Distribution and relative abundance of sea turtles caught incidentally by the U.S. pelagic longline fleet in the western North Atlantic Ocean, 1992–1995

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The distribution and abundance of threatened and endangered species of sea turtles in offshore waters are not well understood. Early oceanographic flights designed to record sea surface temperatures along the Atlantic continental shelf by the U.S. Coast Guard illustrated that aerial surveys for large pelagic fish, marine mammals, and sea turtles were possible (Deaver[1]). Aerial surveys have since proven a cost-effective method of obtaining observational data on sea turtles and have helped researchers understand basic distributional patterns (Hoffman and Fritts, 1982; Fritts et al., 1983; Schroeder and Thompson, 1987; Shoop and Kenney, 1992). Additional sources of pelagic sea turtle data are fishery observer and vessel logbook programs. The U.S. Atlantic pelagic longline fishery for tuna, *Thunnus* spp., and swordfish, *Xiphias gladius*, incidentally captures threatened and endangered sea turtles, which have either ingested baited hooks or become entangled or hooked externally, or both. This paper examines the seasonal distribution and relative abundance of these turtles caught incidentally by the U.S. Atlantic pelagic longline fleet from 1992 through 1995.

Materials and methods

The fishery data used in this analysis are from the National Marine Fisheries Service (NMFS) pelagic logbook program managed by the Southeast Fisheries Science Center, Miami Laboratory. The logbook program was initiated in 1991 and requires U.S. Atlantic longline vessels to report daily catch and effort data. Specific longline information from the pelagic logbooks includes target species, type of bait, set and haulback dates and positions, length of mainline, number and lengths of gangions and floatlines, and numbers of light sticks and hooks set (Cramer, 1996). Sea turtle bycatch information was added to the logbook data form in 1992. Only sets targeting tuna or swordfish, or both, are analyzed here because the shark longline fishery is significantly different temporally, spatially, and geographically. NMFS logbook data for 1992–95 were analyzed by nine geographic fishing areas established by the NMFS Miami Laboratory (Fig. 1). Biological data of captured turtles were provided by NMFS observers placed aboard selected longline vessels (Lee et al., 1995; Gerrior, 1996). Sea turtle species identifications from the logbook data were edited to include only leatherback, *Dermochelys coriacea*, and loggerhead, *Caretta caretta*, sea turtles. This decision was based on the known distribution, abundance, and biology of sea turtles in the area, and the fact that some vessel captains and NMFS observers were unable to identify accurately all turtles encountered.

Results and discussion

The typical U.S. pelagic tuna and swordfish longline consists of a mainline, suspended horizontally by floats at a set depth, that has a series of baited hooks hanging vertically. The gears used for both target species are essentially the same. However, swordfish fishermen generally work at night using chemical light sticks suspended above the hooks to attract bait fish and tuna fishermen generally fish during the day without light sticks. Still, there are indications from logbook data that some of the longline fleet apparently target both tunas and swordfish and alter fishing strategies and gear configurations depending on the main target species, geographic location, and season (Hoey, 1983; Sakagawa et al., 1987). The U.S. pelagic longline fishery has evolved over the years from cumbersome New England style gears to lighter Florida style gears (Berkeley et al., 1981) and are significantly different from the gears used by the Japanese who targeted bluefin tuna in the western Atlantic (Lopez et al., 1979; Witzell, 1984). The gears currently in use on U.S. vessels vary considerably; they average about 47 km long and have 429 hooks suspended by 174 floats 54 m below the sur-

[1] Deaver, J. W. 1975. Aerial oceanographic observations, July 1969–June 1970, Cape Cod, Massachusetts to Miami, Florida. U.S. Dep. Trans., Coast Guard Oceanogr. Unit, Oceanogr. Rep. CG 373-68, 27 p. [NTIS Accession No. AD-A014 415.]

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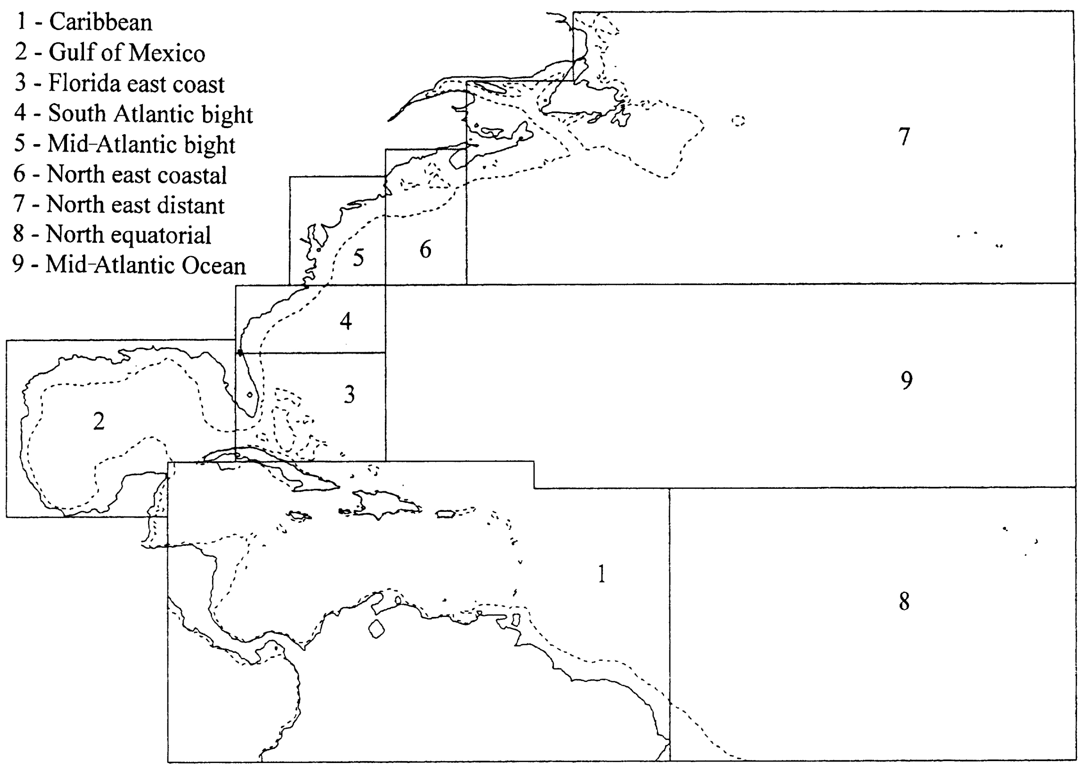

Figure 1

The NMFS pelagic fishing areas. Dashed line represents the 200-m isobath.

face (Power[2]). Pelagic longline fishing effort also changes temporally and spatially, depending on target species, season, and location (Fig. 2), although the overall effort for the entire area has not changed significantly over recent years (Cramer, 1996). Most effort is closely associated near the 200-m isobath along the edge of the continental shelf off the U.S. and off the shelf near the southeastern edge of the Grand Banks and often coincides with major current systems and thermally dynamic areas (Podesta et al., 1993). The most noticeable seasonal shift in fishing effort is the summer–fall swordfish fishery at the Grand Banks that moves to the Caribbean in the winter.

Leatherback sea turtles

A total of 1264 leatherback sea turtle captures were recorded in the NMFS pelagic logbooks for 1992–95 (Table 1). Total numbers of individual turtles caught are unknown because some turtles may have become entangled more than once. Year-round leatherback captures averaged 316 individuals per year (range: 198–452); June through November were the most important months with 1047 captures (82.7%). The mid-Atlantic, northeast coast, and northeast distant waters (areas 5–7) were the most productive, with 1035 (81.9%) combined captures. Of these, the northeast distant (area 7) accounted for 593 (46.8%) of the total leatherback turtle captures. Leatherback sea turtles are captured sporadically throughout the fishing area in the winter and spring seasons and become more abundant during the summer and fall, particularly in fishing areas 5–7 (Fig. 3). September was the most productive month with 278 (21.9%) captures for these areas combined. Reported catches varied annually (Table 2). Leatherback sea turtles were too large for observers to bring on deck for length and weight measurements, but the mean estimated carapace length of 110 individuals observed from the decks of northwest Atlantic fishing vessels was 160 cm.

Catch-per-unit-of-effort (CPUE) values indicated that loggerhead sea turtle capture rates varied considerably between areas (Table 3) but were highest

[2] Power, J. H. 1995. Analysis of the longline fishery effort, catch, and bycatch in the southwest Atlantic and Gulf of Mexico. U.S. Dep. Commer., Natl. Mar. Fish. Serv. Southeast Regional Office, 9721 Executive Center Drive, North, St. Petersburg, FL 33702. NOAA-NMFS-MARFIN Final Report, NA37FF0040-01, 96 p.

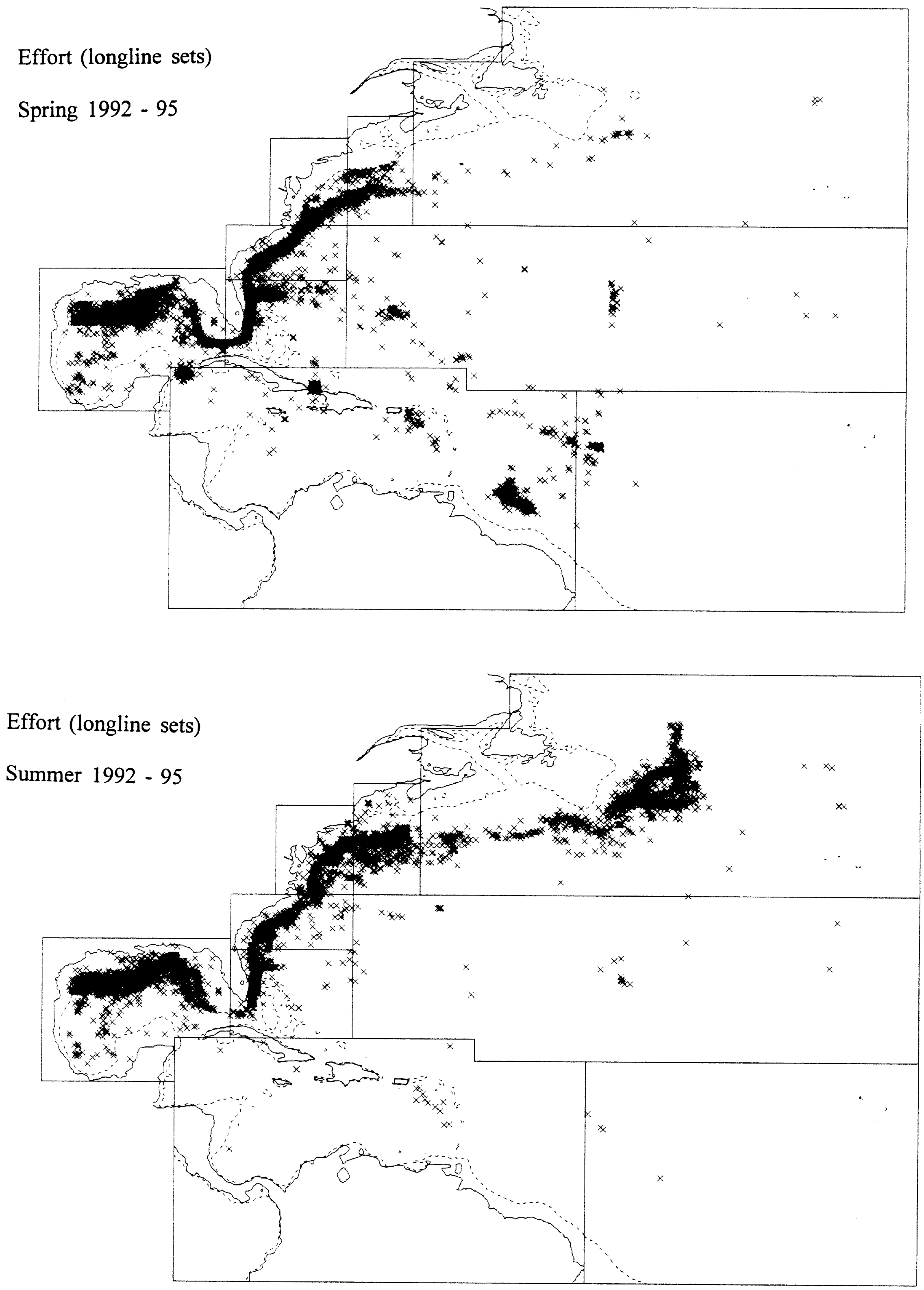

Figure 2

Pelagic longline fishing effort (sets), by season. Dashed line represents the 200-m isobath.

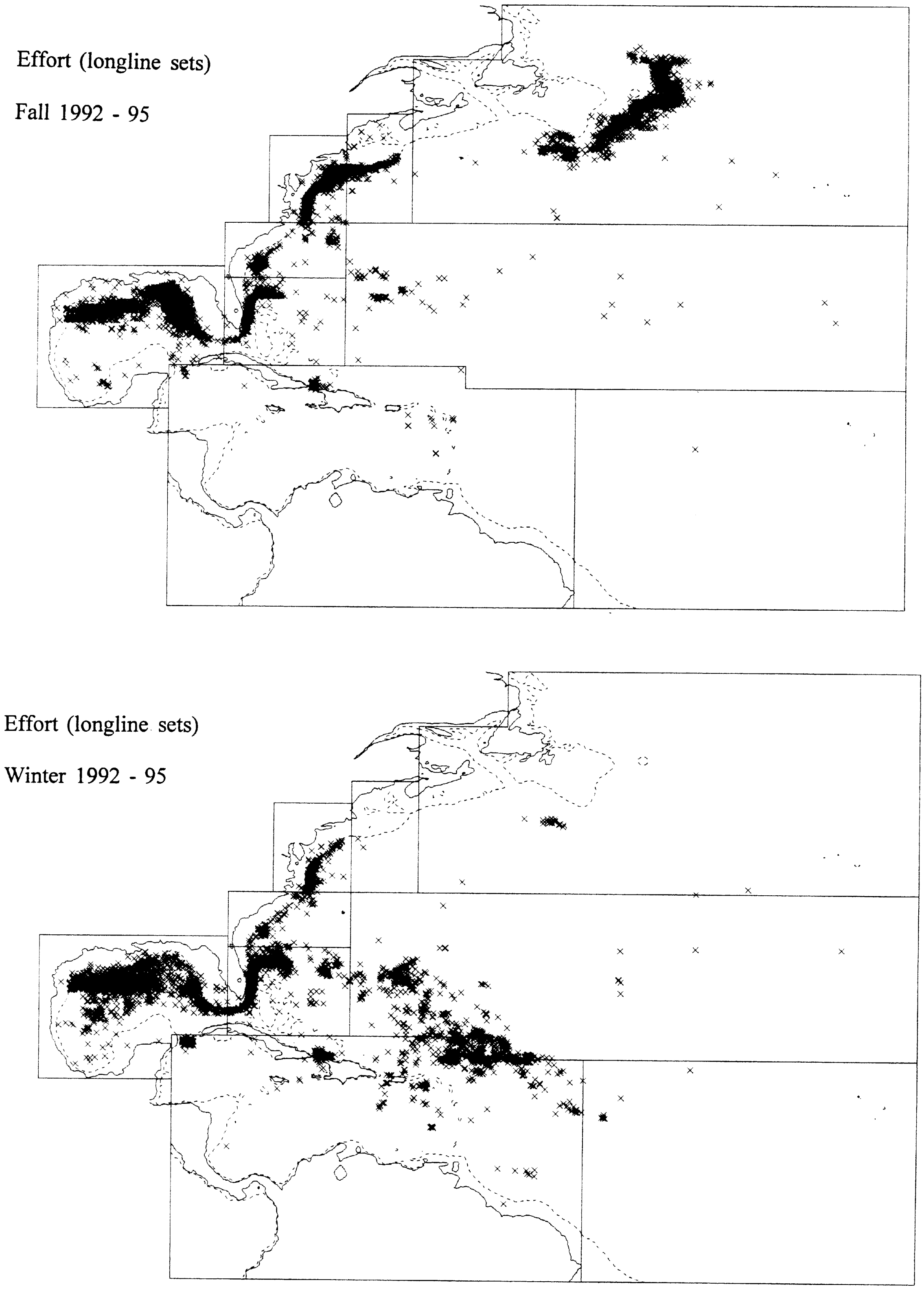

Figure 2 (continued)

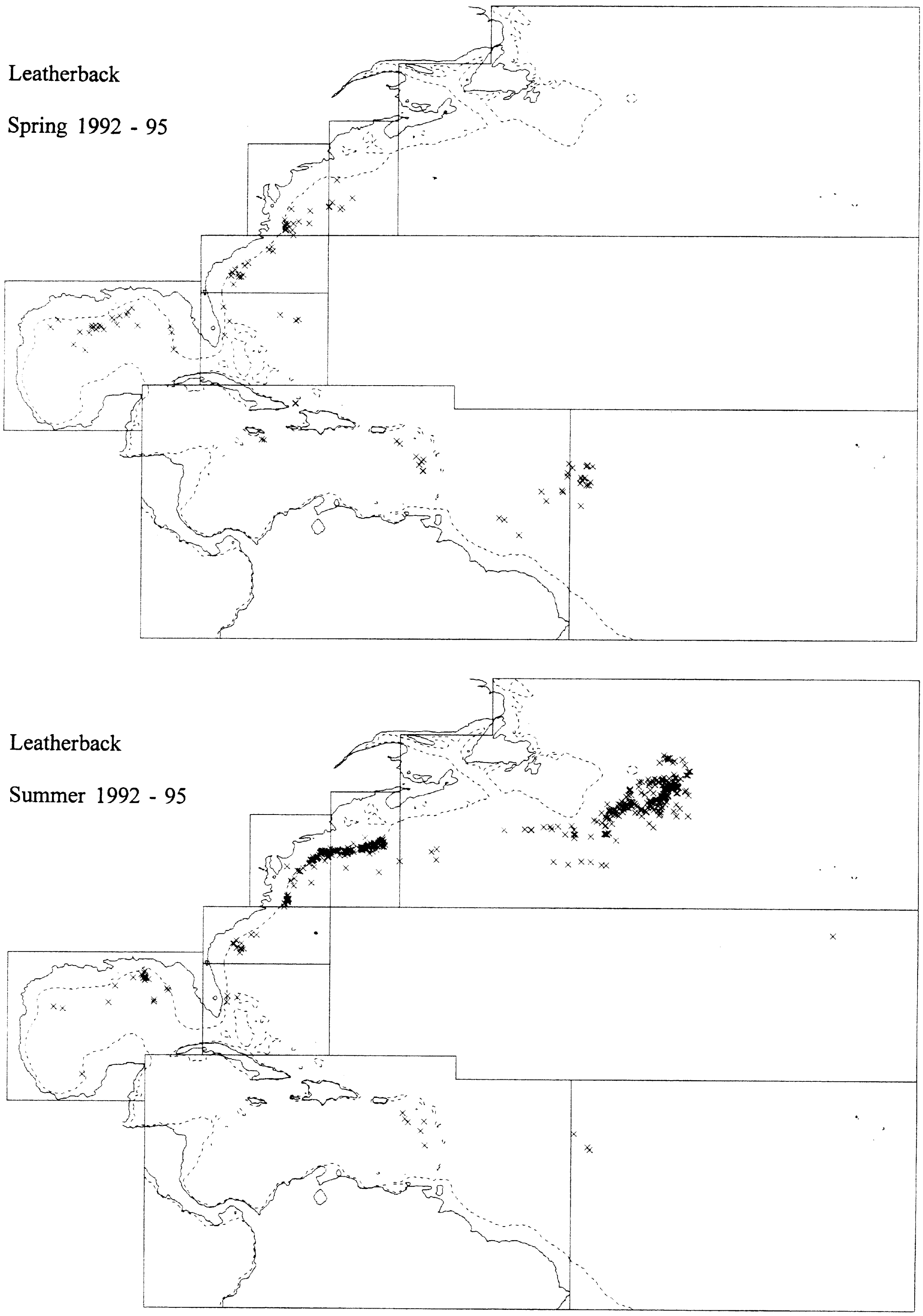

Figure 3

Leatherback sea turtle catches, by season (1992–95). Dashed line represents the 200-m isobath.

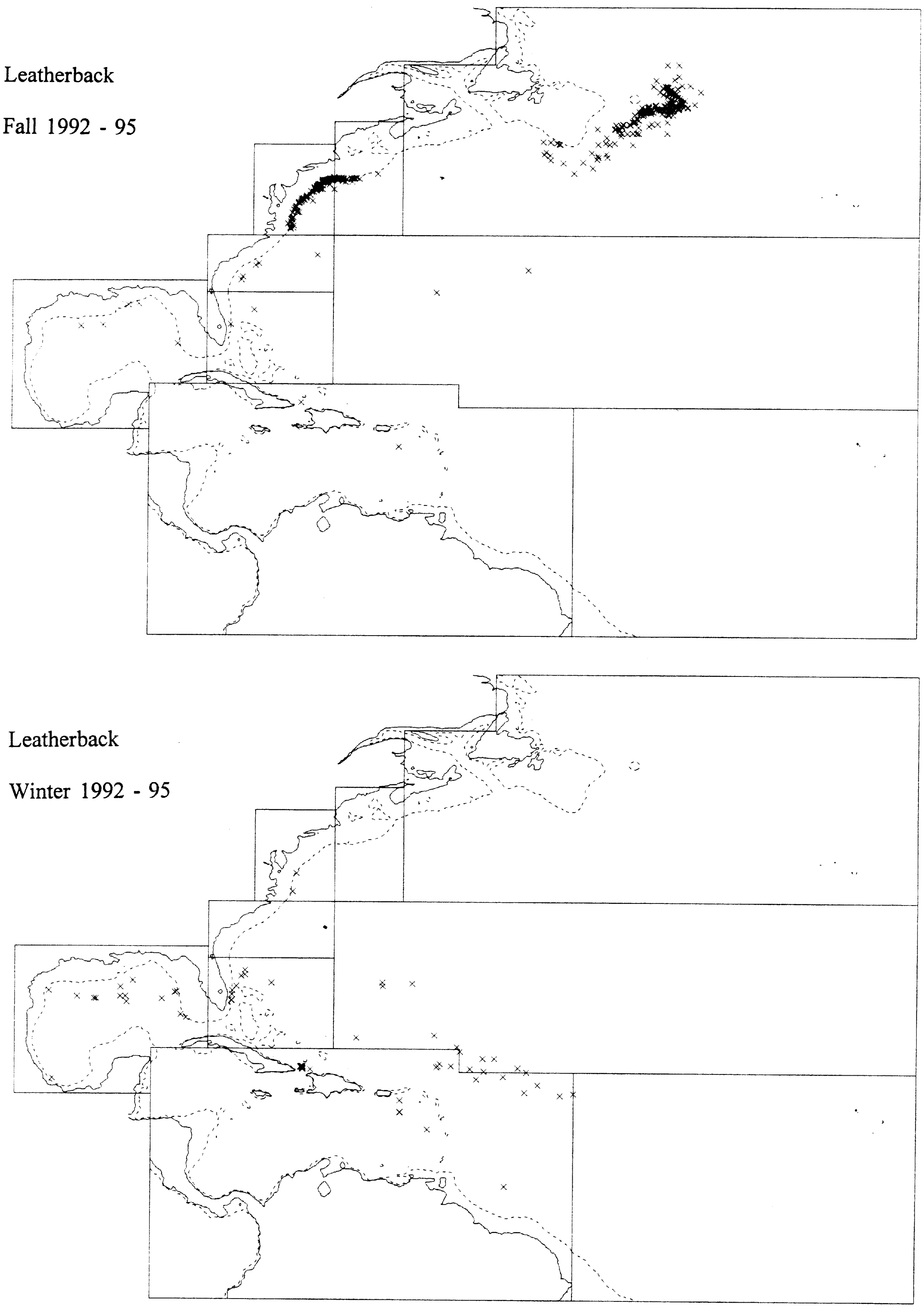

Figure 3 (continued)

Table 1
Leatherback (Lb) and loggerhead (Lh) turtle captures by the U.S. pelagic longline fleet, by NMFS fishing area, by month, for 1992–95.

	Area 1		Area 2		Area 3		Area 4		Area 5		Area 6		Area 7		Area 8		Area 9		All areas combined	
Month	Lb	Lh	Lb	Lh	Lb	Lh	Lb	Lh	Lb	Lh	Lb	Lh	Lb	Lh	Lb	Lh	Lb	Lh	Lb	Lh
01	16	12	4	6	4	2	0	0	1	4	0	0	0	0	0	0	5	4	30	28
02	17	7	12	1	2	3	0	0	0	7	0	0	0	0	0	0	2	3	33	21
03	13	24	8	4	6	2	3	1	6	7	0	0	0	0	4	2	0	1	40	41
04	4	4	7	3	2	1	3	2	1	3	2	1	0	0	1	1	0	0	20	15
05	5	1	1	4	1	1	7	4	13	3	5	3	0	0	11	1	0	0	53	17
06	1	1	3	9	2	1	6	3	22	24	35	49	40	39	3	0	1	0	113	126
07	2	0	10	5	0	0	3	3	19	10	48	62	170	233	0	0	0	0	252	313
08	3	0	10	7	1	0	2	2	32	24	48	14	152	212	0	0	0	0	248	259
09	0	1	0	1	1	1	4	2	76	11	30	4	167	310	0	0	0	0	278	330
10	1	1	2	5	1	0	0	3	84	8	12	6	56	123	0	0	0	0	156	146
11	3	1	3	2	0	1	2	0	7	5	0	4	8	19	0	0	2	0	25	32
12	4	4	3	1	3	1	0	0	1	2	0	0	0	0	0	0	5	1	16	9
Total	69	56	73	48	23	13	30	20	252	108	180	143	593	936	19	4	15	9	1264	1337

in the northeast distant (area 7). The overall CPUE for leatherback sea turtles caught by longline vessels using chemical light sticks was higher than the CPUE with vessels not using light sticks (Table 3), suggesting that the chemical light sticks might simulate bioluminescent gelatinous prey and attract leatherback sea turtles to the branchlines. Fortunately, these turtles tend to become entangled in the branchlines rather than consume baited hooks.

Leatherback sea turtles inhabit coastal and offshore pelagic waters in the North Atlantic Ocean (Pritchard, 1971). Morreale et al. (1994) speculated that they migrated along specific bathymetric contours outside the 200-m isobath, and Lutcavage (1996) proposed that they seek high concentrations of gelatinous prey along the oceanic fronts and meanders of the Gulf Stream. Shoop and Kenney (1992) reported that most were scattered along the continental shelf, except off Rhode Island in 1978, when a number of individuals were observed in association with a large concentration of *Cyanea*. Pelagic longline data, however, suggest that large numbers of leatherback sea turtles apparently also inhabit deep waters extending over the edge of the continental shelf outside the 200-m isobath from Cape Hatteras, North Carolina, to Georges Bank and the Grand Banks in the summer and fall months.

Loggerhead sea turtles

A total of 1337 loggerhead sea turtle captures were recorded in NMFS pelagic logbooks, 1992–95 (Table 1).

Table 2
Leatherback (Lb) and loggerhead (Lh) turtle captures by the U.S. pelagic longline fleet, by NMFS fishing area, by year.

	1992		1993		1994		1995	
Area	Lb	Lh	Lb	Lh	Lb	Lh	Lb	Lh
1	19	12	17	6	8	11	25	27
2	20	9	25	8	12	6	16	25
3	3	2	6	4	11	3	3	4
4	10	2	3	6	7	5	10	7
5	147	30	68	13	29	32	18	33
6	81	26	54	51	19	19	26	47
7	84	59	67	33	105	278	337	566
8	0	0	0	1	3	0	16	3
9	5	0	5	5	4	2	1	2
Total	369	140	245	127	198	356	452	714

Total numbers of individual turtles caught are unknown because observer data indicate that some turtles may have been captured more than once. Year-round loggerhead sea turtle captures averaged 334 individuals per year (range: 127–714); June through November was the most productive period with 1174 (87.8%) captures. The mid-Atlantic Bight, northeast coast, and northeast distant waters (areas 5–7) were the most productive with a combined total of 1187 (88.7%) loggerhead sea turtle captures. Of these, the northeast distant area (7) accounted for 936 (70.0%) of the captures. Like leatherback sea turtles, logger-

Table 3

Leatherback (Lb) and loggerhead (Lh) turtle incidental CPUE from 1992–95 pelagic logbooks, by area, with (Y) and without (N) chemical light sticks. CPUE is turtle captures per 1000 hooks fished.

Area	Lights	Hooks	Lb Captures	Lh Captures	Lb CPUE	Lh CPUE
1	Y	1,036,600	66	54	0.0637	0.0521
1	N	101,716	3	2	0.0295	0.0197
2	Y	2,580,340	38	37	0.0147	0.0143
2	N	3,132,180	35	11	0.0112	0.0035
3	Y	1,389,240	23	13	0.0166	0.0094
3	N	45,773	0	0	0.0000	0.0000
4	Y	937,620	30	19	0.0320	0.0203
4	N	88,089	0	0	0.0000	0.0114
5	Y	1,523,970	154	53	0.1011	0.348
5	N	2,052,910	108	55	0.0526	0.0268
6	Y	1,356,540	132	83	0.0973	0.0612
6	N	835,484	48	60	0.0575	0.0718
7	Y	2,086,660	591	932	0.2832	0.4466
7	N	55,214	2	4	0.0362	0.0724
8	Y	51,593	18	4	0.3489	0.0774
8	N	1,285	1	0	0.7782	0.0000
9	Y	497,265	15	9	0.0302	0.0181
9	N	25,696	0	0	0.0000	0.0000
1–9	Y	11,459,800	1067	1204	0.0931	0.1051
1–9	N	6,338,350	197	133	0.0311	0.0210

head sea turtles were sporadically captured throughout the entire fishing area in the winter and spring and became abundant during the summer and fall in fishing areas 5–7 (Fig. 4). September was the most productive month with a combined total of 330 (24.7%) loggerhead sea turtle catches. Reported catches varied annually (Table 2). The mean curved carapace length (nuchal notch to tip of marginal) and weights of these captured sea turtles from the north east distant area (7) were 55.9 cm (SD=6.5 cm, n=98) and 22.1 kg (SD=11.1 kg, n=72). These turtles were smaller than coastal loggerheads from the northeastern United States (Lutcavage and Musick, 1985).

CPUE values indicated that loggerhead capture rates varied between areas (Table 3) and were highest for the northeast distant area (7). CPUE analysis indicated that the overall loggerhead sea turtle capture rates with light sticks were higher than the CPUE without light sticks (Table 3). Unlike leatherback sea turtles, loggerhead sea turtles readily consumed baited hooks. The fate of such hooked turtles is unknown, but they have been observed trailing multiple gangions; therefore some turtles previously hooked have remained actively feeding in the area.

Pelagic longline data indicate that loggerhead turtle distribution extends from coastal waters to the edge of the continental shelf from Cape Hatteras, North Carolina, to Georges Bank and the Grand Banks in the summer and fall months and also extends into deep waters off the shelf. These turtles are apparently able to move out of critically cold winter slope water to more hospitable southern waters. NMFS tagging data revealed that turtles hooked on their flippers were tagged in the spring in areas 6 and 7 and recovered in warmer winter waters in areas 4 and 2, respectively (NMFS[3]).

Conclusions

It is not surprising that pelagic longline fisheries incidentally catch turtles because fishing effort is concentrated either near the 200-m isobath or near interactions between major current systems. In these areas a variety of potential prey species (various nektonic organisms associated with *Sargassum*, as well as cephalopods, coelenterates, and schooling fish) concentrate and consequently attract tunas, swordfish, and sharks (Laurs et al., 1984; Maul et al., 1984; Kurowicki, 1987; Fiedler and Bernard, 1987; Podesta et al., 1993; Lutcavage, 1996). Aerial survey data off the eastern United States (Shoop and Kenney, 1992) and pelagic longline data presented here indicate that

[3] NMFS Cooperative Marine Turtle Tagging Program, Miami Laboratory, 75 Virginia Beach Drive, Miami, FL 33149.

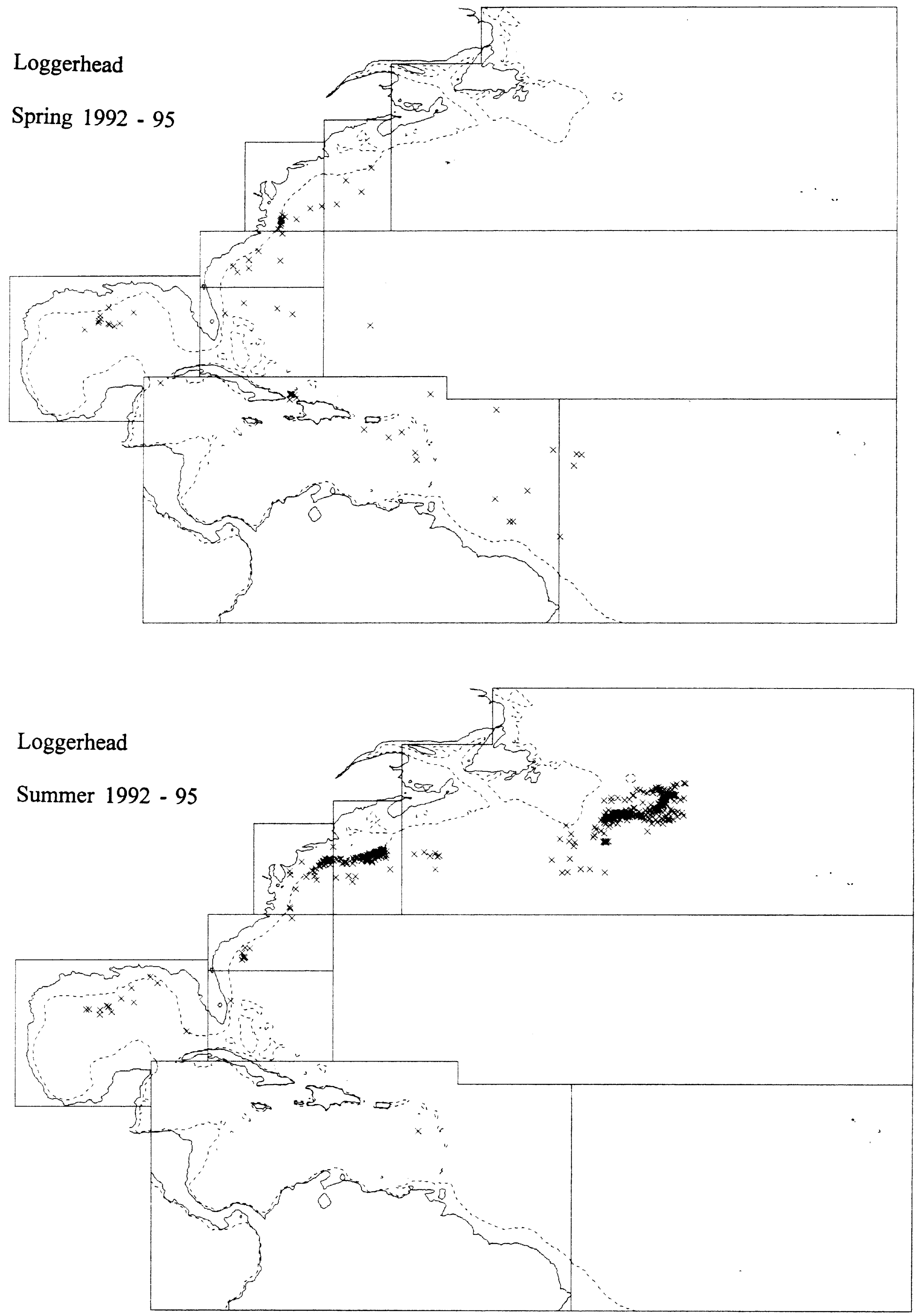

Figure 4

Loggerhead sea turtle catches, by season (1992–95). Dashed line represents the 200-m isobath.

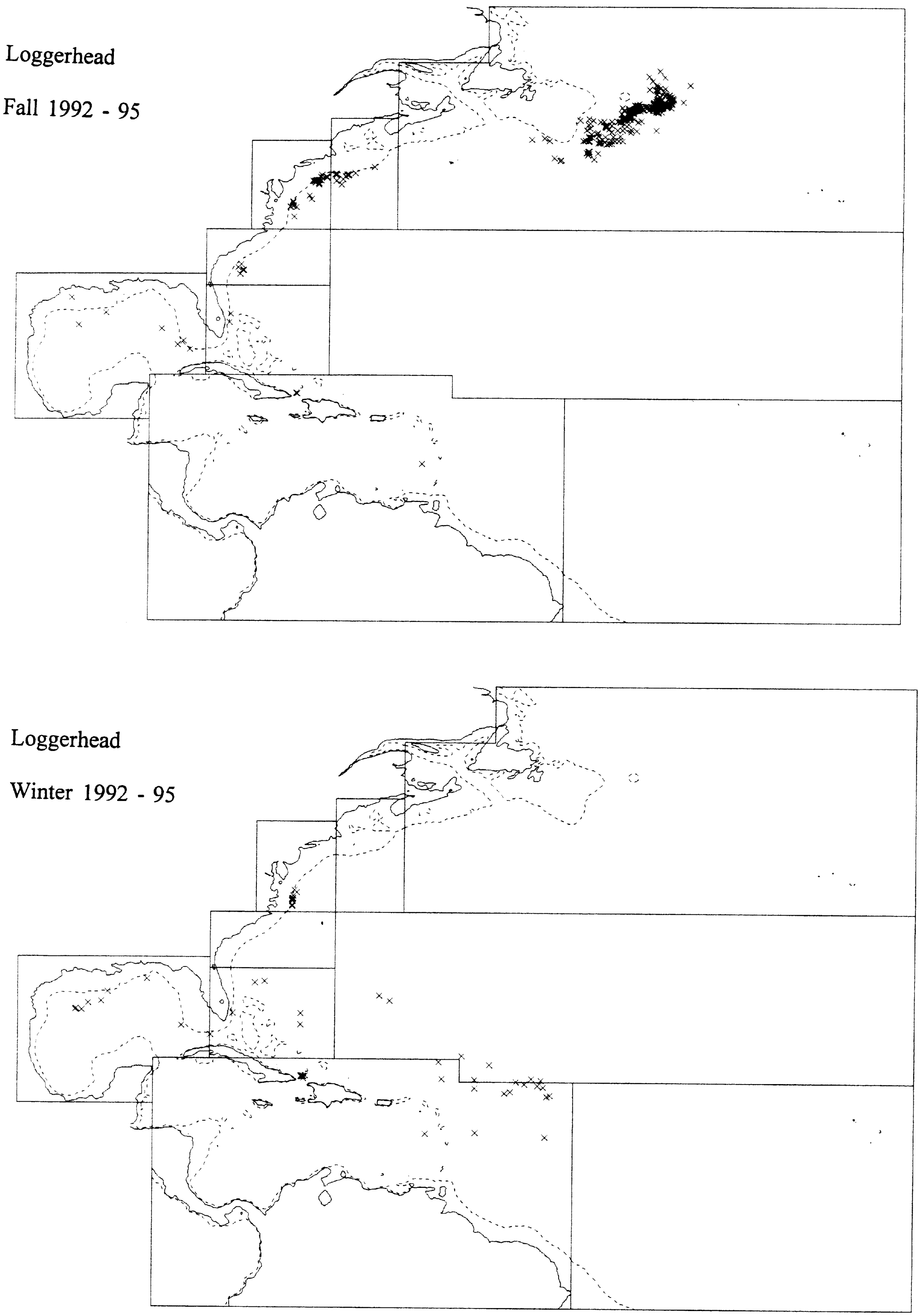

Figure 4 (continued)

leatherback and loggerhead sea turtles use the entire continental shelf, as well as the thermally dynamic waters off the continental edge.

The northeast distant fishing area (7) is particularly productive. The circulation and thermodynamics of fishing area 7 are very complex and provide a unique pelagic habitat. The Gulf Stream begins to meander northeastward off Cape Hatteras, and the western edge of the Gulf Stream eventually passes south of the Grand Banks as it turns eastward toward Europe. The thermodynamics of north Atlantic circulatory process near the Grand Banks is complicated (Schmitz and McCartney, 1993), and it is this interaction of cold slope water and warm Gulf Stream water that is productive for large pelagic fish and sea turtles. Moreover, the Gulf Stream spins off warm-core rings on the cooler northeastern slope water (Auer, 1987), where pelagic longline fishing is heaviest. These warm-core rings have been well studied, resulting in a plethora of published literature (Wiebe and McDougall, 1986). Unfortunately, these biological studies have concentrated on planktonic productivity and mesopelagic fishes rather than on larger pelagic apex predators; however, these rings affect the distribution and abundance of large pelagic fish, marine mammals, and sea turtles.

Fishery managers and sea turtle researchers need to develop conservation strategies that mitigate sea turtle and longline interactions. The high numbers of potentially lethal loggerhead sea turtle captures in the northeast distant area (7) during the summer and fall swordfish fishery particularly need to be addressed by fishery managers.

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