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The Distribution of Purse-Seine Sets and Catches in the Gulf Menhaden Fishery in the Northern Gulf of Mexico, 1994–98

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Captains Daily Fishing Reports (CDFRs) are daily logs of fishing activities that are completed by vessel captains in the gulf menhaden purse-seine fishery. CDFRs of menhaden vessels from Mississippi and Louisiana for 1994–98 were computerized and analyzed. Over the 5-yr study period, 33,780 CDFRs were processed, representing 115,104 purse-seine sets. On average, the fleet made 23,021 sets per year. Airplane pilots assisted for 64.0–75.8% of the sets. Modal number of sets per day ranged from 4 to 5, and median catch per set ranged from 17 to 22 metric tons. Vessels made at least one set on 63–76% of the available fishing days. Vessels failed to leave the dock most often because of adverse weather. Between 86 and 92% of the annual catch occurred off the Louisiana coast, with lesser quantities coming from the Texas, Mississippi, and Alabama waters. Cumulatively, 55% of the harvest occurred within three miles of shore, and 93% came from within 10 miles of shore. Two main centers of fishing activity were located off the Louisiana coast: one, within Breton and Chandeleur sounds and the other along the western Louisiana coast from Atchafalaya Bay to Sabine Pass. Annual catch by 10 × 10–min rectangles of latitude and longitude within these centers of fishing activity regularly exceeded 20,000 metric tons. Areas of the greatest catches and effort tended to cluster near extant menhaden factories. Catch per unit effort was generally high across the range of the gulf menhaden fishery, and exceeded 20 metric tons per purse-seine set in a majority of the areas.

Gulf menhaden, *Brevoortia patronus,* are small clupeid fishes, of generally <22-cm fork length (FL), that form large, dense, near-surface schools in the inshore waters of the northern Gulf of Mexico from spring through fall. Schools of *B. patronus* are harvested by large (up to 200 feet) purse-seine vessels for an industrial reduction fishery (Smith, 1991). The chief products of the menhaden industry are fish meal, fish oil, and fish solubles. Gulf menhaden are short-lived, and approximately 95% of the commercial catch is comprised of age-1 and -2 fish (Vaughan et al., 2000). Port samples of specimens from the 1998 fishing season averaged 173-mm FL and 111 g. Gulf menhaden tend to migrate inshore in spring and offshore in the fall (Roithmayr and Waller, 1963) but are not known to undergo extensive coastal migrations. Ahrenholz (1991) reported a tendency of older fish to move toward the Mississippi River delta. Overwintering or spawning areas are believed to be along the inner and middle continental shelf in the northern Gulf (Christmas and Waller, 1975).

The gulf menhaden fishery operates from Alabama to eastern Texas, although a majority of catch occurs off the Louisiana coast (GSMFC, 1995). Fishing occurs in the Gulf of Mexico proper and its contiguous sounds in southeastern Louisiana and Mississippi (Breton, Chandeleur, and Mississippi sounds), whereas purse seining is prohibited in the "inside" (estuarine) bodies of water, passes, and inlets (GSMFC, 1995). Area-specific distance from shore restrictions exist in Florida, Alabama, Mississippi, and Texas. The current fishing season extends from mid-April through 1 Nov. (GSMFC, 1995), representing approximately 140 potential fishing days (weekdays only). Peak monthly landings usually occur from June through Aug. whereas landings in April and Oct. are often highly weather dependent. Tropical cyclones in the Gulf of Mexico often curtail fishing operations during summer and early fall.

As recently as 1983, up to 11 factories on the Gulf Coast processed gulf menhaden harvested by up to 81 vessels. During the 1990s, the fishery experienced considerable corporate consolidation. By 1994–95, only six factories located at Moss Point, MS, and Empire, Dulac, Morgan City, Abbeville, and Cameron, LA (Fig. 1) processed *B. patronus* from approximately 50 purse-seine vessels. After 1995 the factory at Dulac was closed, although the number of vessels in the fleet remained about the same. In recent years, 1994–98, purse-seine landings of gulf menhaden have averaged 560,500 metric tons per year. Record harvests occurred in the mid-1980s when annual landings exceeded

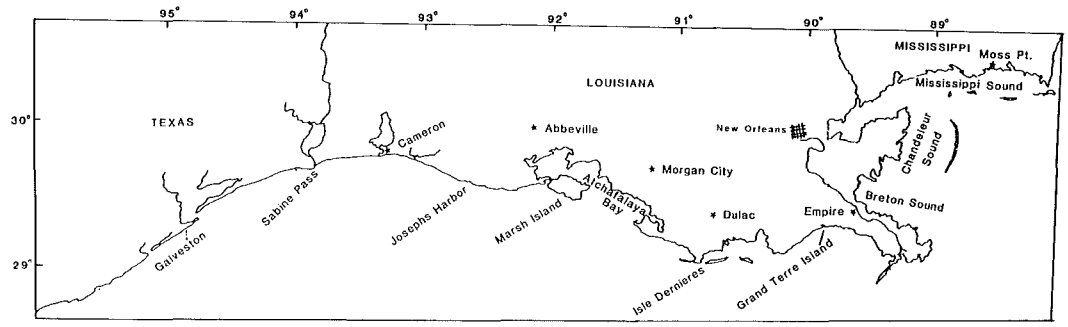

Fig. 1. The northern Gulf of Mexico showing the site of extant menhaden factories (★), during 1994–98, and locales noted in the text.

800,000 metric tons for six consecutive years (1982–87). Peak landings of 982,800 metric tons occurred in 1984.

Fishing operations for gulf menhaden occur during daylight hours, and concentrations of fish schools are located by spotter pilots in small aircraft. Spotter pilots direct the purse boat crews via radio to encircle a menhaden school with the purse seine (one set). Normally, a set is made on a single school of menhaden, although multiple schools are occasionally taken in by the seine. Because the carrier vessels, or "steamers", are equipped with large fish holds and refrigerated seawater systems, they are capable of long-range, multiple-day fishing trips. Generally, vessels fish in the vicinity of their home port (Fig. 1). Vessels from Moss Point, MS, normally fish in Breton, Chandeleur, or Mississippi sounds and, occasionally, west of the Mississippi River delta. Likewise, vessels from ports in western Louisiana (Dulac, Morgan City, Abbeville, and Cameron) rarely fish east of the delta, although depending upon fish distributions, they may unload at a factory other than their home plant. Vessels from Empire, LA, fish on both sides of the delta but rarely farther west than Atchafalaya Bay.

Since 1964, the National Marine Fisheries Service (NMFS) has monitored the gulf menhaden fishery for landings, fishing effort, and size and age composition of the catch (Smith, 1991). Additionally between 1964 and 1969, gulf menhaden captains were asked to complete the logbooks (Nicholson, 1978) designed to assess daily fishing activities and patterns. Although fleet compliance was incomplete and some vessels kept only partial records, Nicholson (1978) summarized information on over 48,000 purse-seine sets for the 6-yr period. More synoptic logbook summarizations for the Atlantic menhaden fleet were published by Roithmayr (1963) and Nicholson (1971).

During the late 1970s, menhaden companies and vessel captains were asked to participate in another logbook project called Captains Daily Fishing Reports (CDFRs). The project evolved as a joint industry, state, and federal effort with many of the original formats and guidelines developed by Standard Products of Virginia, Inc. The gulf menhaden fleet has continuously participated in the program since its inception. Through 1991, CDFRs existed primarily as paper files, although several unsuccessful attempts were made to computerize the data. In 1992 we began entering CDFR information into database files on personal computers. The impetus for our work came mainly through information requests posed by federal and state fisheries managers and menhaden industry personnel regarding gulf menhaden catch and effort by state territorial waters and distance from shore. Without CDFRs, the answers to these types of questions were crude estimates based on apportionment of landings by location of port samples. In this paper we report on CDFR data summarizations for the gulf menhaden purse-seine fishery during 1994–98. Information on the distribution of purse-seine sets by state, longitude, and distance from shore, and on the spatial distribution of purse-seine catches, sets, and catch per unit effort (CPUE) in the northern Gulf of Mexico is included.

Materials and Methods

CDFRs are deck logs of daily menhaden fishing activities (Fig. 2). For each fishing (and nonfishing) day, captains (although the task is often accomplished by the vessel pilot) are asked to enumerate the date and time of departure and return, the time and location of each purse-seine set (or the reason if no sets were made), and for each set the estimated

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CAPTAIN'S DAILY FISHING REPORT

NET No. A-1-97 — 98680224

NAME OF VESSEL 1: Frosty Morn — PLANT 2: Abbeville — DATE OF SETS 3: 8-13-98 — 4

LEFT DOCK 5 ANCHORAGE — DATE: 8-13-98 — TIME: 6:00 ☑AM ☐PM

IF DID NOT LEAVE DOCK (CHECK ONE) 6
☐ WEATHER UNFIT FOR FISHING ☐ UNLOADING
☐ LACKING SUFFICIENT CREW ☐ RADIO
☐ MECHANICAL ☐ OTHER
☐ NET ☐ HOLIDAY

IF NO SETS WERE MADE (CHECK ONE) 7
☐ ROUGH SEAS ☐ OTHER
☐ FOGGY
☐ NO FISH SHOWING
☐ NO PLANES
☐ CHANGING LOCATION

8 SET NO.	9 TIME START	9 TIME END	10 FISH (000)	11 PLANE NO.	12 LOCATION	13 MILES AND DIRECTION TO SHORE		14 WEATHER CONDITIONS AND REMARKS	15 SEA WATER TEMP.
1	0845	0925	15	0	55-229	1	N	3-80-9-12	
2	1245	1315	0	0	55-231	3	N	3-92-9-12	
3	1420	1450	35	0	55-280	4	N	3-90-9-12	
4	1505	1540	50	0	55-280	4	N	3-90-9-10	
5	1610	1645	60	0	55-239	4	N	3-86-9-10	
6	1725	1800	55	0	55-239	4	N	3-86-9-10	
7	1820	1850	50	0	55-239	4	N	3-85-9-10	
8									
9									
10									
11									
12									

16 REMARKS & COMMENTS 17

DATE/TIME RETURN TO DOCK: 8-13-98 - 2315

CAPTAIN'S SIGNATURE 18

This form is required by State Law

Fig. 2. An actual gulf menhaden CDFR form.

catch, distance, and direction from shore, and weather conditions. Crewmen maintained CDFRs even if no sets were made and indicated the reason for no fishing activity (e.g., weather unfit for fishing, mechanical problems).

Set-specific information was manually coded on CDFR forms after each individual purse-seine set. For the days when sets were made, "Set start" and "Set finish" times were coded in military time. The captain's estimate of the catch was in thousands of "standard fish" (1,000 standard fish = 670 pounds; see Smith, 1991). If the set was assisted by an airplane spotter pilot, the company's two-digit spotter code was used. Unassisted sets were coded with a "0" or "self" indicating a "self-set." In a guidebook distributed to captains of menhaden vessels, each state's coastline in the northern Gulf of Mexico was highlighted and coded with a unique two-digit number. Within a state's territorial sea, specific fishing sites, usually adjacent to well-known geographic points, were coded with three-digit numbers. For example, Oyster Bayou on the Louisiana coast (Area 55) was coded as "55-279." Captains were asked to identify new fishing areas not listed in the CDFR manual, and these areas were later assigned new codes. For each purse-seine set, miles from and direction to the nearest shoreline were recorded, as well as weather conditions at the time of the set (cloud cover, air temperature, and wind direction and speed). Menhaden company staff routinely mailed batches of CDFRs to the laboratory, where each CDFR form was stamped with a unique eight-digit collection number. Annual CDFR data sets were key-entered into relational databases and edited for errors. Later, databases were merged and analyzed using Statistical Analysis Systems (SAS Institute, 1995).

In order to plot catch and effort statistics geographically, each fishing location in the CDFR guidebook (n = 264) was identified on charts that were divided into whole degrees of latitude and longitude and then further subdivided into 10- × 10-min rectangles [the "subareas" of Nicholson (1978)]. Catch (in thousands of metric tons), fishing effort (number of purse-seine sets), and CPUE (in metric tons per set) were summarized annually by these 10- × 10-min rectangles. CPUE values were excluded from the analyses where the number of sets per rectangle was <20. In separate analyses,

TABLE 1. Total adjusted CDFR catch (see text) vs actual gulf menhaden purse-seine landings from reduction, during 1994–98 and the percent difference from the reported landings.

Year	CDFR total catch (metric tons)	Actual reduction fishery landings (metric tons)	% Difference
1994	747,908	761,584	−2
1995	457,458	463,936	−1
1996	470,520	479,376	−2
1997	589,571	611,217	−4
1998	468,602	486,205	−4

catches by distance from shore were averaged over the five-year study period by "zones" of one degree of longitude across the range of the fishery. Distance from shore strata were arbitrarily selected based on contemporary information requests from fisheries managers.

Menhaden captains are adept at estimating the size of individual purse-seine catches. For example, in 1995, vessel-specific ratios of total annual catch (as reported in menhaden company records) to CDFR estimates of total catch ranged from 0.77 to 1.13 for the 50-vessel fleet (68% of the ratios ranged from 0.95 to 1.05). Captains' at-sea catch estimates for individual sets were modified using vessel-specific adjustment factors. Daily records of vessel landings provided by menhaden companies were summed over the fishing year. Total annual landings for a vessel from company records were divided by the respective captain's estimate of annual catches from the CDFRs. Individual catch estimates from CDFRs were multiplied by the appropriate adjustment factor and then by 0.3039 to convert to metric tons (Smith, 1991, 1999). During each analysis year, two vessels, one each at Morgan City and Cameron, harvested gulf menhaden primarily for bait but occasionally unloaded their catch at reduction plants. These vessels maintained CDFRs sporadically and were excluded from our analyses. Additionally, for various reasons, a few vessels in 1997 (n = 2) and 1998 (n = 1) kept incomplete CDFRs. These vessels were also excluded from our analyses. Missing and excluded data accounted for 4% or less of the total reported landings for the reduction fishery (Table 1).

RESULTS

Summary statistics for CDFR data sets, 1994–98.— During 1994–98, between 47 and 53 purse-seine vessels, nearly the entire fleet, annually participated in the CDFR program (Table 2). A total of 33,780 CDFRs were processed, representing 115,104 purse-seine sets. On average, the fleet completed 6,756 CDFRs per year, representing 23,021 purse-seine sets. Airplane spotter pilots assisted vessel crews with 64.0–75.8% of the annual purse-seine sets. Modal number of sets per day ranged from four to five, and the maximum number of sets per day was 16. Median catch per set ranged from 17 to 22 metric tons, and mean set time ranged from 41 to 48 min.

On an annual basis, purse-seine vessels completed at least one purse-seine set on 63–76% of the available fishing days during the analysis years (Table 3). Couched in terms of an individual menhaden vessel, an average purse-seiner fished (made at least one set) on 88–106 d of the approximately 140-d fishing season. Conversely, an average vessel failed to make at least one set on 34–52 of the available 140 fishing days. The most frequently cited reason for not leaving the dock was poor weather (Table 4). The percentage of nonfishing days when vessels failed to leave the dock because of adverse weather varied widely from 39.7% (1994) to 73.2% (1995). Mechanical problems and "waiting to unload catch" were the other two reasons most often cited for not leaving port. At sea, vessels most frequently failed to make

TABLE 2. Summary statistics for gulf menhaden CDFR data set during 1994–98.

Year	CDFRs processed	Vessels	Total sets	% Airplane assisted	Modal sets/day	Set size (metric tons)		Mean set time (min)
						Median	25–75 percentiles	
1994	6,975	53	26,234	75.8	5	22	12–39	48
1995	6,823	50	21,264	64.0	4	17	9–30	44
1996	6,719	49	22,777	65.1	4	17	8–29	43
1997	6,712	48	23,512	69.9	5	19	10–34	44
1998	6,551	47	21,317	70.5	5	18	9–30	41
Totals	33,780		115,104					
Means	6,756		23,021					

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TABLE 3. Fishing days vs nonfishing days for the gulf menhaden purse-seine reduction fleet during 1994–98.

Year	CDFRs completed	Fishing days		Nonfishing days					
				Did not leave dock		Did not set at sea		Total days not fished	
		n	(%)	n	(%)	n	(%)	n	(%)
1994	6,975	5,271	(76)	932	(13)	771	(11)	1,703	(24)
1995	6,823	4,665	(68)	1,271	(19)	887	(13)	2,158	(32)
1996	6,719	4,869	(72)	908	(14)	942	(14)	1,850	(28)
1997	6,712	4,755	(71)	1,342	(20)	615	(9)	1,957	(29)
1998	6,551	4,154	(63)	1,686	(26)	711	(11)	2,397	(37)

at least one daily purse-seine set because of rough seas or no fish showing.

Catch by state and distance from shore.—Between 1994 and 1998, the vast majority of gulf menhaden, 86–92% of the annual catch, was harvested off the Louisiana coast (Fig. 3). Catches off the Texas (5–10%) and Mississippi (2–6%) coasts ranked a distant second and third, respectively. Catches in Alabama waters were minimal (≤1%). Over the five-year study period, catches off Louisiana, Texas, Mississippi, and Alabama annually averaged approximately 483,000, 40,000, 20,000, and 4,000 metric tons, respectively.

Mean annual catch by distance from shore revealed the coastal nature of the gulf menhaden fishery (Table 5). On average, 20% of the annual coastwide catch during 1994–98 came from within one mile of shore and 55% from within three miles of shore. An additional 18% of the harvest occurred within the 3.1- to 5-mile stratum, whereas another 20% of the harvest occurred within the 5.1- to 10-mile stratum. Cumulatively, 93% of the mean catch came from within 10 miles of the Gulf coastline.

Near the center of the fishery's range and near 91°W, catch data by distance from shore may be misleading because of the shoreline configuration. Within this zone, 69% of the catch occurred beyond five miles from shore (Table 5). By comparison, in the adjacent 92°W zone only 30% of the catch occurred beyond five miles from shore. Within the 91°W zone, a weakly undulating Louisiana shoreline is interrupted by the concave profile of Atchafalaya Bay. We believe that captains probably use the shore of the Bay's interior to gauge distance from shore information. If an artificial shoreline were drawn across the mouth of Atchafalaya Bay, catches representing 69% of the 91°W zone in the 5.1- to 10-mile and >10-mile strata would shift to more inshore strata.

Catch by zone of longitude across the northern Gulf of Mexico revealed that two regions

TABLE 4. Reasons for and percentage of days the vessels did not leave the dock on nonfishing days, and reasons for and percentage of days the vessels did not make sets at sea on nonfishing days during 1994–98.

	1994	1995	1996	1997	1998
Reasons for not leaving dock					
Weather unfit for fishing	39.7	73.2	61.1	53.9	68.8
Insufficient crew	3.3	2.4	2.2	1.8	2.8
Mechanical problems	13.8	5.0	7.4	6.2	4.4
Net problems	0.9	0.2	0.1	0.3	0.1
Unloading	16.6	2.7	5.8	9.2	3.0
Radio problems	0	0.1	0	0.1	0
Not indicated	25.7	16.5	18.1	28.6	20.9
Reasons for not setting at sea					
Rough seas	30.7	23.8	30.6	34.5	44.0
Fog	0.4	0.7	1.8	0.3	0.6
No fish showing	29.6	44.2	36.9	36.9	37.4
No planes available	0.1	0.2	0	0.2	0.3
Changing locations	3.6	2.1	2.6	2.6	3.5
Not indicated	35.6	20.0	28.2	25.6	14.2

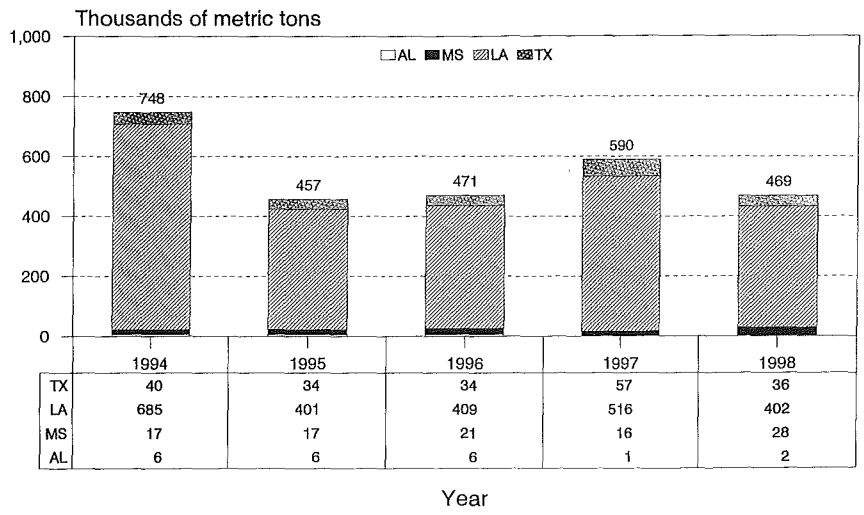

Fig. 3. Purse-seine catch of gulf menhaden for reduction by state in thousands of metric tons, as estimated from CDFRs.

of the coast accounted for 89% of the mean annual harvest of gulf menhaden (Table 5). East of the Mississippi River, 29% of the mean annual catch occurred within the 89°W zone, an area encompassing most of Breton and Chandeleur sounds and western Mississippi Sound. West of the Mississippi River, mean annual catches within the 91, 92, and 93°W zones were evenly distributed (22, 19, and 19%, respectively) and collectively accounted for 60% of the mean annual coastwide catch.

Geographic distribution of catch, number of purse-seine sets, and CPUE.—General and repeated patterns of menhaden fishing activity emerged when annual distributions of catch and effort (number of sets) were plotted in 10- × 10-min rectangles of latitude and longitude. Trends in catch and number of sets tended to parallel one another across the range of the fishery and over the analysis years (Figs. 4, 5). Toward the extremes of the fishery's range, catches and effort were relatively low. In the east, catches in Mississippi Sound were consistently ≤10,000 metric tons per unit area over the five-year period, and effort was rarely >250 sets. Dauphin Island, Alabama, was the eastern limit of fishing activity. Similarly, in the west along the Bolivar Peninsula near Galveston, TX, catches were generally ≤10,000 metric tons per unit area, and effort was <250 sets. Fishing activity southwest of Galveston, TX (to Freeport and Rockport) was rare. A third area of low fishing activity occurred west of the Mississippi River delta from approximately Grand Terre Island west to Isles Dernieres, LA. As in the eastern and western extremes of the fishery, catches in this region per unit area were <10,000 metric tons, and effort rarely exceeded 250 sets.

Two regions along the Louisiana coast are the centers of gulf menhaden fishing activity.

TABLE 5. Mean annual catch of gulf menhaden in thousands of metric tons by one degree of longitude and distance (miles) from shore, during 1994–98.

Distance from shore (miles)	95°	94°	93°	92°	91°	90°	89°	88°	Totals
0–0.5	0	<1	4	3	1	3	14	<1	25
0.6–1.0	<1	5	14	11	3	7	35	3	79
1.1–2.0	<1	7	28	19	7	7	36	7	110
2.1–3.0	<1	3	21	16	8	4	24	5	81
3.1–5.0	<1	3	24	20	18	3	28	4	100
5.1–10.0	<1	<1	11	22	51	2	17	1	106
>10	0	<1	<1	8	31	<1	1	<1	41
Totals	<1	17	103	101	119	26	156	20	543

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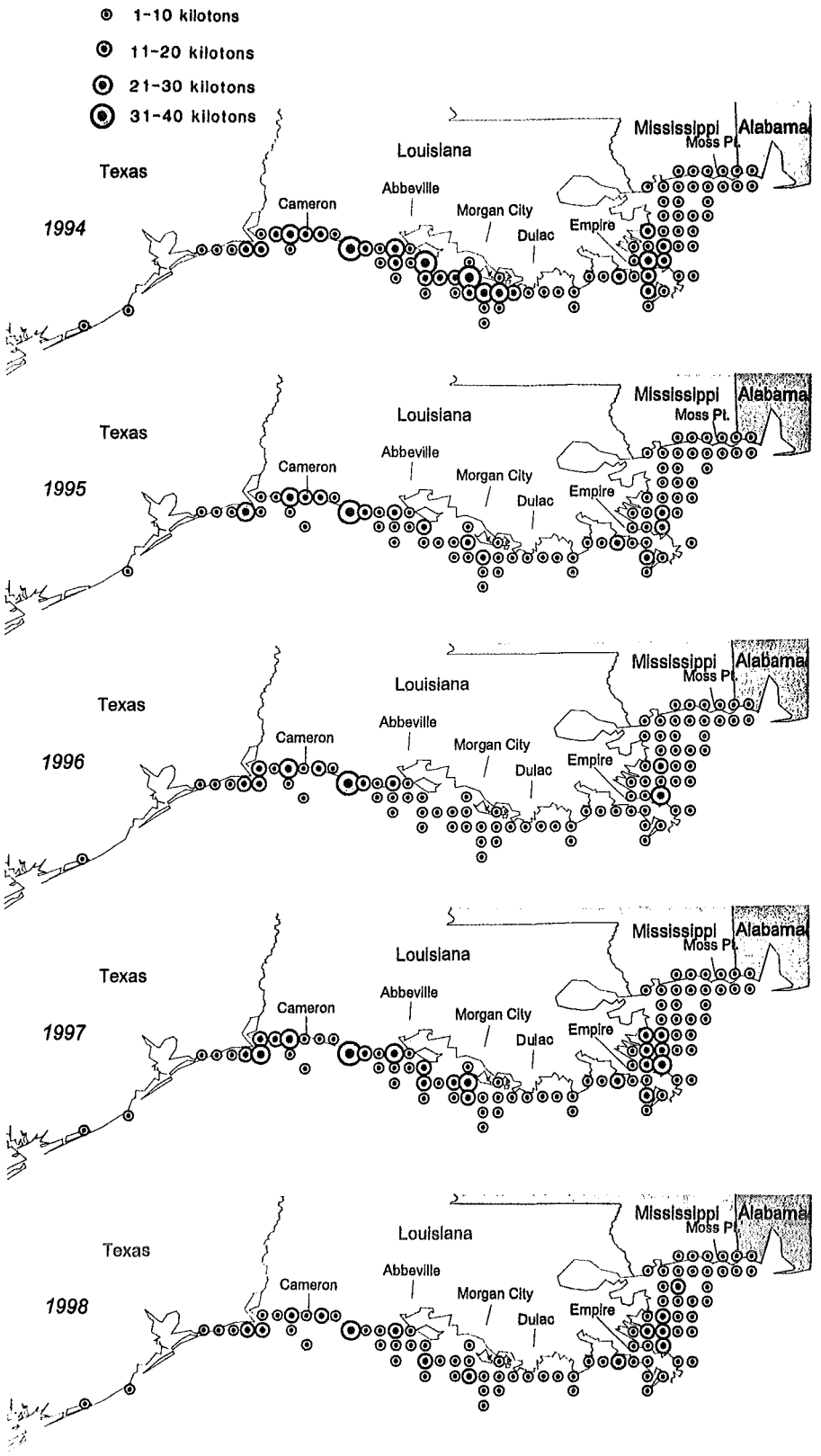

Fig. 4. Annual catch of gulf menhaden in thousands of metric tons by 10- × 10-min rectangles of latitude and longitude for 1994–98, as estimated from CDFRs.

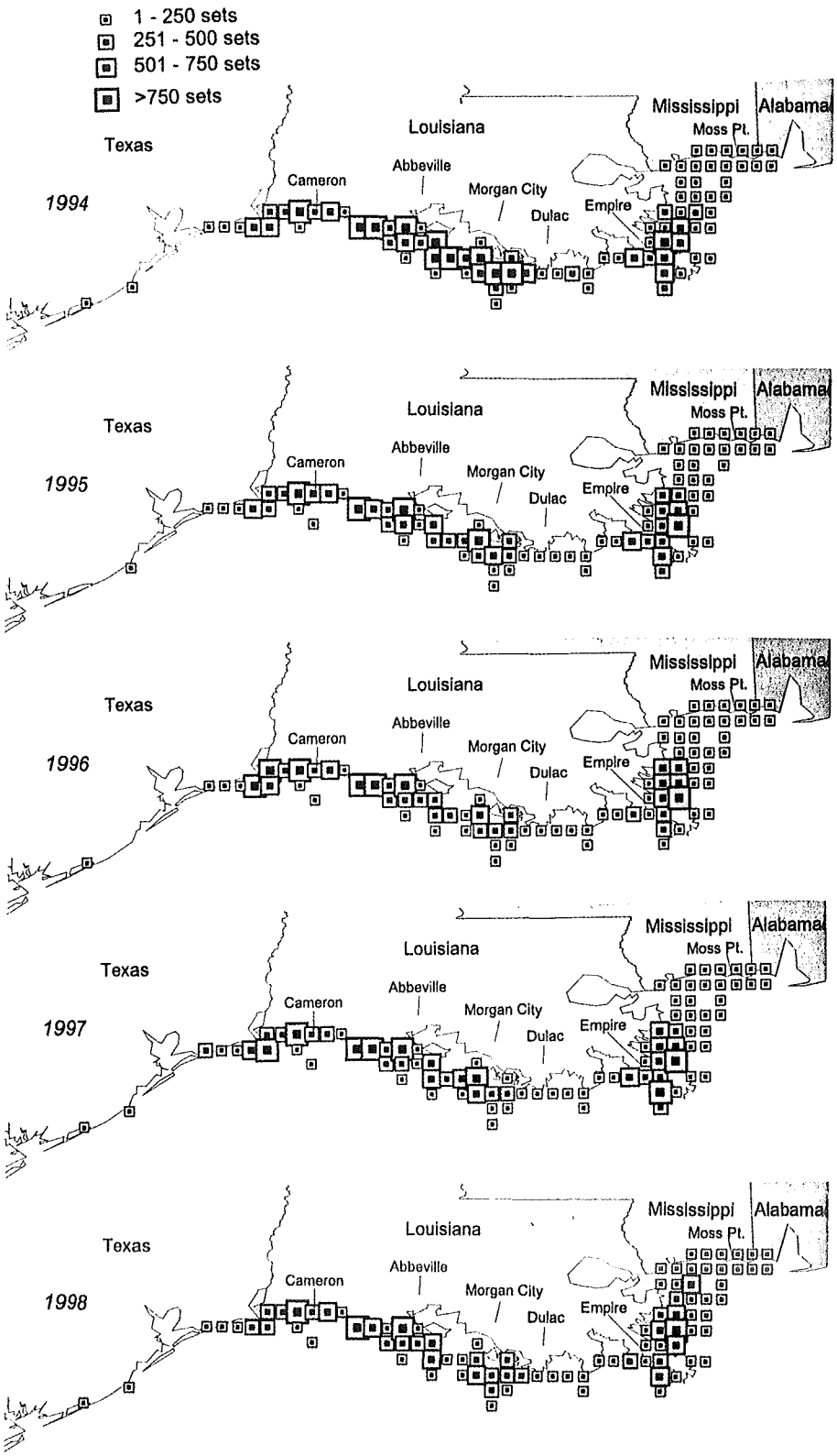

Fig. 5. Annual number of purse-seine sets on gulf menhaden by 10- × 10-min rectangles of latitude and longitude for 1994–98, as estimated from CDFRs.

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The eastern center is relatively well defined and lies within the barrier island system of Breton and Chandeleur sounds. Catch per unit area regularly exceeded 10,000 metric tons and occasionally exceeded 20,000 metric tons. Likewise, effort per unit area routinely exceeded 500 sets. The western center of the fishery is more dispersed and extends almost 200 miles along the western Louisiana coast from Atchafalaya Bay west to Sabine Pass. There, catches in most analysis rectangles were greater than 10,000 metric tons and often greater than 30,000 metric tons. Effort per unit area regularly exceeded 500 sets, and in several instances it exceeded 750 sets.

Within these centers of activity were numerous areas, or "hotspots," where catch regularly exceeded 20,000 metric tons, and often 30,000 metric tons, while number of sets often exceeded 1,000. In general, these hotspots were adjacent to the menhaden processing factories at Empire, Dulac, Morgan City, Abbeville, and Cameron. The analysis rectangle that included Joseph's Harbor, LA, was an exception to this trend, although it was nearly equidistant from the factories at Abbeville and Cameron.

CPUE was generally high across the entire gulf menhaden fishery, and exceeded 15 metric tons per set at a majority of areas during all years (Fig. 6). This was most evident for 1994 and 1997 when the coast-wide landings for reduction reached 761,584 and 611,217 metric tons, respectively. The highest CPUE values consistently occurred in Breton, Chandeleur, and Mississippi sounds and off eastern Texas. During 1994, exceptionally high CPUE values of >30 metric tons per set also occurred near Grand Terre Island west to Isle Dernieres, LA.

Discussion

In terms of annual tonnage, landings of gulf menhaden have surpassed landings of Atlantic menhaden since 1963, often doubling or tripling those of its congener species on the East Coast of the United States (Smith, 1991). Despite the magnitude of the gulf menhaden fishery, detailed descriptions of the daily activities of the gulf menhaden fleet were heretofore unavailable. Nicholson (1978) summarized logbooks (cf. June and Reintjes, 1959) from the gulf menhaden fleet for 1964–69 that were essentially the precursors to CDFRs, but compliance was low (probably <50%), catch estimates were unreliable, and fishing locations were coarsely identified by whole degrees of longitude and 10-mile intervals from shore. Historic data summaries of set distributions and catch estimates exist for the Atlantic menhaden fleet (Roithmayr, 1963; Nicholson, 1971). Moreover, CDFRs for the Atlantic fleet from 1985–96 were recently analyzed by Smith (1999). Our current examination of gulf menhaden CDFRs for 1994–98 provides the first comprehensive analysis of the daily fishing activities of the reduction purse-seine fleet in the northern Gulf of Mexico.

The gulf menhaden fleet relies heavily on spotter pilots to locate concentrations of menhaden and to set the purse seine around schools of fish. A majority of the purse-seine sets during 1994–98 were assisted by spotter aircraft (64.0–75.8%). The remaining sets were accomplished without the aid of aircraft. Several tell-tale signs enable crewmen to detect menhaden schools at or near the water's surface: "whips" of menhaden tails on an otherwise calm surface, sediment plumes or "mud roils" in otherwise less turbid waters, and feeding seabirds atop menhaden schools. The Atlantic menhaden fleet relied on aircraft more frequently: spotter pilots assisted with 83.1–93.4% of the sets on the East Coast of the United States (Smith, 1999). External factors sometimes interfere with fish-spotter activities on the Gulf coast, especially in 1998. For about 2 wk in May 1998, haze from forest fires in Mexico obscured the spotters' vision of nearshore waters west of the Mississippi River delta. Likewise in early August 1998, local marsh fires had a similar effect along the coastline between Abbeville and Cameron, LA. Heavy rainfall, associated runoff, and the resultant nearshore turbidity may also hinder pilots from locating schools of fish.

Several catch statistics for the gulf and Atlantic menhaden fisheries are remarkably similar. The modal number of daily sets in the gulf menhaden fishery ranged from four to five sets, identical to the modal number of sets per day in the Atlantic menhaden fishery (Smith, 1999). Median set size in the gulf fishery ranged from 17 to 22 metric tons, whereas the median set size for most years in the Atlantic fishery was 15–23 metric tons (Smith, 1999). Median set size for the Gulf fishery was noticeably higher in 1994 (22 metric tons) than in the other study years. Average time required to set and retrieve the purse seine and pump the catch on board the "steamer" was slightly longer for gulf menhaden vessels (41–48 min; Table 2) than for their Atlantic counterparts (34–43 min; Smith, 1999).

Strong onshore winds (>ca. 15–20 knots) in the northern Gulf of Mexico create nearshore wave action that makes purse-seine operations

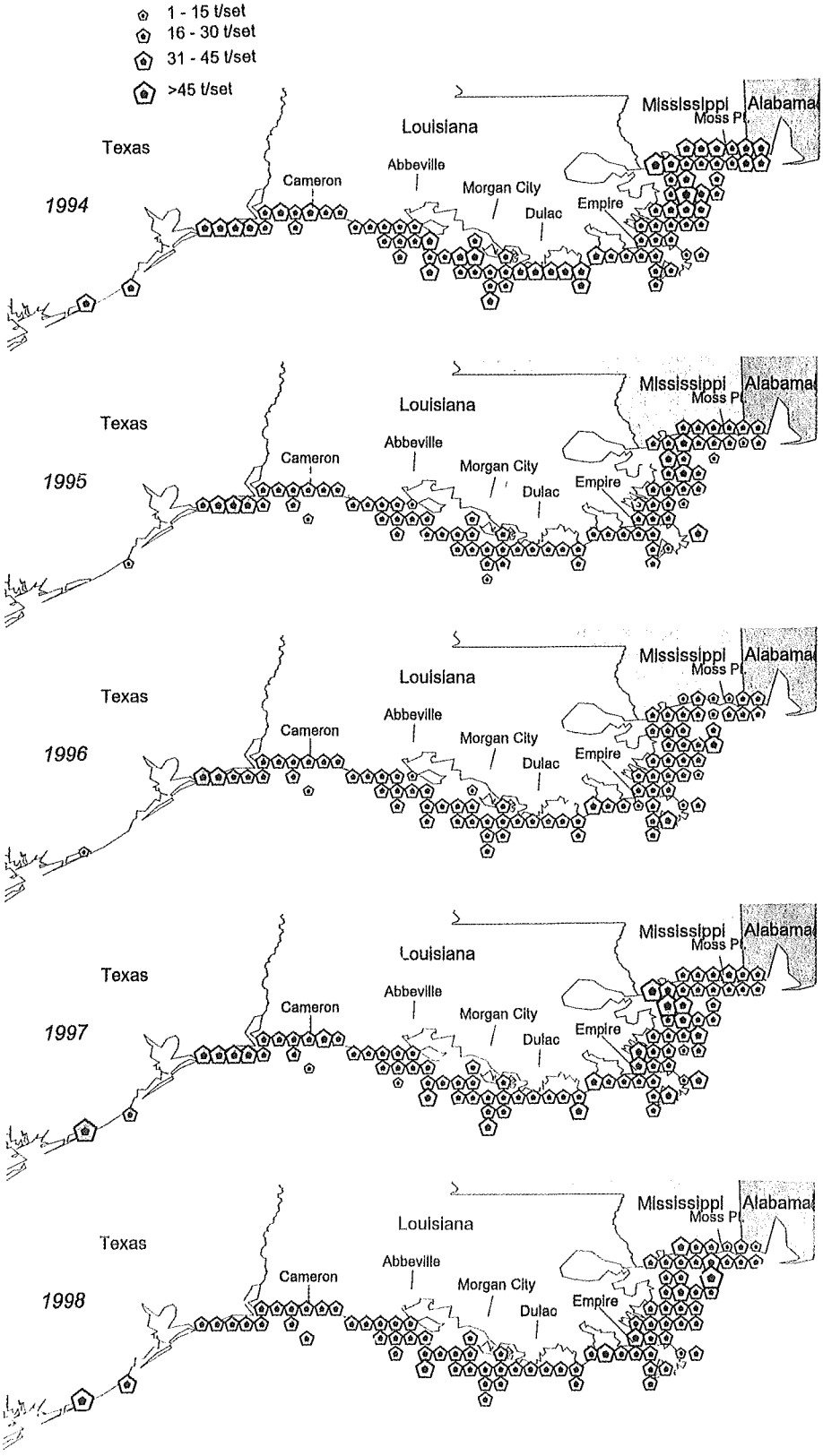

Fig. 6. Annual CPUE (metric tons per set) for the gulf menhaden fishery by 10- × 10-min rectangles of latitude and longitude for 1994–98, as estimated from CDFRs.

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difficult. In this vein, tropical storms sometimes cause fleets to idle at given ports for an entire week. Multiple tropical storms during summer tend to suppress fishing effort and, in turn, landings. For example, over our study period, fair weather prevailed during the 1994 and 1997 fishing seasons, with few or no tropical storms in the northern Gulf of Mexico. Landings of 761,584 metric tons in 1994 (Table 1) were the best since 1987 (894,222 metric tons), and landings of 611,217 metric tons in 1997 were third best since 1987. Conversely, numerous tropical storms frequented the northern Gulf of Mexico in summer 1995 and 1998; annual landings declined to 463,936 and 486,205 metric tons, respectively. The summer of 1996 was anomalous in that tropical storm activity was negligible, yet landings were only 479,376 metric tons. CDFR data confirmed that in 1994 and 1997 vessels lost the fewest fishing days to adverse weather (Table 4), whereas in 1995 and 1998 the fleet lost the most fishing days to weather. Vessels averaged 490–495 sets per season in 1994 and 1997 vs 425–454 sets per season in 1995 and 1998. Concurrent with the 1994 fishing season, recruitment of age-1 gulf menhaden in 1993 and 1994 was very good and above the 20-billion fish level (Vaughan et al., 2000). Thus, we suspect that in the gulf menhaden fishery, fair weather (i.e., minimal tropical storm activity) combined with consecutive years of above-average recruitment potentially set the stage for total annual landings exceeding 600,000 metric tons.

CDFR data also suggest that when catches are exceptionally good, reduction factories often reach their level of maximum processing capacity. Loaded vessels then wait to unload their catch and lose time on the fishing grounds. For instance, in 1994 and 1997 when catches were good, vessels lost the highest percentage of fishing days because they were waiting at the dock to unload (Table 4). Idle vessels waiting to unload essentially become refrigerated, dockside holding facilities.

Historic records of the distribution of fishing activity on the gulf menhaden fishery are lacking, except for Nicholson's (1978) attempt to consolidate 6 yr of partial logbook data from 1964–69. To portray the results, he stratified the northern Gulf of Mexico into zones by whole degrees of longitude and by 10-mile intervals from shore. Nicholson (1978) found most effort (=number of sets) concentrated in two areas: 1) east of the Mississippi River delta, in the 88 and 89°W zones and within 10 miles of the shoreline, and 2) west of the delta, in the 91°W zone near Morgan City and Abbeville within 20 miles from shore. Our contemporary CDFR data reinforce and expand upon Nicholson's (1978) findings. In terms of catch, we found that east of the Mississippi River delta, most of the fishing activity was centered in Breton, Chandeleur, and Mississippi sounds, roughly within the 89°W zone, and within 10 miles of shore (Table 5). West of the Mississippi River delta, we found that fishing activity has expanded west since the 1960s from 91°W to currently include the 92 and 93°W zones (approximately to the Louisiana–Texas border), with most of the catch taken within 10 miles from shore (Table 5).

Before CDFRs were computerized, estimates of gulf menhaden catches by state or water body (e.g., Mississippi Sound) were tenuous and generally based on apportioning landings by catch locations retrieved from port sampling data. Using CDFRs has enabled us to estimate more accurately catches of gulf menhaden by area. Historically, landings of gulf menhaden by state have underscored the importance of the Louisiana coast to the menhaden fishery (Nicholson, 1978; Smith, 1991). Data from CDFRs clearly demonstrated that 86–92% of the gulf menhaden catch in 1994–98 was harvested off the Louisiana coast. Catches along the Texas coast ranked a distant second in terms of catch by state; however, Texas waters provided valuable alternative fishing grounds to the fleet from Cameron usually during mid- to late summer. Catches in Mississippi waters, generally in Mississippi Sound, ranked slightly behind those in Texas and were minimal compared with catches on the Louisiana coast. Nonetheless, Mississippi Sound was important to the fleet of vessels (six–eight vessels) from the factory at Moss Point. What little fishing activity occurred in the Alabama waters was in the vicinity of Dauphin Island at the eastern end of Mississippi Sound. Gulf menhaden purse-seiners (vessels from Moss Point) have not fished along the western Florida Panhandle since the early 1990s. It is unlikely that purse seining for reduction purposes could resume off Florida, given the state's stringent commercial net restrictions.

Computerization of CDFRs enabled us to refine fisheries statistics for the gulf menhaden fishery into 10-min rectangles of latitude and longitude. Accordingly, repeated annual patterns of catch and effort during 1994–98 identified two major areas of purse-seine fishing activity in the northern Gulf of Mexico. East of the Mississippi River, vessels from Empire and to some extent Moss Point experienced their

greatest catches in Breton and Chandeleur sounds. Numerous adjacent analysis rectangles in the area had repeated catches exceeding 20,000 metric tons per year and effort over 500 sets per year. Catches and effort tended to be greatest during 1994 and 1997. Historically, Nicholson (1978) identified Breton and Chandeleur sounds as an area with the greatest effort (14,486 sets) during 1964–69. West of the Mississippi River delta, vessels from Dulac, Morgan City, Abbeville, and Cameron experienced their greatest contemporary catches along the Louisiana coast from Isles Dernieres and Atchafalaya Bay west to Sabine Pass. The year 1994 was noteworthy, when catches in most contiguous analysis rectangles exceeded 10,000 metric tons. Nicholson (1978) identified the Atchafalaya Bay region as an area with the second greatest number of sets in the northern Gulf during 1964–69 (10,328 sets), with lesser activity farther west (4,672 sets in 92°W and 4,310 sets in 93°W).

Major riverine outflows onto marine continental shelves are sites of high marine primary productivity and major world-class fisheries production (Caddy and Bakun, 1994). Menhaden are obligate filter feeders, with juveniles straining plankters as small as 7–9 μm from the water column (Friedland et al., 1984). Thus, high catch rates of gulf menhaden in Breton, Chandeleur, and Mississippi sounds and off the coast of west and central Louisiana are not unexpected and are coincident with high primary productivity and major outflows from the Mississippi and Atchafalaya river systems, respectively.

Given the technological advances in marine navigation during recent decades (e.g., LORANs and Global Position Systems), CDFRs are antiquated in terms of their precision with regard to fishing locations. Nevertheless, crews of menhaden vessels complete the forms scrupulously, and compliance is near 100%. To date, information supplied on CDFR forms has been adequate for most fisheries-related managerial questions regarding catch, fishing effort, and distance from shore. As discrete as the fleet is (with under 60 vessels on the Atlantic and Gulf coasts combined in the year 2000) and with only a few corporate entities active, the menhaden fishery would be an ideal candidate to showcase a state-of-the-art vessel monitoring system. Satellite-linked transponders could provide real-time data on fish catches and locations, vessel or fleet search patterns, and environmental conditions on the fishing grounds. In the meantime, we will continue to compile and analyze current-year CDFRs and to computerize historical CDFR data sets.

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