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Spatial And Temporal Occurrence Of Spanish Mackerel Scomberomorus-Maculatus In Chesapeake Bay

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The Spanish mackerel *Scomberomorus maculatus* is a pelagic, warm-temperate, or subtropical species that inhabits continental waters from Cape Cod, Massachusetts, south along the Atlantic coast to Florida and through the Gulf of Mexico to the Yucatan Peninsula (Collette et al. 1978, Collette & Russo 1984). In summer, it is considered common along the U.S. east coast north to Chesapeake Bay (Bigelow & Schroeder 1953, Musick 1972). This species was abundant in Chesapeake Bay in the late 1800s, and the most extensive fishery for it in the U.S. occurred there then (Earll 1883). In recent years, Spanish mackerel have again become abundant in Chesapeake Bay (Chittenden et al. In review).

Much work has been done on Spanish mackerel (see Berrien & Finan (1977) and Lukens (1989). However, other than Chittenden et al. (In review), no studies have been directed at this species in the cold-temperate waters north of Cape Hatteras NC, since Ryder (1882) and Earll (1883) over 100 years ago. As a result, little information exists from which to plan collection of basic biological data on this species in the Chesapeake Region, much less to manage it there.

The objectives of the present study are to describe spatial and temporal distributions of Spanish mackerel in Chesapeake Bay using catch estimates from direct observations of catches and interviews of commercial fishermen, and to relate the temporal distribution of this species to water temperature. This basic information is needed to plan other research on this species in the Bay.

Methods

Our data cover the period 1988–90, but primarily 1989, and were obtained from commercial pound-net fisheries that cover a broad area of the Virginia waters of Chesapeake Bay (Fig. 1). The individual Chesapeake Bay fisheries are generally small in scale, usually fishing 1–7 nets in the local waters of each fishery. The nets are usually emptied daily, depending on wind conditions, size of the local catch, and market conditions. Reid (1955) and Chittenden (1991) describe the Chesapeake Bay pound-net fisheries, e.g., gear, fishing, and catch-processing procedures.

We present next our sampling design for 1989, the major period of study. At weekly or fortnightly intervals, we made 51 on-site observations and 66 telephone calls to cooperating fishermen to get daily catch-record information to estimate the size of Spanish mackerel catches at their commercial pound-net fisheries (see Fig. 2 for the spatial and temporal distribution of these data contacts). We studied four fisheries, which were chosen because they were usually cooperative in providing information, were widely-spaced along the Chesapeake Bay, and were among the major fisheries in their areas. These characteristics facilitated data collection, giving the study widespread geographic coverage and pertinence to major portions of the Chesapeake Bay pound-net fishery. Three of the contacted fisheries were located along the 'Western Shore' of Chesapeake Bay (Fig. 1), off (1) Lynnhaven, (2) the lower York River, and (3) Reedville; the fourth was located along the lower 'Eastern Shore' near Kiptopeke. Though not all the nets were emptied every day, in 1989 these fisheries fished 21 pound-nets (Table 1), about 10% of the roughly 200 net licenses issued in the Chesapeake Bay pound-net fishery. The pound-net fisheries begin fishing each year (and our initial contacts were made) well before Spanish mackerel enter Chesapeake Bay; the fisheries continue operating (and our later contacts were made) well after this species leaves the Bay (see the occurrence of zero catches in Fig. 2).

Findings in 1989 were supplemented with information from 1988 and 1990, which was obtained using the same sampling design and procedures as in 1989 but with less regular and extensive contacts. In 1988 contacts were primarily made in the last half of the fishing season; we used this data to describe when Spanish mackerel disap-

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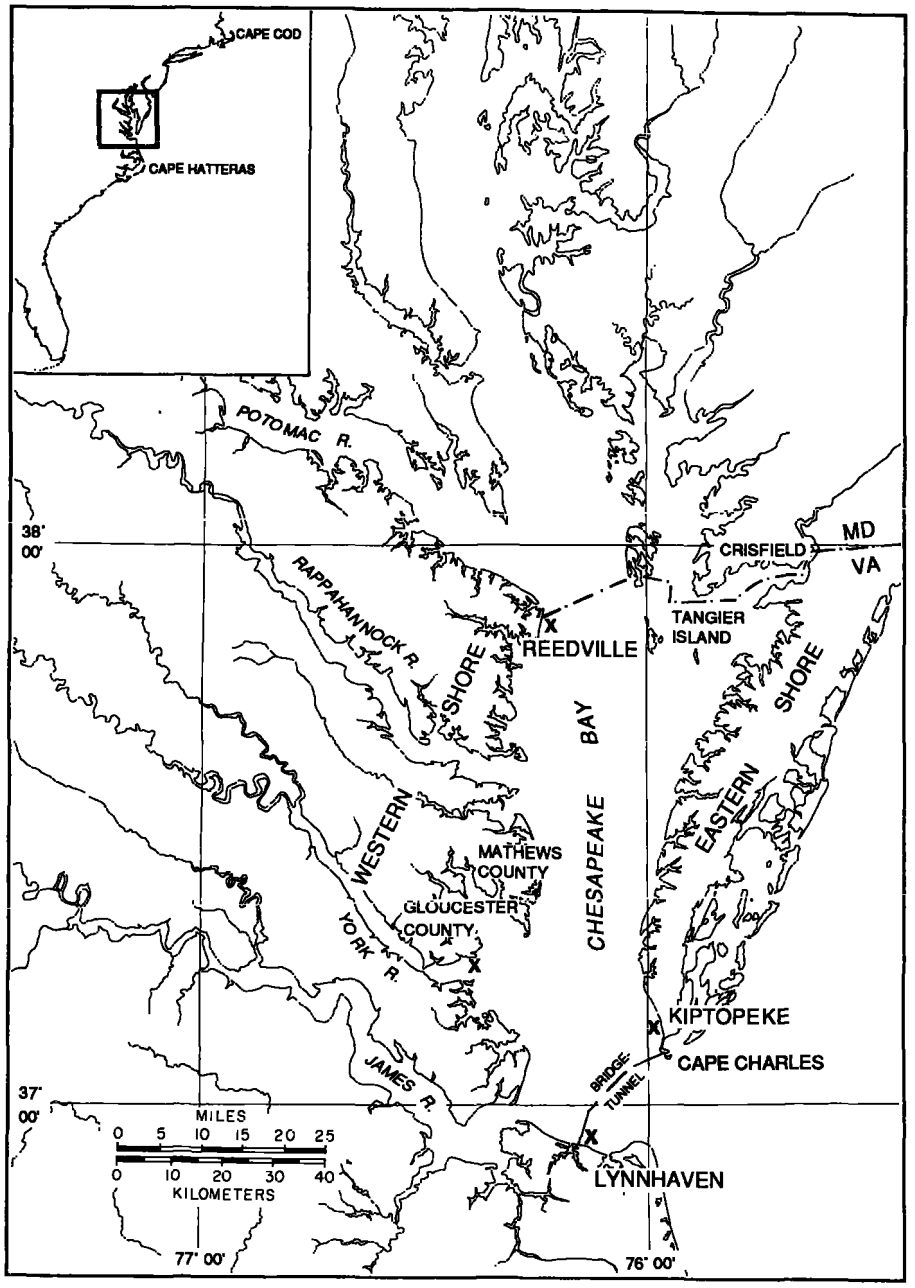

Figure 1
Chesapeake Bay geography. The four fishery locations are indicated by x's.

peared that year. In 1990, contacts were primarily made in the first half of the fishing season; we used that data (Fig. 3) to describe when Spanish mackerel appeared and became abundant that year. Catch-size information for 1989 and 1990 was related to daily surface-water temperature records at Kiptopeke and at the Chesapeake Bay Bridge Tunnel, provided by the National Ocean Survey (Fig. 1).

The accuracy of our estimates of catch size varied from data contact to contact, because the estimates were not always simple catch data. Most estimates were quite accurate, particularly when catches were zero or very small (e.g., records being "none caught," "few caught," etc.), when, as usual, the fishermen were willing to give a specific estimate ("*n* boxes caught"), or when the catch was stacked in boxes on pallets for shipment and could be counted by us. In some cases, our estimates were verbal (e.g., records being "larger than last week," etc.). To compare estimates, the size of the catch from each data contact in 1989 and 1990 was scored in the following categories: (0) no Spanish mackerel caught, (1) <1 22.6 kg box of fish caught, (2) 1–5 boxes, (3) >5–10 boxes, (4) >10–20 boxes, and (5) >20 boxes. Adjacent categories may show some overlap, because the original records are inexact. However, these categories permitted a distinct separation of zero or small catches (categories 0,1) from large catches (categories 3,4,5), but a less-distinct separation of intermediate-sized catches. We feel the error of these estimates is small and does not affect the broad spatial and temporal patterns described.

To evaluate temporal distributions, differences in monthly catches in 1989 were tested for each location using a Kruskal-Wallis one-way nonparametric analysis of variance (Table 1) after ranking the scores (SAS 1988). This was supported by Tukey's multiple comparisons tests (Table 2), applied to the ranked scores to evaluate specific monthly differences. Similar procedures were followed to evaluate spatial distributions. We interpret significance tests on spatial differences with caution, because the number of nets varied among locations and information does not exist to standardize nets and nominal effort. We feel this has little

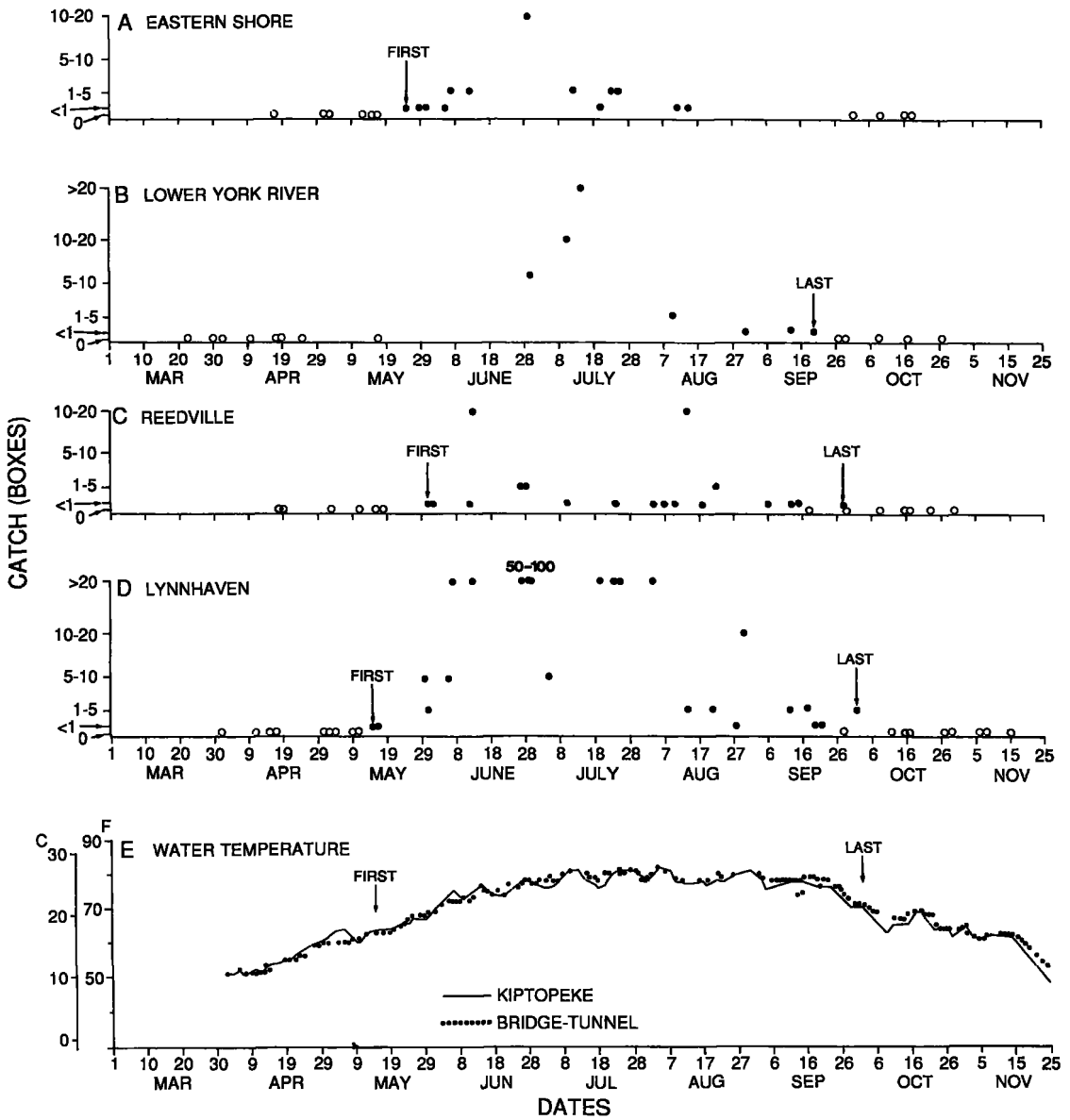

Figure 2

Estimates of daily Spanish mackerel *Scomberomorus maculatus* catches (no. of 22.6 kg boxes landed) in 1989 in Chesapeake Bay: **(A)** Eastern Shore, **(B)** lower York River, **(C)** Reedville, and **(D)** Lynnhaven, with daily water temperatures **(E)** at Kiptopeke and off the Chesapeake Bay Bridge-Tunnel. All data contacts are indicated. Zero catches are indicated by open circles. One box = 22.6 kg fish. "First" and "Last" indicate dates when first and last fish were captured; this is not specified when a long time-lapse in sampling occurred before the "First" or after the "Last" record.

effect on temporal trends, however, because the same number of nets was generally used in a fishery throughout the season.

To make significance tests for differences between areas, we converted the raw catch records to catch-per-unit-effort (C/f) by using the nominal number of nets (Table 1) to estimate effort. The resulting C/f records were then scored into the categories described above. This procedure does not change the original scores for records of "no catch" or "<1 box"; it does tend to lower scores for larger catches, thereby making it more difficult to declare significance.

Table 1

Summary, by location, of Kruskal-Wallis one-way nonparametric significance tests for monthly differences in Spanish mackerel *Scomberomorus maculatus* catches in 1989. *n* = number of records at one location, df+1 = number of months sampled.

Location	Nets	*n*	χ^2	df	Prob.
Reedville	2	31	21.83	6	0.0013
York River	7	20	16.37	7	0.0219
Lynnhaven	5	43	31.86	7	0.0001
Eastern Shore	7	23	16.94	5	0.0046

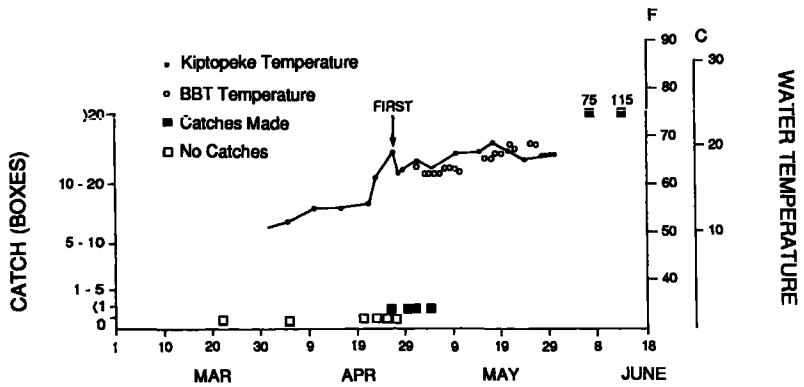

Figure 3

Estimates of daily Spanish mackerel *Scomberomorus maculatus* catches (no. of 22.6 kg boxes landed), early 1990 at Lynnhaven in Chesapeake Bay, with daily surface-water temperatures at Kiptopeke and off the Chesapeake Bay Bridge-Tunnel (BBT). "First" indicates date when first fish were captured. No records collected mid-May to early June.

Table 2

Summary, by location, of Tukey's multiple comparisons tests to evaluate specific monthly differences in Spanish mackerel *Scomberomorus maculatus* catches in 1989. Mean ranks (of scores for catch sizes; see Methods) without the same letters are significantly different at α=0.05.

Month	*n*	Mean rank	Significance			Month	*n*	Mean rank	Significance		
		Reedville						**York River**			
Jun	5	25.3	a			Jul	2	19.5	a		
Aug	6	23.1	a			Jun	1	18.0	a		
Jul	2	20.0	a	b		Aug	2	16.0	a		
Sep	6	15.7	a	b	c	Sep	4	11.0	a	b	
May	5	9.6		b	c	Mar	2	7.0		b	
Apr	2	7.0			c	Apr	5	7.0		b	
Oct	5	7.0			c	May	1	7.0		b	
						Oct	3	7.0		b	
		Lynnhaven						**Eastern Shore**			
Jun	6	36.8	a			Jun	4	19.3	a		
Jul	4	36.3	a			Jul	4	18.5	a	b	
Aug	5	29.1	a	b		Aug	2	14.0	a	b	c
Sep	4	21.1		b	c	May	8	8.7		b	c
May	9	16.7		b	c	Apr	1	5.5			c
Oct	7	12.4			c	Oct	4	5.5			c
Apr	4	10.0			c						
Nov	3	10.0			c						

Spatial distribution

Results

Spanish mackerel become widely distributed in summer throughout Virginia waters of the Chesapeake Bay. In 1989, we observed large catches, at least on occasion, at Lynnhaven, off the lower York River, on the Eastern Shore, and at Reedville (Fig. 2). Catches were consistently large in June, July, and early August off Lynnhaven and apparently off the lower York River, although records were not as complete there. Comparatively low catches were consistently made at Reedville and on the Eastern Shore. We formed the distinct impression from our data and observations that Spanish mackerel were much more abundant in the summer along the lower Western Shore of Chesapeake Bay in 1989 than either along the Eastern Shore or upbay at Reedville.

Our interpretation of spatial patterns in Spanish mackerel abundance is supported by significance tests that evaluate the null hypothesis, within months, of no difference in C/f between areas. Kruskal-Wallis non-parametric tests for 1989 showed significant differences in C/f between areas in June and July (Fig. 4), when peak abundance occurred, but there were no significant differences in the other months when abundance was lower (Table 3). Tukey's multiple comparisons tests (Table 4) showed significantly higher C/f in July at Lynnhaven and the lower York River than at Reedville or the Eastern Shore. In June, these tests showed significantly higher C/f at Lynnhaven than on the Eastern Shore. Reedville C/f in June was intermediate and not significantly different from either Lynnhaven or the Eastern Shore; data from the Lower York River were not included in the Tukey's test presented because only one data contact was made there in June.

Discussion

Spanish mackerel primarily occur in the lower Chesapeake Bay, i.e.,

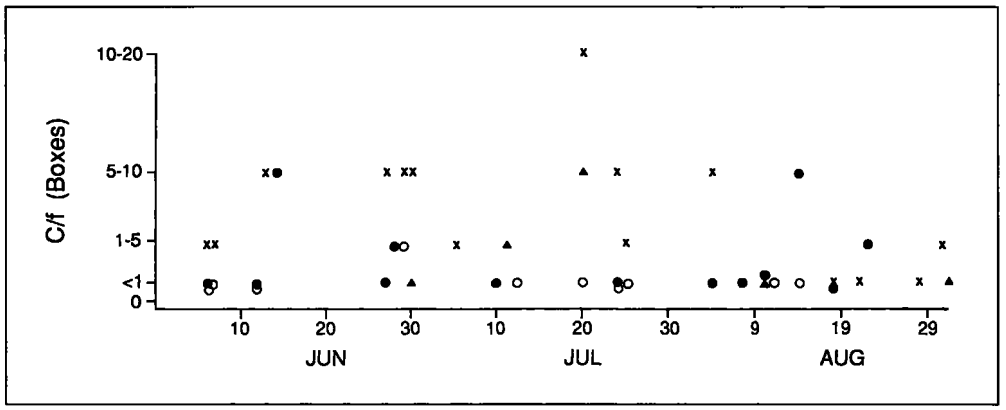

Figure 4
Estimates of daily Spanish mackerel *Scomberomorus maculatus* catch-per-unit-effort (C/f, no. of 22.6 kg boxes landed), June–August 1989 by location. Comparatively few or no fish were landed March–May and September–November. (x) Lynnhaven, (▲) lower York River, (●) Reedville, (○) Eastern Shore.

Table 3
Summary, by month, of Kruskal-Wallis one-way nonparametric significance tests for differences between areas in Spanish mackerel *Scomberomorus maculatus* catches in 1989. *n* = number of records in one month, df+1 = number of areas.

Month	*n*	χ^2	df	Prob.
Apr	12		none caught	
May	23	1.51	3	0.6799
Jun	16	8.34	3	0.0395
Jul	12	9.68	3	0.0215
Aug	15	1.86	3	0.6011
Sep	14	0.53	2	0.7673
Oct	19	1.71	3	0.6338

Table 4
Summary, by month, of Tukey's multiple comparisons tests to evaluate specific differences between areas in Spanish mackerel *Scomberomorus maculatus* catches in 1989. Mean ranks (of scores for catch-per-unit-effort, see Methods) without the same letters are significantly different at α=0.05. There were no significant differences in months not tabulated.

Area	*n*	Mean rank	Significance	
June				
Lynnhaven	6	11.50	a	
Reedville	5	6.40	a	b
Eastern Shore	4	4.75		b
July				
Lynnhaven	4	9.63	a	
York River	2	9.25	a	
Reedville	2	3.50		b
Eastern Shore	4	3.50		b

the waters of Virginia. We found regular occurrences at Reedville near the Potomac River mouth, occasionally in high numbers as noted by Uhler & Lugger (1876), although Hildebrand & Schroeder (1928) reported few occurrences north of the Rappahannock River. Many fish may enter Maryland waters in years of abundance (Butz & Mansueti 1962), such as in 1880 when landings were 8.2 t (Earll 1883). However, catches there have always been small compared with those in Virginia, where landings made up 97–99% of the reported bay-wide catch in 1880 (Earll 1883), in 1920 (Hildebrand & Schroeder 1928), in 1887–1967 (Lyles 1969), and in 1968–76 (Trent & Anthony 1979), and in 1978–90 (from annual printouts, "(*Year*) landings for the U.S.," provided by the NMFS Office of Data Information Management to VIMS library).

Spanish mackerel may be abundant throughout much of the Chesapeake Bay in Virginia. Large pound and gillnet fisheries existed for it in the 1880s off Gloucester and Mathews counties on the Western Shore, off the Eastern Shore from Cape Charles to Crisfield MD, and off Tangier Island VA (Earll 1883 and 1887, McDonald 1887). Fish also enter the more-saline, lower parts of tributaries like the Potomac and York Rivers (Baird cited in Goode 1888, Hildebrand & Schroeder 1928).

Though they may be useful for management and environmental impact assessment, little data exist to describe in fine detail the spatial distribution of Spanish mackerel in Chesapeake Bay. Such data would be difficult and probably expensive to obtain without mandatory catch-reporting by all the commercial fisheries, because this is a pelagic, fast-swimming, and widely-distributed species that is not well suited to most fishery-independent collecting programs. However, the large-scale distributional patterns of this species apparently have been stable for over 100 years. Our data, biological notes, and anecdotal information from the years 1870–80 (Uhler & Lugger 1876, Earll 1883 and 1887, McDonald 1887) and 1920–60 (Hildebrand & Schroeder 1928, Butz & Mansueti 1962), and long-term landings data from Maryland and Virginia indicate that this species primarily occupies waters which, according to Lippson & Lippson (1984), are of polyhaline salinity (18–30 ppt) and the saltier portions of mesohaline waters (5–18 ppt).

Temporal distribution

Results

Spanish mackerel occur in Chesapeake Bay from late April to early October. They first appeared in the catches on 15 May 1989 (Fig. 2) when three fish were taken off Lynnhaven, on 26 April 1990 (Fig. 3) when two fish were taken there, and, anecdotally according to those fishermen, on about 10 May 1991. Though fishing continued well afterwards, the last catches were on 3 October 1988 and 2 October 1989, dates when we recorded only a few individuals at the lower York River and Lynnhaven fisheries, respectively.

Peak abundance of Spanish mackerel in Chesapeake Bay occurs from early or mid-June through mid-August, based on pound-net records. After the first appearance in 1989, catches at Lynnhaven rapidly rose to high levels in early to mid-June and remained high through mid- to late August (Fig. 2). Combined catches at Reedville, the lower York River, and the Eastern Shore showed the same pattern. Comparatively few fish were captured in any area after late August or early September in that year. After fish appeared in late April 1990, catches at Lynnhaven remained low through at least early May (Fig. 3) when our observations temporarily ceased. Catches were large at Lynnhaven by early to mid-June when observations were made again.

Our interpretation of temporal patterns in Spanish mackerel abundance is supported by significance tests that evaluate the null hypothesis of no difference in catch between months within locations. Significant differences in catch were found between months at each location in 1989 (Table 1). Catches were significantly higher at each location in summer months (June, July, August) than in early spring (March, April) or late fall (October, November) (Table 2). As typically occurs with multiple comparisons tests, intermediate-size catches in May and September were or were not significantly different from adjacent periods of higher or lower catch; the trend of increasing abundance to midsummer and decreasing abundance into fall is the most important feature here.

Spanish mackerel abundance during the season follows a unimodal pattern. Catches in 1989 at Lynnhaven especially, along the Eastern Shore, and off the lower York River show a roughly bell-shaped distribution (Fig. 2). Catches may be bimodal at Reedville near the upbay margin of the range.

Spanish mackerel occur in Chesapeake Bay when water temperatures near the Bay mouth exceed about 17°C. The first fish were taken at Lynnhaven when temperatures had risen to 17°C in 1989 (Fig. 2), and, in 1990, 19°C after a period of rapid temperature increase in late April (Fig. 3). Large catches began in late May in 1989, soon after temperatures rose to 20°C (Fig. 2), and catches remained large through midsummer at 21–27°C. The last fish were taken at Lynnhaven on 2 October 1989 when temperatures decreased and remained below 21°C.

Discussion

Our data on the temporal occurrence of Spanish mackerel in Chesapeake Bay agree with Earll (1883) and Hildebrand & Schroeder (1928) in that (1) the overall period of occurrence in this species is generally mid-May through early October, (2) peak abundance is early June through mid-August or mid-September, (3) the last records of catches are all in early October, and (4) the initial records of appearance are generally in mid-May (10, 15 May in our records; 12, 20 May in previous records), though fish may appear considerably earlier (26 April, our records). Our late-April record may reflect the early, rapid temperature increase that occurred in 1990. The period when Spanish mackerel occur in Chesapeake Bay is shorter than their late-April to early-November distribution off North Carolina (Earll 1883, Smith 1907, Roelofs 1951) but is somewhat longer than their distribution off New York and New Jersey, variously reported as late May or late July to late September–early October (Earll 1883, Bean 1903, Nichols & Breder 1926). The bell-shaped distribution of catches that we, and apparently Hildebrand & Schroeder (1928), observed for Chesapeake Bay differs from a bimodal distribution (i.e., peak abundance in spring and fall) reported for North Carolina (Smith 1907, Hildebrand & Cable 1938, Roelofs 1951). Presumably, this reflects a north-south migration by part of the population(s) through North Carolina waters in spring and fall, in contrast to a summer residence in the Chesapeake.

Munro (1943) reported that the genus *Scomberomorus* is subtropical and tropical in distribution, the optimum range of all species being within the 20°C ocean isotherm in summer. Our findings agree, in that Spanish mackerel initially appear in Chesapeake Bay at temperatures of about 17-19°C and become abundant at about 20°C. Other reports also support that value (Earll 1883, Manooch 1984, Goode 1888). Perret et al. (1971) captured one fish at 10°C, but that appears unusual. Beaumariage (1970) related the 20°C ocean isotherm to Spanish mackerel distribution and suggested Long Island would be near their northern limit in August. Indeed, they are uncommon off Massachusetts (Nichols & Breder 1926, Bigelow & Schroeder 1953). The time-period when temperatures are above 20°C decreases with increasing latitude, and

that probably explains why, as noted above, this species occurs for respectively shorter periods in the summer off New Jersey-New York, in Chesapeake Bay, and off North Carolina.

Timing of the appearance and disappearance of Spanish mackerel in Chesapeake Bay is probably regulated, in part, by temperature differences between the Bay and ocean. Bay waters warm up faster than the ocean in spring and cool faster in fall, due to their different volumes. Cooler ocean temperatures probably limit the time when fish arrive in Chesapeake Bay in spring, and cooler Bay temperatures probably limit the length of time they remain there in fall. Ocean isotherms off the Bay mouth in May and September–October show slightly warmer water along the southern (e.g., Western) shore of the Bay (Anonymous 1989a,b,c). In spring, this might encourage fish to initially enter the Bay along the Western Shore as our records suggest. In fall, it might encourage them to leave that area last.

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