982	10341	1076	9014.5	853.9	94.7
1983	14523	1485	8902.7	923.5	103.7
1984	15936	1599	11119.2	982.8	88.4
1985	13225	1324	11451.6	881.1	76.9
1986	16494	1652	9369.7	822.1	87.7
1987	16458	1647	11115.3	894.2	80.4
1988	12402	1240	8088.5	623.7	77.1
1989	13950	1392	7241.5	569.6	78.7
1990	11456	1152	5824.4	528.3	90.7
1991	11378	1164	4803.7	544.3	113.3
1992	14214	1524	3916.2	421.4	107.6
1993	14576	1537	5237.9	539.2	102.9
1994	16062	1680	7317.0	761.6	104.1
1995	13489	1470	3896.3	463.9	119.1
1996	12115	1506	4566.8	479.4	105.0
1997	9923	1121	5950.0	611.2	102.7
1998	9043	1072	4598.4	486.2	105.7
1999	10641	1183	6198.3	684.3	110.4
2000	8383	964	5607.9	579.3	103.3
2001	6222	740	3951.7	521.3	131.9
2002	5597	836	4999.8	574.5	114.9
2003	7839	1066	5274.7	517.1	98.0
2004	6644	942	5001.3	468.7	93.7
2005	6206	895	4398.3	433.8	98.6
2006	4698	594	4895.1	464.4	94.9
2007	3989	657	4750.1	453.8	95.5
2008	4663	593	3608.2	425.4	117.9
2009	6193	748	3603.3	457.5	127.0
2010	3678	461	3891.6	379.7	97.6

Table 4. Estimated reduction landings of gulf menhaden in numbers by age (in millions), 1964-2010.

Year	0	1	2	3	4	5	6	Total
1964	2.8	3329.3	1495.2	118.1	4.4	0.0	0.0	4949.6
1965	43.4	5031.4	1076.6	80.3	0.7	0.0	0.0	6232.4
1966	30.5	3314.4	865.2	33.8	0.3	0.0	0.0	4244.1
1967	22.4	4267.7	337.7	13.0	0.0	0.0	0.0	4640.8
1968	65.1	3475.2	1001.3	37.5	0.5	0.0	0.0	4579.5
1969	20.8	6075.0	1286.3	31.7	0.0	0.0	0.0	7413.8
1970	50.2	3279.9	2280.0	36.1	0.0	0.0	0.0	5646.1
1971	21.6	5761.1	1955.5	181.8	4.1	0.0	0.0	7924.1
1972	19.1	3047.7	1733.5	88.5	4.0	0.0	0.0	4893.0
1973	49.9	3033.0	1107.0	99.6	1.3	0.0	0.0	4290.8
1974	1.4	3846.8	1471.7	59.1	0.0	0.0	0.0	5378.9
1975	108.8	2440.5	1499.2	461.8	0.2	0.0	0.0	4510.5
1976	0.0	4591.4	1373.9	203.9	0.0	0.0	0.0	6169.3
1977	0.0	4660.0	1331.7	110.4	5.6	0.0	0.0	6107.7
1978	0.0	6787.4	2742.0	52.7	5.2	0.0	0.0	9587.4
1979	0.0	4701.2	2877.2	337.2	6.1	0.8	0.0	7922.4
1980	65.9	3409.4	3261.1	436.2	46.3	1.6	0.0	7220.4
1981	0.0	5750.5	1424.9	329.4	29.7	3.3	1.2	7539.1
1982	0.0	5146.7	3302.0	503.5	58.5	2.1	1.7	9014.5
1983	0.0	4685.7	3809.2	382.6	23.8	1.3	0.0	8902.7
1984	0.0	7749.6	2881.5	438.4	49.0	0.7	0.0	11119.2
1985	0.0	8682.7	2498.6	233.7	36.5	0.0	0.0	11451.6
1986	0.0	4276.0	4892.0	174.9	25.8	1.0	0.0	9369.7
1987	0.0	6699.5	3975.6	427.8	12.5	0.0	0.0	11115.3
1988	0.0	5337.7	2581.4	151.5	18.0	0.0	0.0	8088.5
1989	0.0	5550.4	1622.0	67.0	2.1	0.0	0.0	7241.5
1990	0.0	3889.2	1785.0	136.2	13.1	0.3	0.4	5824.4
1991	0.0	2217.5	2339.9	215.6	28.2	2.5	0.0	4803.7
1992	0.0	2187.3	1505.8	197.1	24.2	1.7	0.2	3916.2
1993	0.0	3492.8	1532.9	193.5	15.7	2.8	0.2	5237.9
1994	0.0	3627.6	3195.6	441.2	49.0	3.7	0.0	7317.0
1995	0.0	1369.2	2423.4	99.7	3.9	0.2	0.0	3896.3
1996	0.0	1784.2	2513.7	251.1	16.8	0.9	0.0	4566.8
1997	0.0	3235.6	2398.8	276.1	38.2	1.3	0.0	5950.0
1998	0.0	1804.8	2587.1	189.7	15.2	1.6	0.0	4598.4
1999	0.0	3368.8	2393.0	416.9	19.7	0.0	0.0	6198.3
2000	0.0	2029.8	3164.5	347.7	62.5	3.4	0.0	5607.9
2001	0.0	987.7	2654.2	290.2	18.9	0.8	0.0	3951.7
2002	0.0	1585.6	2863.1	534.0	17.1	0.0	0.0	4999.8
2003	0.0	1910.1	3011.7	339.6	13.4	0.0	0.0	5274.7
2004	0.0	2799.4	1764.0	400.3	37.6	0.0	0.0	5001.3
2005	82.0	1731.9	2381.0	189.0	13.6	0.0	0.8	4398.3
2006	0.0	2246.5	2301.3	317.8	29.6	0.0	0.0	4895.1
2007	0.0	2199.7	2421.4	111.8	13.3	3.9	0.0	4750.1
2008	0.0	960.6	2465.7	160.3	21.7	0.0	0.0	3608.2
2009	0.0	455.0	2633.4	466.6	47.9	0.4	0.0	3603.3
2010	0.0	2057.6	1572.3	238.8	22.5	0.4	0.0	3891.6

Table 5. Gulf menhaden catch in numbers (in millions) at age from the reduction, bait and recreational fisheries combined, 1964-2010.

Year	0	1	2	3	4	5	6	Total
1964	2.76	3330.81	1495.84	118.12	4.35	0.00	0.00	4951.88
1965	43.46	5035.16	1077.44	80.33	0.70	0.00	0.00	6237.09
1966	30.48	3318.17	866.14	33.80	0.26	0.00	0.00	4248.85
1967	22.45	4270.48	337.88	13.01	0.00	0.00	0.00	4643.83
1968	65.12	3478.62	1002.28	37.49	0.50	0.00	0.00	4584.01
1969	20.81	6078.48	1287.08	31.68	0.00	0.00	0.00	7418.05
1970	50.23	3282.53	2281.84	36.11	0.00	0.00	0.00	5650.71
1971	21.61	5765.24	1956.85	181.97	4.12	0.00	0.00	7929.79
1972	19.13	3050.40	1735.04	88.62	4.03	0.00	0.00	4897.21
1973	49.96	3036.62	1108.30	99.74	1.27	0.00	0.00	4295.89
1974	1.41	3849.64	1472.75	59.12	0.00	0.00	0.00	5382.93
1975	108.84	2442.15	1500.21	462.14	0.19	0.00	0.00	4513.53
1976	0.00	4595.39	1375.14	204.10	0.00	0.00	0.00	6174.63
1977	0.00	4664.78	1333.10	110.48	5.64	0.00	0.00	6114.00
1978	0.00	6792.40	2744.01	52.71	5.24	0.00	0.00	9594.36
1979	0.00	4712.97	2884.35	338.04	6.08	0.75	0.00	7942.19
1980	65.97	3415.29	3266.73	436.90	46.38	1.56	0.00	7232.84
1981	0.00	5762.11	1427.81	330.06	29.72	3.35	1.22	7554.27
1982	0.00	5156.57	3308.27	504.50	58.58	2.05	1.74	9031.71
1983	0.00	4694.68	3816.50	383.34	23.82	1.33	0.00	8919.67
1984	0.00	7767.86	2888.30	439.40	49.15	0.72	0.00	11145.42
1985	0.00	8716.66	2508.39	234.62	36.66	0.00	0.00	11496.35
1986	0.00	4321.65	4944.28	176.79	26.10	0.97	0.00	9469.79
1987	0.00	6830.36	4053.23	436.13	12.69	0.00	0.00	11332.41
1988	0.00	5478.97	2649.72	155.48	18.45	0.00	0.00	8302.61
1989	0.00	5686.31	1661.73	68.62	2.11	0.00	0.00	7418.77
1990	0.00	3971.82	1822.92	139.10	13.42	0.35	0.44	5948.05
1991	0.00	2252.87	2377.23	219.06	28.61	2.58	0.00	4880.35
1992	0.00	2246.49	1546.51	202.46	24.88	1.75	0.16	4022.24
1993	0.00	3572.84	1568.02	197.93	16.06	2.86	0.15	5357.86
1994	0.00	3691.06	3251.52	448.88	49.82	3.71	0.00	7444.99
1995	0.00	1393.14	2465.87	101.40	3.99	0.15	0.00	3964.55
1996	0.00	1830.16	2578.50	257.57	17.27	0.96	0.00	4684.46
1997	0.00	3298.83	2445.72	281.50	38.97	1.33	0.00	6066.34
1998	0.00	1808.39	2592.24	190.04	15.22	1.57	0.00	4607.45
1999	0.00	3374.07	2396.76	417.51	19.69	0.00	0.00	6208.02
2000	0.00	2033.29	3169.96	348.27	62.62	3.39	0.00	5617.52
2001	0.00	989.17	2658.24	290.60	18.88	0.84	0.00	3957.73
2002	0.00	1587.23	2865.99	534.50	17.14	0.00	0.00	5004.86
2003	0.00	1912.31	3015.25	339.95	13.37	0.00	0.00	5280.88
2004	0.00	2802.27	1765.86	400.73	37.61	0.00	0.00	5006.47
2005	82.06	1733.25	2382.76	189.11	13.59	0.00	0.83	4401.61
2006	0.00	2247.56	2302.40	317.93	29.58	0.00	0.00	4897.47
2007	0.00	2201.05	2422.88	111.82	13.34	3.90	0.00	4752.99
2008	0.00	960.94	2466.62	160.38	21.72	0.00	0.00	3609.66
2009	0.00	455.19	2634.45	466.80	47.94	0.38	0.00	3604.76
2010	0.00	2058.94	1573.34	238.95	22.47	0.40	0.00	3894.10

Table 6. Nominal fishing effort information for the gulf menhaden fishery from CDFR, 1983-2010. Note CDFR data sets for 1992, 1993, and 2005 are incomplete.

		CDFR data				
Year	Gulf menhaden landings (1000 mt)	Total no. of sets	No. of vessel-days w/ 1 or more sets	Total no. of possible vessel-days	Percent days fished [at least one set made]	Catch (mt)/Set
1983	923.5	37,587	7,764	10,412	0.75	24.6
1984	982.8	42,040	7,821	10,023	0.78	23.4
1985	881.1	25,145	4,987	6,921	0.72	35.0
1986	822.1	33,860	6,634	9,027	0.73	24.3
1987	894.2	34,898	7,026	8,779	0.80	25.6
1988	623.7	28,262	6,115	8,430	0.73	22.1
1989	569.6	26,427	6,174	8,621	0.72	21.6
1990	528.3	28,163	6,711	8,829	0.76	18.8
1991	544.3	26,648	5,624	7,372	0.76	20.4
1992	421.4	-	-	-	-	
1993	539.2	-	-	-	-	
1994	761.6	26,234	5,272	6,975	0.76	29.0
1995	463.9	21,264	4,662	6,824	0.68	21.8
1996	479.4	22,777	4,870	6,718	0.72	21.0
1997	611.2	23,378	4,707	6,623	0.71	26.1
1998	486.2	21,317	4,153	6,552	0.63	22.8
1999	684.3	24,704	4,617	6,058	0.76	27.7
2000	579.3	23,733	4,077	5,592	0.73	24.4
2001	521.3	21,223	4,043	5,788	0.70	24.6
2002	574.5	22,579	4,056	5,655	0.72	25.4
2003	517.1	22,825	3,940	5,391	0.73	22.7
2004	468.7	22,839	3,973	5,557	0.71	20.5
2005	433.8	-	-	-	-	
2006	464.4	21,913	3,772	5,193	0.73	21.2
2007	453.8	19,428	3,570	5,396	0.66	23.4
2008	425.4	15,532	3,112	5,409	0.58	27.4
2009	457.5	18,260	3,752	5,579	0.67	25.1
2010	379.7	14,604	2,868	5,384	0.53	26.0

Table 7. Number of fishing trips, catch per trips, and standard error of mean catch per trip by the gulf menhaden reduction fleet, 1964-2010. Note that trip information is incomplete (*) for 1983 and 1984.

	All Data		
Year	N	Catch (mt)	SE (mt)
1964	4692	87.3	1.186
1965	4235	109.4	2.508
1966	3617	99.3	1.617
1967	3221	98.6	1.521
1968	3176	117.6	1.736
1969	3638	144.0	1.840
1970	3769	145.5	1.854
1971	4453	163.6	1.755
1972	3659	137.2	1.609
1973	3437	141.5	1.654
1974	3943	149.0	1.676
1975	3987	136.1	1.515
1976	4066	138.0	1.576
1977	3724	120.1	1.417
1978	4474	183.3	1.727
1979	4078	190.8	1.880
1980	4186	167.5	1.717
1981	3811	145.0	1.566
1982	4695	181.9	1.712
1983	1218*	151.0	3.280
1984	2128*	190.6	2.487
1985	3343	263.6	2.139
1986	4028	204.1	1.793
1987	4427	202.0	1.694
1988	3629	171.9	1.757
1989	3618	157.4	1.743
1990	3557	148.5	1.657
1991	2977	182.8	2.060
1992	2468	170.8	1.955
1993	2928	184.2	1.952
1994	3238	235.2	2.137
1995	2587	179.3	2.135
1996	2693	178.0	2.090
1997	2831	215.9	2.222
1998	2447	198.7	2.307
1999	2811	243.4	2.339
2000	2600	222.8	2.622
2001	2434	214.2	2.613
2002	2552	225.1	2.533
2003	2370	218.2	2.666
2004	2371	197.7	2.499
2005	2083	208.3	2.675
2006	2088	222.4	2.807
2007	2193	206.9	2.731
2008	1896	224.4	3.041
2009	2280	200.6	2.579
2010	1755	216.4	3.223

Table 8. Mean net tonnage (metric) of the gulf menhaden purse-seine fleet by selected fishing years since 1970.

Mean net tonnage of the gulf menhaden fleet since 1970			
Fishing Year	Mean net tonnage	No. of vessels in calculation	Range of net tonnages
1970	248	72	80-386
1980	315	79	139-453
1990	317	75	147-447
2000	338	43	197-453
2010	354	40	187-453

Figure 1. Annual values of gulf menhaden reduction landings (1000 mt) and nominal effort (vessel-ton-week), 1948-2010.

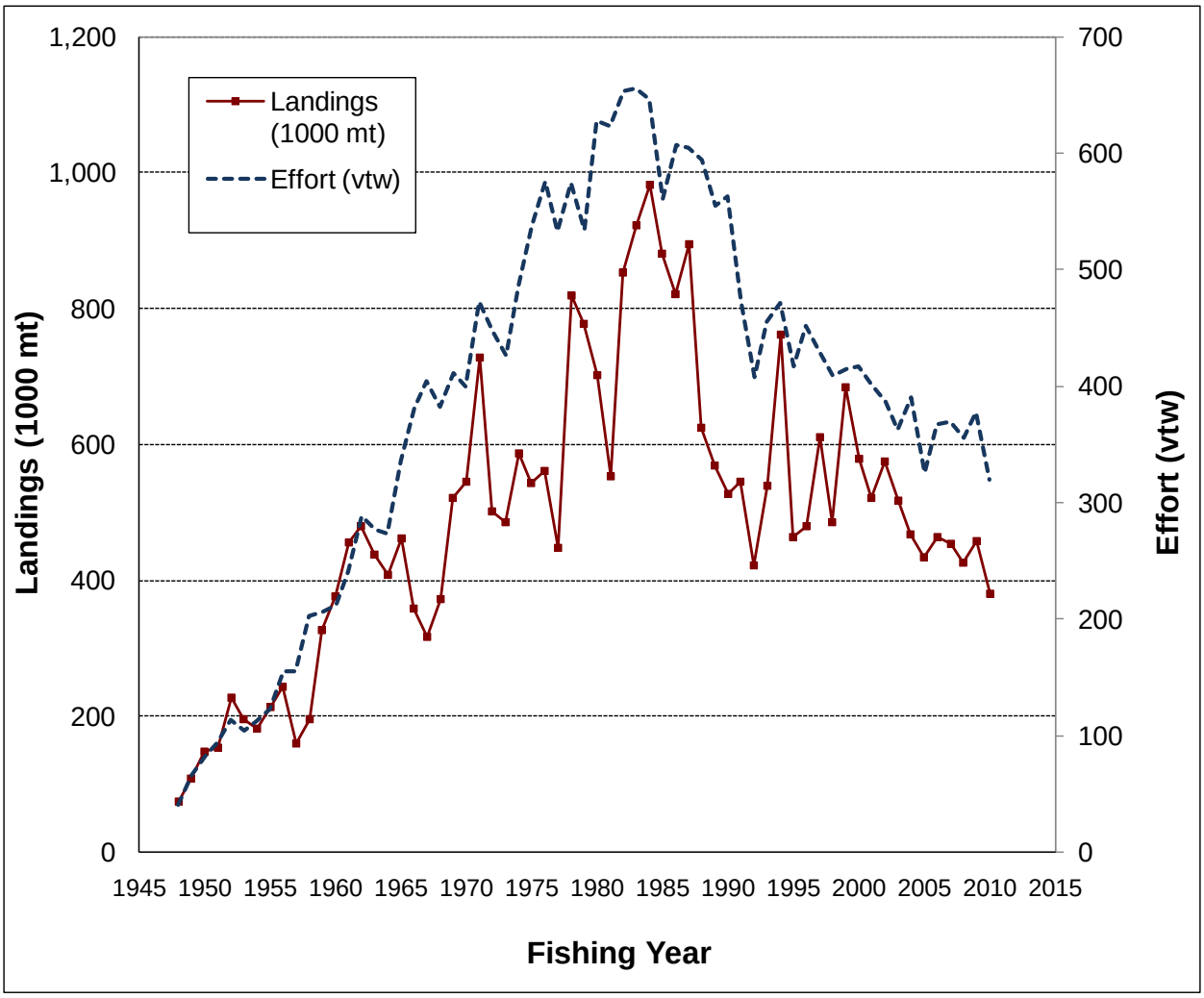

Figure 2. Percent age-1 and age-2 gulf menhaden in the catch-at-age matrix, 1964-2010.

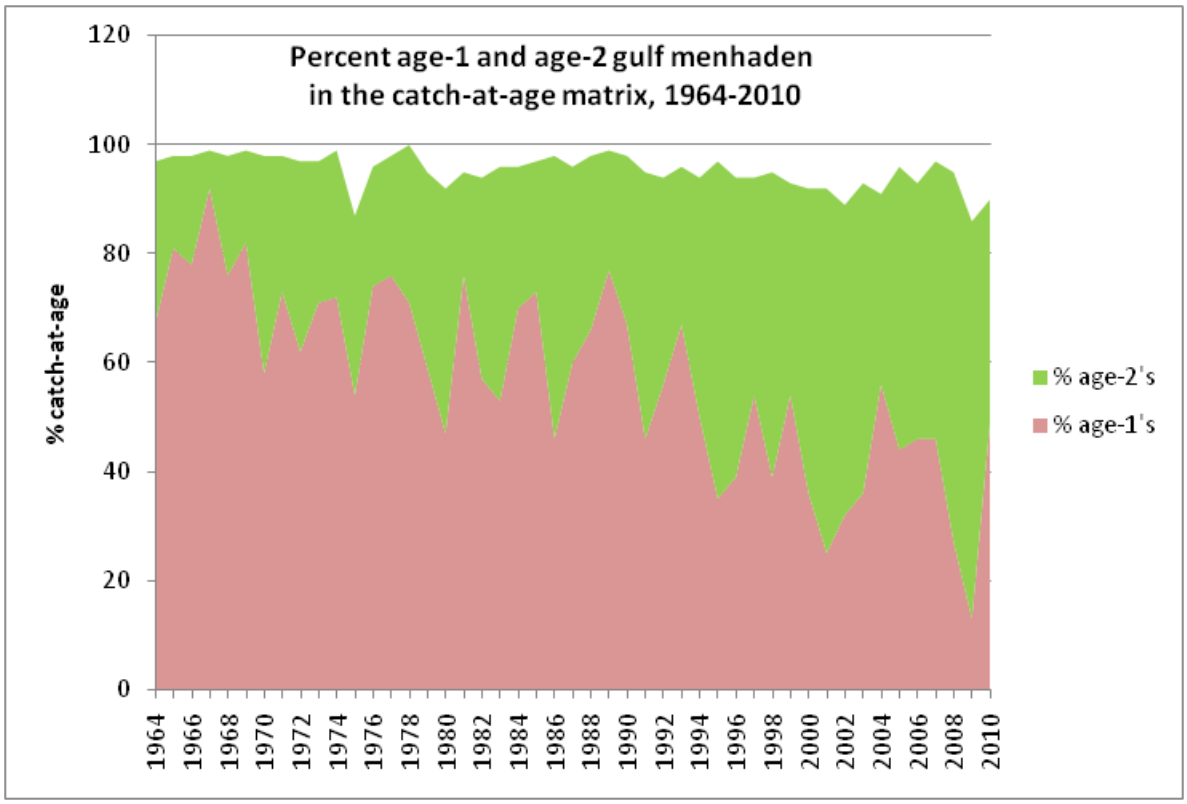

Figure 3. Comparison of reduction fishery with combined bait and recreational fisheries, 1948-2010.

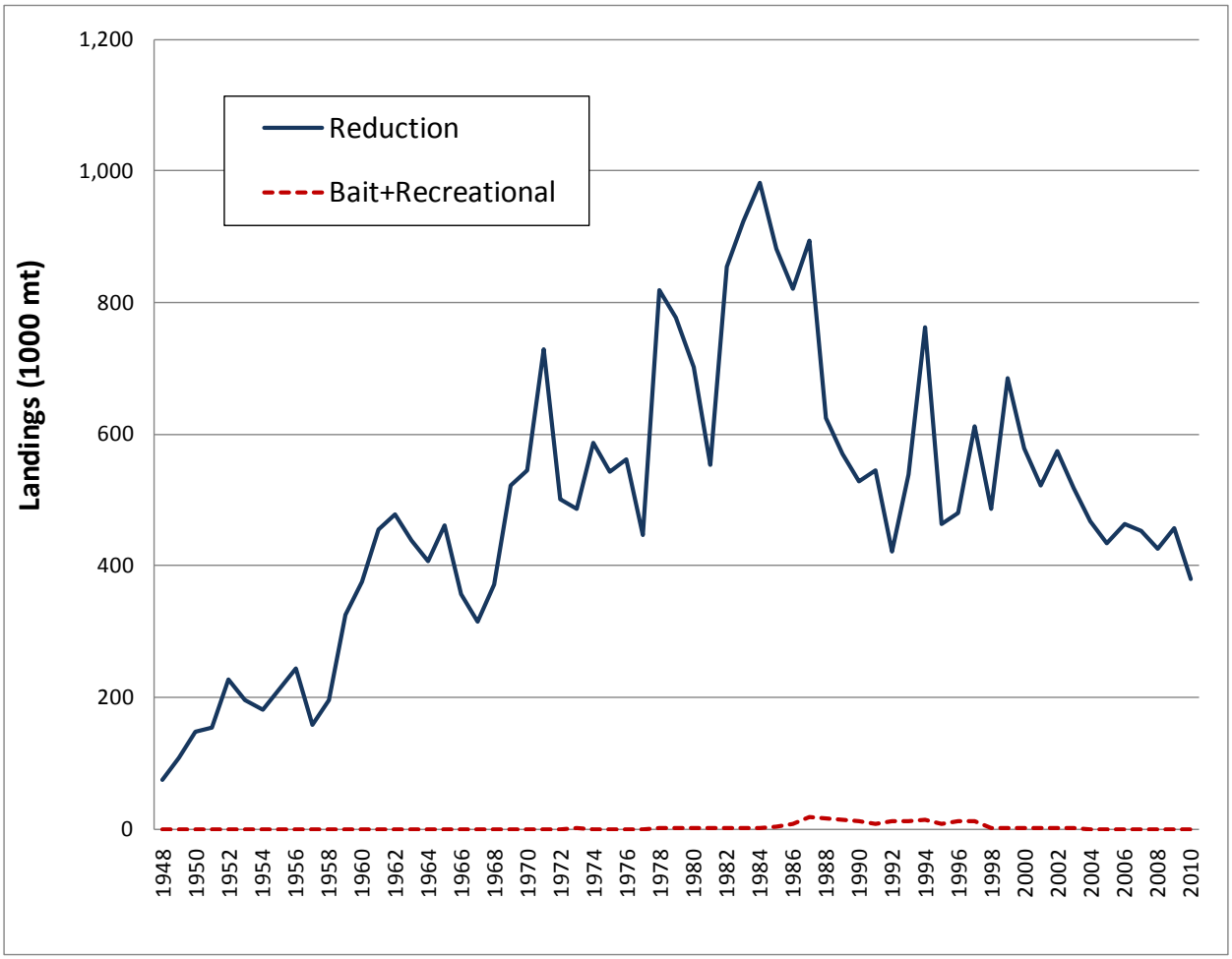

Figure 4. Relationship between gulf menhaden reduction landings (1000 mt) and nominal fishing effort (vessel-ton-week), 1948-2010. The linear regression of landings on effort explains 79% (r^2) of the annual variability in landings.

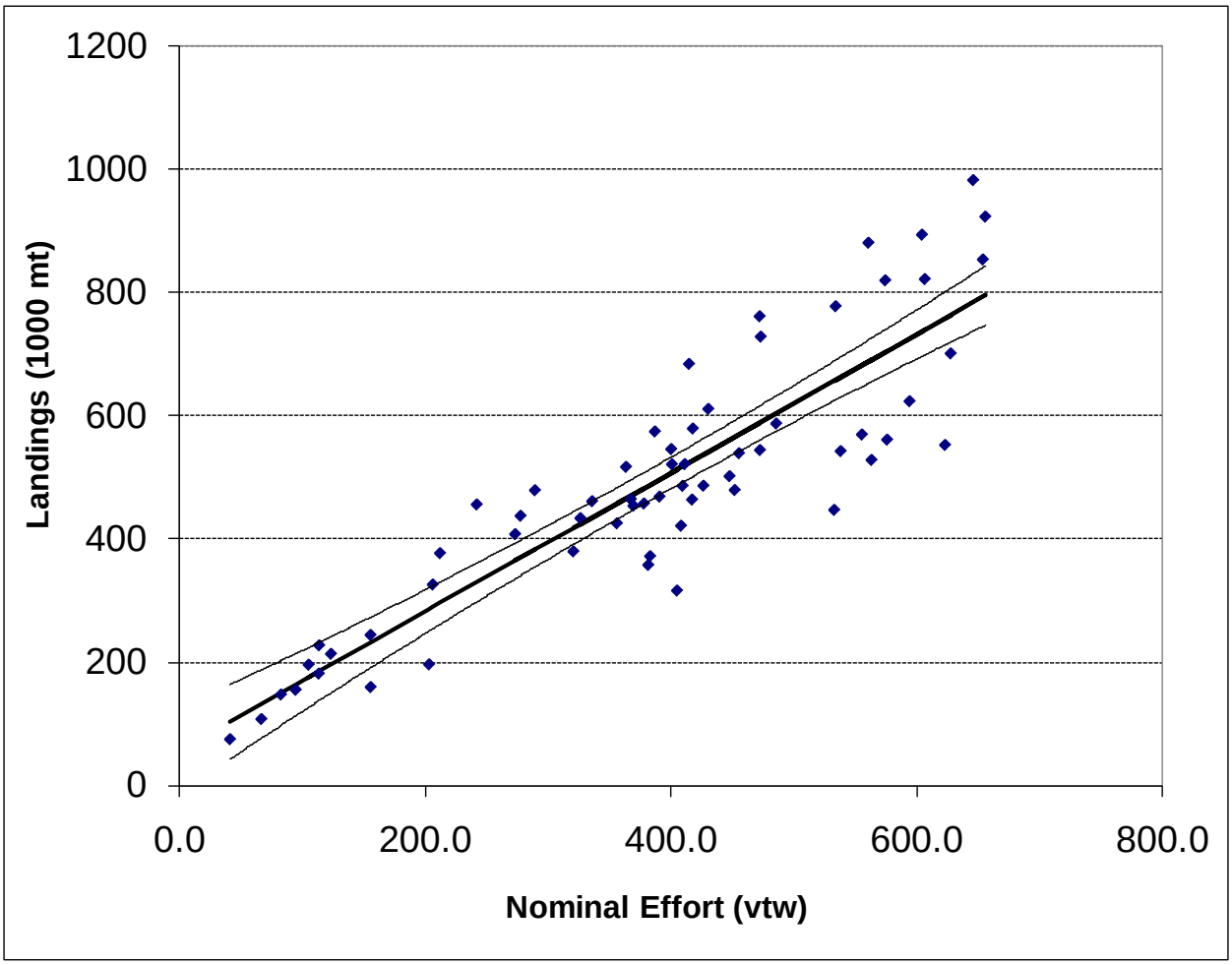

Figure 5. Comparison of nominal fishing effort for gulf menhaden reduction fleet. Effort compared includes: (1) vessel-ton-week, 1948-2010, (2) trips, 1964-2010, and (3) purse-seine sets, 1983-2010. All effort estimates are standardized by dividing by the respective value in 2010 to put them on a common scale. Years with incomplete data (sets in 1992, 1993, and 2005) are left blank.

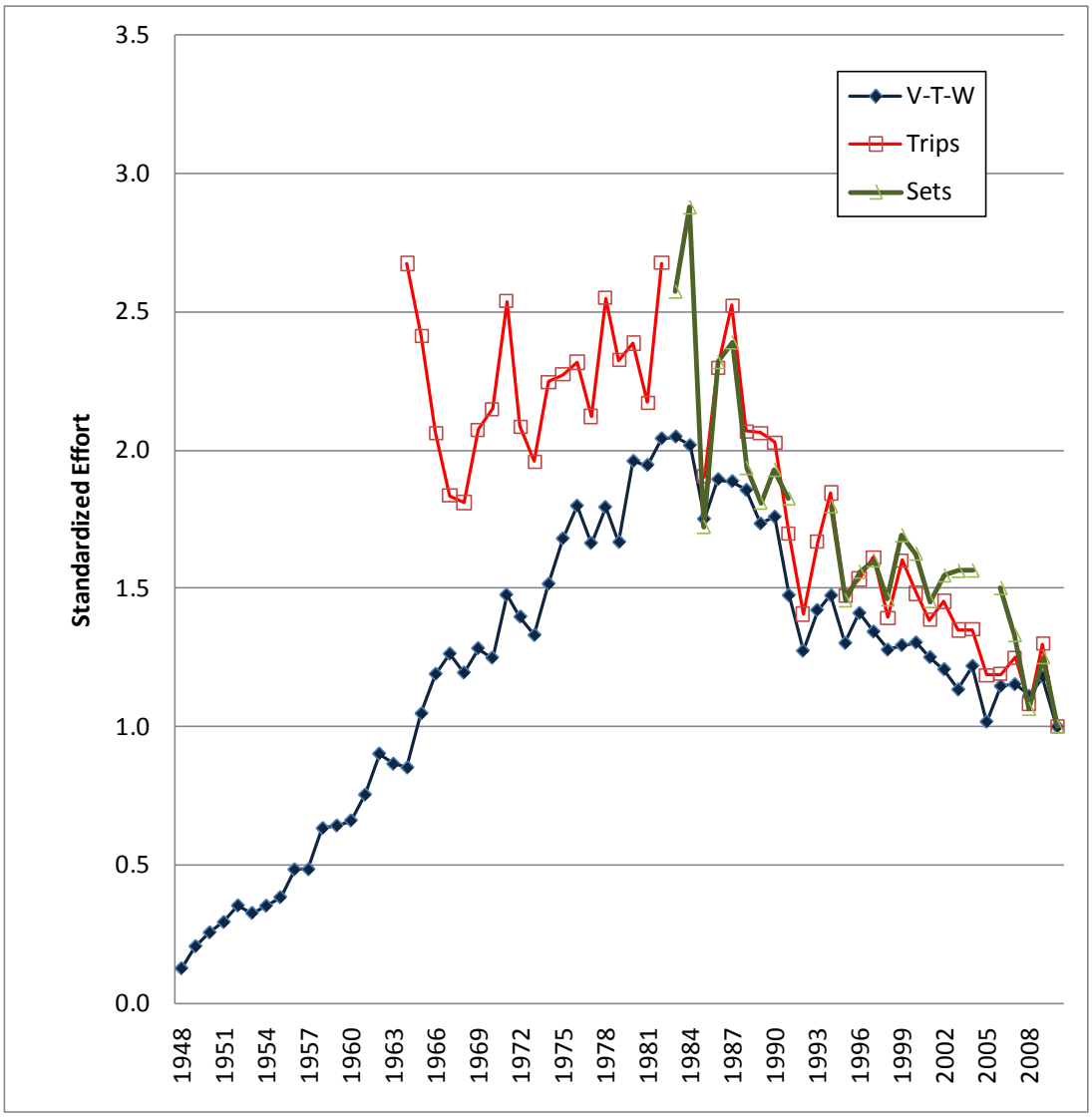

Figure 6. Comparison of calculated CPUE across different measures of fishing effort, including landings per vessel-ton-week (C/VTW), landings per trip (C/Trip) and catch per set.