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Fluctuations in Abundance of Spanish Mackerel in Chesapeake Bay and the Mid-Atlantic Region

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Abstract.—Spanish mackerel *Scomberomorus maculatus* have shown great fluctuations in abundance in Chesapeake Bay and the mid-Atlantic region. Early anecdotal accounts indicate they were very abundant in the later 1600s but were not common in the early–mid-1800s. Both annual landings and anecdotal accounts indicate they were very abundant about 1860–1910 and much less so since. Early patterns may reflect, in part, a natural long-term component in abundance. Large early landings were probably at levels not sustainable in the Chesapeake and mid-Atlantic region, because the classical response of a stock to fishing is a process of juvenescence and reduction of the virgin standing stock to a new, lower, equilibrium level. Fluctuations due to recruitment have probably been superimposed on the juvenescence process since the inception of the early fishery about 1865. Repeated lows in Chesapeake Bay landings in 1910–1936, 1947–1960, and 1977–1985 indicate repeated, prolonged series of weak year-classes in that region or poor escapement from fisheries in more southern waters. Two brief periods of high landings in 1937–1938 and 1944–1946 probably each reflected one or two strong year-classes. The nature and duration of the recent period of high landings (1986–1991) is not yet clear. This apparent increase in abundance may reflect (1) increased survivorship and escapement of adults due to recent management actions in Florida, and (2) possible production of at least one strong year-class at the beginning of, if not throughout, the period, a phenomenon that may have been enhanced by increased spawning stocks reflecting recent management or earlier voluntary actions.

The Spanish mackerel *Scomberomorus maculatus* is a pelagic, warm-temperate or subtropical species of continental waters. Except for strays, it ranges 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 and Russo 1984). At least two populations exist, as Wollam (1970) suggested, one along the east coast of the United States and another in the Gulf of Mexico (Skow and Chittenden 1981; Nakamura 1987). This species has long supported important recreational and commercial fisheries in both these areas (Lyles 1969; Trent and Anthony 1979).

Along the U.S. east coast, Spanish mackerel are now considered common, in summer, north to only about Chesapeake Bay (Bigelow and Schroeder 1953; Musick 1972). However, early accounts reported them common north to Long Island, New York (Scott 1875; Goode 1888), and at one time the most extensive fisheries for this species occurred from Chesapeake Bay to Long Island (Earll 1883). The reality of and reasons for this apparent change in Spanish mackerel abundance or distribution have never been addressed.

Much work has been done on Spanish mackerel. Most studies have been directed at stocks off Florida (e.g., Powell 1975; Fable et al. 1987) or in the Gulf of Mexico (Dwinnell and Futch 1973; McEachran et al. 1980), though some recent studies have focused on the Atlantic coast north of Florida (Finucane and Collins 1986; Collins and Stender 1987; Collins and Wenner 1988). Other than work on the spatial and temporal distribution of Spanish mackerel in Chesapeake Bay (Chittenden et al. 1993), there has been no study directed at the species in the cold-temperate waters north of Cape Hatteras, North Carolina, since Ryder's (1882) and Earll's (1883) over 100 years ago. Through use of long-term landing records and early anecdotal accounts, the present study describes and evaluates fluctuations in the abundance of Spanish mackerel in Chesapeake Bay and the mid-Atlantic region (New Jersey–New York). We argue that fluctuations of this species in Chesapeake Bay and mid-Atlantic region landings may reflect, in

part, escapement from southern fisheries, e.g., from Florida waters; hence, this study adds to a coastwide perspective desirable in management of Spanish mackerel.

Methods

Annual landings, which this paper is largely based on, form the only set of quantitative information available to describe fluctuations in abundance of Spanish mackerel in Chesapeake Bay (Figure 1) and the mid-Atlantic region from 1879 to 1990. Accordingly, our data were taken from annual commercial landings statistics for the periods 1879–1880 (Earll 1883), 1887–1967 (Lyles 1969), 1968–1976 (Trent and Anthony 1979), and 1977 (Thompson 1984). Data for 1978–1990 came from annual printouts provided by the National Marine Fisheries Service (NMFS), Office of Data Information Management, to the library of the College of William and Mary, Virginia Institute of Marine Science. No records of Chesapeake Bay landings apparently exist for 1910–1919 other than Hildebrand and Schroeder's (1928) statement that landings were 10,000–25,000 lb then. However, these values may be too low and not comparable to the scale of long-term landings reported by Lyles (1969), as indicated by the threefold difference in values these authors reported for 1920 (42,000 lb by Lyles; 13,766 lb by Hildebrand and Schroeder). To address this problem, we have presented two sets of landings estimates for 1910–1919 (Figure 1): (1) the estimates given by Hildebrand and Schroeder (1928), and (2) higher values that were approximated by ratio estimate procedures (Cochran 1977) and scaled to Lyles' (1969) records by

$$\hat{Y} = (\hat{y}/\hat{x})\hat{X};$$

- $\hat{Y}$ = estimates for annual Chesapeake Bay landings, 1910–1919, scaled to Lyles' (1969) data;
- $\hat{y}$ = Lyles' (1969) estimate that landings were 42,000 lb in 1920;
- $\hat{x}$ = Hildebrand and Schroeder's (1928) estimate that landings were 13,766 lb in 1920; and
- $\hat{X}$ = Hildebrand and Schroeder's (1928) statement that annual landings were 10,000–25,000 lb in the period 1910–1919.

The ratio procedure may best scale the estimates for 1910–1919 to Lyles' long-term data set, but both sets of estimates lead to the same interpretation of trends in abundance.

The preceding landings data and estimates were supplemented by (1) anecdotal information, largely for years before 1879, the only information on abundance then, and (2) data on nominal effort, landings, and catch per unit effort of the Virginia pound-net fishery in Chesapeake Bay for the period 1929–1990, the only period for which nominal effort is available. Data on annual pound-net landings and nominal effort in 1929–1938 were taken from "Fishery Industries of the United States," published by the U.S. Bureau of Fisheries; for 1939–1977 data were taken from "Fisheries Statistics of the United States," published by the U.S. Fish and Wildlife Service and the NMFS. These series formed the basis for annual landings data reported by Lyles (1969), Trent and Anthony (1979), and Thompson (1984). Only unpublished data were available for 1978–1990. Nominal effort in the latter period represents the number of pound-net licenses sold annually by the Virginia Marine Resources Commission (VMRC) (E. Barth, VMRC, personal communication); this is the same type of effort information as that published in earlier years. Pound-net landings for 1978–1990 were provided by the NMFS (B. O'Bannon, Fisheries Statistics Division, personal communication). We argue in Results ("The Period after 1878") that fluctuations in total Chesapeake Bay landings from 1929 to 1990 well reflect fluctuations in Virginia pound-net landings and the nominal catch per unit effort of that fishery. This accord may also hold for years prior to 1929 because (1) Virginia landings made up 97–99% of the total Chesapeake Bay landings of Spanish mackerel reported throughout the period 1880–1990 (Chittenden et al. 1993), and (2) the pound-net fishery made greater than 91% of the total landings of Spanish mackerel in Virginia in the period 1930–1990; on an annual basis it usually was much greater than 85%. Descriptions of the Chesapeake Bay pound-net fisheries can be found in Reid (1955) and Chittenden (1991).

Results

The Period prior to 1878

Spanish mackerel have long shown large fluctuations in Chesapeake Bay and the mid-Atlantic region; this observation is not new. Many early accounts specifically noted that abundance of this species fluctuated greatly in that area (Scott 1875; Earll 1883; Goode 1884, 1888; Dresslar and Fessler 1889). Earll (1883) and Goode (1884) evaluated very early reports from the colonial period and concluded that Spanish mackerel was very

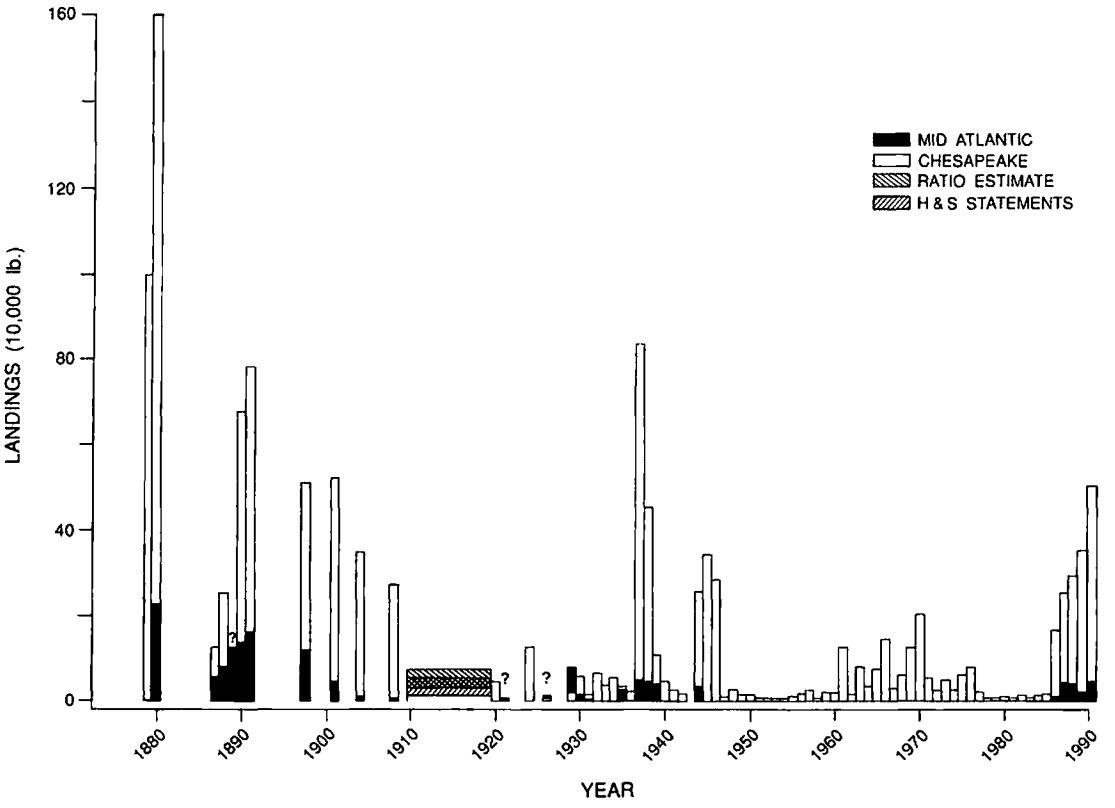

FIGURE 1.—Annual landings of Spanish mackerel in Chesapeake Bay and the mid-Atlantic region, 1879–1990. Mid-Atlantic landings are not indicated when they were less than 1,000 lb after 1939; question mark indicates years when only mid-Atlantic landings are available. In the key to symbols, H & S refers to Hildebrand and Schroeder (1928).

abundant in the later 1600s and had since declined. Little information is available from the later 1600s until the 1800s. However, in the 1800s, according to Scott (1875) and Bean (1903), Spanish mackerel were apparently not abundant in the mid-Atlantic region until about 1860. Many accounts, however, noted the great abundance of this species after 1860 (Scott 1875; Earll 1883; Goode 1884, 1888). For example, Earll (1883) reported catches of 100–200 fish/seine haul on the eastern shore of Chesapeake Bay in 1866, and Scott (1875) stated that Spanish mackerel were as abundant as bluefish *Pomatomus saltatrix* off Long Island, New York, in the 1870s, when he observed shoals more than 5 mi square.

The Period after 1878

Landings statistics exist for many years after 1878 (Figure 1). We use them to describe fluctuations in abundance before and after 1910.

The period before 1910 was a golden age, which probably began about 1860, for Spanish mackerel; they were very abundant in Chesapeake Bay and the mid-Atlantic region. Recorded Chesapeake landings were at their peak in 1879 and 1880, 1–1.6 million pounds (Figure 1). Chesapeake landings then more or less continuously declined to 31,000 lb by 1910. Recorded mid-Atlantic landings were also at their peak in 1880, 225,000 lb. They remained near 100,000 lb over much of the later 1800s and then declined after 1900. Smith reported in 1907 that Spanish mackerel had become much less abundant in Chesapeake Bay than 25 years previously. In a similar vein, Dickinson (1939) later reported that Spanish mackerel, once a most important pound-net fish, had declined till they were rare off Long Island. However, there had been great fluctuations even in the later 1800s period. For example, Chesapeake landings declined from 1.6 million pounds in 1880 to 122,000 lb in 1887 and then rebounded to 785,000 lb in 1891.

After 1910 Spanish mackerel landings in Chesapeake Bay and the mid-Atlantic region were generally low, but they again show marked fluctuations, a boom-or-bust pattern. Chesapeake landings were consistently low from 1910 to 1936, generally less than 50,000 lb (Figure 1). Since that time Chesapeake records show intervals of very low catches, in 1947–1960 and 1977–1985, interspersed with intervals of relatively high catches, in 1937–1938, 1944–1946, and 1986–1990. Our observations of pound-net fisheries indicate that the recent higher catches continued in 1991. Landings from 1961 to 1976 varied from low to intermediate in size. Mid-Atlantic landings generally paralleled those in the Chesapeake. They were low from 1910 to 1936, usually less than 10,000 lb. From 1939 to 1985 they were almost nonexistent, usually below 1,000 lb when they occurred. There were no landings in many of those years: 1945, 1947–1952, 1954–1955, 1957, 1960–1963, and 1965. Landings increased in the interval 1987–1990, and they were also high in other intervals when Chesapeake landings were high.

Virginia pound-net landings and nominal catch per unit effort showed fluctuations in 1929–1990 generally similar to those for total landings in Chesapeake Bay. Pound-net landings and catch per unit effort showed intervals of high catch in 1937–1938, 1944–1945, and 1986–1990 (Figure 2). Catches were generally low in most other years except 1961–1976, when they were intermediate in size (landings) or intermediate to high (catch per unit effort). Nominal catch per unit effort was much higher in the interval 1986–1990 than in any other years from 1929 to 1990, a pattern that may reflect, in part, much lower effort in recent years and a reduction in competition for fish among nets, as we argue in the Discussion.

Discussion

Patterns and causes of fluctuations in Spanish mackerel abundance in Chesapeake Bay and the mid-Atlantic region are not entirely clear, because (1) little biological information has been published for this area to help evaluate landings trends, and (2) the nature of landings and effort data requires certain reservations and assumptions.

There have been no studies of Spanish mackerel north of Cape Hatteras since those of Ryder (1882) and Earll (1883). No age composition data exist to describe which year-classes were strong or weak, and how long they influenced landings, in Chesapeake Bay and the mid-Atlantic region. Fish in that area presumably exhibit annual north-and-south migrations along the Atlantic coast. However, the extent of their migrations and the areas that produce these fish are not really known, so important questions remain to be answered about these fish. How far south do they migrate to overwinter? Where were they hatched? Is there natal homing? To what extent does apparent reproduction in Chesapeake Bay, at least, contribute to production there and in the mid-Atlantic region? What fisheries capture fish produced in the Chesapeake? What stocks are involved or is there really only one Atlantic Coast stock? Until questions like these are answered, it will be difficult to explain conclusively the fluctuations in Chesapeake Bay and mid-Atlantic landings.

The nature of landings data does not permit a conclusive analysis of abundance patterns, and some reservations must be made. Expressed in a simple form (Paloheimo and Dickie 1964), landings (C) depend on abundance (N_t), effort (f), and the catchability coefficient (q):

$$C = qfN_t. \quad (1)$$

The catchability coefficient depends (Marr 1951) on availability (k) and the elemental gear efficiency (r):

$$q = kr. \quad (2)$$

We have interpreted landings largely to reflect abundance with two reservations.

(1) Change in availability may affect landings, as McHugh (1977) suggested, but little is known of this. However, the Spanish mackerel is a subtropical or warm-temperate species, and adults are sensitive to temperatures below 20°C (Munro 1943; Beaumariage 1970). Chesapeake Bay, and especially the mid-Atlantic shelf region, is at the northern edge of their range. They invade it only seasonally as temperatures permit. How shelf temperature patterns have affected Spanish mackerel availability in the Chesapeake and mid-Atlantic region over the years is not known.

(2) Change in effort and the elemental gear efficiency may affect landings. Little is known of these factors, except that the number of pound nets, the major gear used to catch Spanish mackerel in Chesapeake Bay, has varied greatly over the long term. For example, there were 162 nets in 1880 (Earll 1883) and 2,262 nets (in Virginia) in 1930 (Figure 2). After 1930, numbers of Virginia nets gradually declined—to 1,323 in 1950 and only 248 in 1985. Despite the decline from 1930 to 1990, the number of nets did not vary greatly from year to year, suggesting that large year-

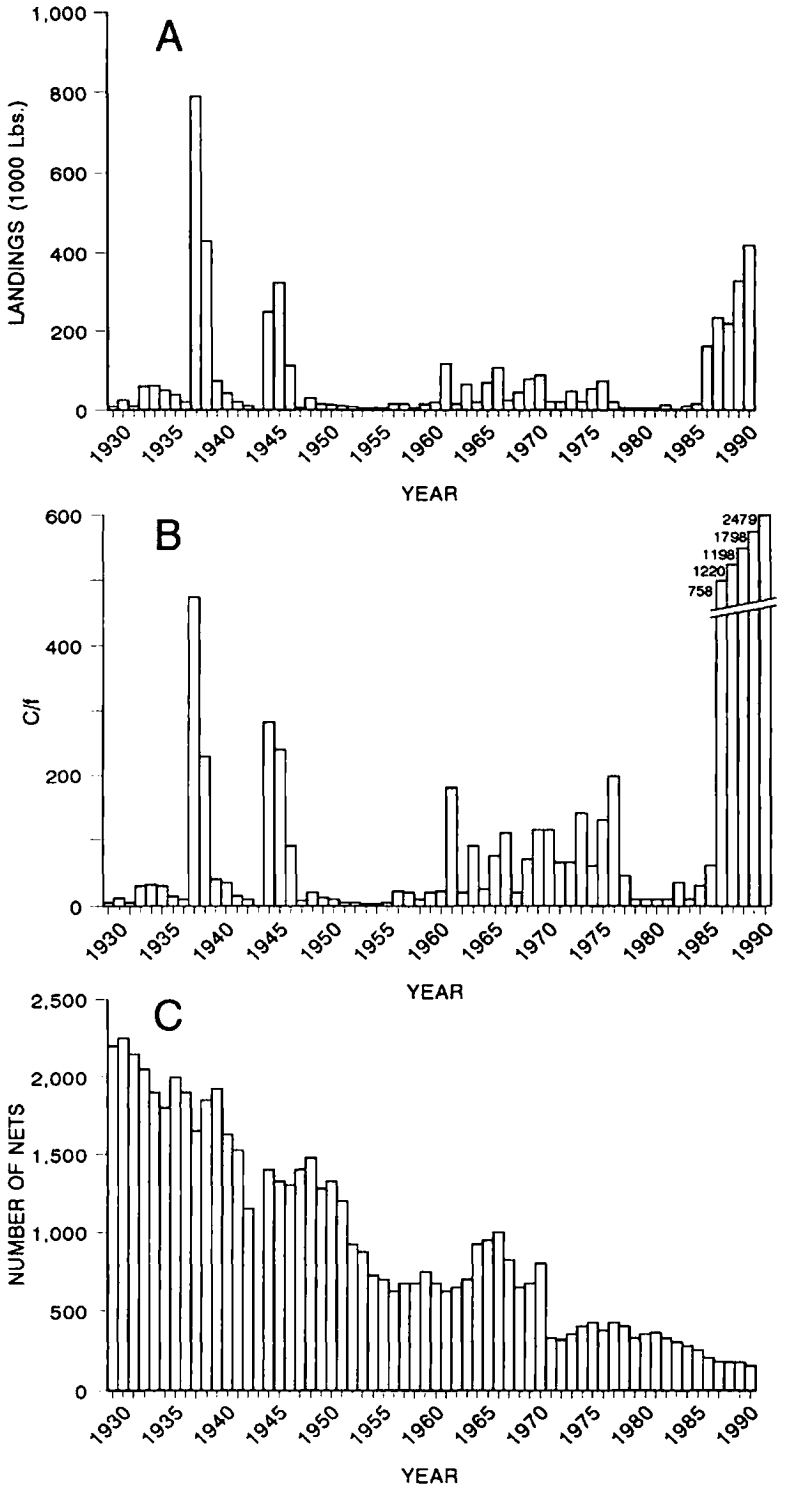

FIGURE 2.—(A) Annual landings, (B) catch per unit effort (c/f), and (C) nominal effort in the Virginia Chesapeake Bay pound-net fishery, 1929–1990. Nominal effort represents the number of nets licensed to fish.

to-year fluctuations in landings reflected more than simple changes in the number of nets. Local market conditions too, probably have had little effect on year-to-year landings, because pound nets are emptied every day and the entire foodfish catch is sold. Numbers of pound nets measure only nominal effort, not actual standardized effort (Rothschild 1977; Rothschild et al. 1981). No information exists to convert the raw numbers of nets to standardized units of effort. One problem in doing so is that landings may not show a linear relation to the number of nets, because f and r in equations (1) and (2) may be inversely related, as Schaaf (1975) implied for purse seines and schooling fishes. Pound-net positions are fixed for the season, yet Spanish mackerel are schooling, pelagic fishes that, presumably, travel great distances in a day. No data exist to evaluate distance traveled, but that distance probably has not greatly changed over the years. As a result, the decrease in gear since 1930 would have reduced fisheries competition for schools, permitting one net to make greater catches today (Rothschild 1977)—that is, to exert a greater rate of fishing mortality (F). Similar reasoning probably applies also to the early fisheries, when numbers of pound nets were low.

Despite the above problems, fluctuations in landings must reflect growth, mortality, and recruitment dynamics that, with environmental modulation, underlie biomass production (Russell 1931; Ricker 1975). As a result, fluctuations may be evaluated from two general perspectives (Cushing 1976, 1977): "growth overfishing" and "recruitment overfishing." We use these terms merely for convenience in referring to perspectives. In neither case do we mean to imply overfishing, because modeling necessary to establish overfishing has not been published.

Growth Overfishing

From the perspective of growth overfishing, classical responses of stocks to fishing modeled by yield-per-recruit theory (Ricker 1963, 1975)—the juvenescence process—suggest early landings were at levels not sustainable in Chesapeake Bay and the mid-Atlantic region. The early fishery, 1860–1880, must have encountered a virgin stock with an accumulated biomass. The developing fishery would have increased the total mortality and decreased biomass to a lower equilibrium level. A given fishing mortality imposed on a smaller stock cannot produce landings like those in a virgin stock. Landings were also negligible in southern waters when the fishery began in Chesapeake Bay and the mid-Atlantic region. However, by 1897, 64% of the U.S. landings came from the southeast Atlantic coast of the United States and the Gulf of Mexico, and by 1920 the fishery was centered in south Florida (Lyles 1969; Trent and Anthony 1979). Presumably, Chesapeake Bay and mid-Atlantic region fisheries competed with these other areas for at least some of the same fish. From the perspective of growth overfishing, therefore, there must now be a lower standing stock that seasonally invades Chesapeake Bay and the mid-Atlantic region.

Recruitment Overfishing

Fluctuations due to recruitment are superimposed on the juvenescence process associated with the growth overfishing perspective.

Caddy and Gulland (1983) suggested that fishery landings follow four basic patterns: steady, cyclical, irregular, and spasmodic. Spanish mackerel abundance in Chesapeake Bay and the mid-Atlantic region seems to exhibit characteristics of the irregular and spasmodic categories; it has a boom-or-bust nature typical of a population on the fringe of its geographic range. Spanish mackerel abundance may also have a natural long-term or spasmodic component given the large pre-1910 landings and early anecdotal accounts of fluctuations since the 1600s. Spanish mackerel have a short life span, 6–9 years at most (Klima 1959; Fable et al. 1987), and ages 1–3 predominate (Powell 1975). Landings of short-lived fish generally fluctuate greatly from year to year as year-class strength varies. Repeated lows in Chesapeake landings in 1910–1936, 1947–1960, and 1977–1985 indicate repeated, prolonged, series of weak year-classes in Chesapeake Bay and the mid-Atlantic region, or poor escapement from fisheries in more southern waters. Short periods of high landings in 1937–1938 and 1944–1946 probably reflect one or two strong year-classes.

The nature and duration of the recent period of high landings in 1986–1991 are not yet fully known, and apparently nothing has been published about this period. High landings in Chesapeake Bay commenced in the spring and summer of 1986. That was the first fishing season in the Bay to follow management actions—increase in gill-net mesh sizes—that had been taken in fall 1985 (R. Williams, Florida Marine Fisheries Commission, personal communication) in an attempt to increase escapement (i.e., reduce landings and fishing mortality) from Florida waters, where the greatest fishery for, and dominant landings of,

Spanish mackerel occur. However, Florida landings remained high in the winter of 1985–1986 (3.9 million pounds; M. Murphy, Florida Marine Research Institute, personal communication), a phenomenon that may reflect some lack of immediate success in increasing escapement via mandated mesh-size regulation, or a natural increase in recruitment. To confound the picture further, at least some fishers voluntarily increased their mesh size starting in 1983 (Williams, personal communication). Additional management actions were taken beginning in fall 1986—landings quotas and bag limits were implemented—in an attempt to reduce Florida landings, and thereby fishing mortality, by 45%. That attempt apparently succeeded, because Florida east coast landings dropped to 2.1 million pounds in the winter of 1986–1987 (Williams and Murphy, personal communications). Florida east coast landings have remained at 2.1–2.9 million pounds since then as the landings quota varied from 1.9 to 3.0 million pounds. We suggest, therefore, that the recent period of high landings in Chesapeake Bay and the mid-Atlantic region reflects a combination of (1) increased survivorship of adults due to recent management that decreased landings and increased escapement from Florida waters, thus increasing standing stocks in the Chesapeake Bay and mid-Atlantic region, and (2) possible production of at least one strong year-class at the beginning, if not throughout, the period, a phenomenon that may have been enhanced by increased spawning stocks reflecting recent management or earlier voluntary actions. This explanation presumes, though it remains to be established (see early Discussion), that Spanish mackerel in Chesapeake Bay and the mid-Atlantic region migrate north in summer from overwintering areas in Florida waters, and that fisheries in the two regions compete for the same fish. If true, it may be that escapement from the southern fisheries has largely regulated the base level of abundance in Chesapeake Bay and the mid-Atlantic region for the last 80 years or more. More complete explanations for the recent period of high landings in the Chesapeake and mid-Atlantic region from 1986 to 1991, and the long-term role of the southern fisheries on landings there, await the collection of pertinent basic biological information.

Finally, seemingly long-term fluctuations of Spanish mackerel in Chesapeake Bay and the mid-Atlantic region may be part of a broader multispecies picture. Long-term fluctuations there, and in New England, have been qualitatively described (Goode, 1884; Roelofs 1951; Bigelow and Schroeder 1953; Joseph 1972) for many important species, including bluefish, weakfish *Cynoscion regalis,* striped bass *Morone saxatilis,* and Atlantic croaker *Micropogonias undulatus,* and their fluctuations have been documented in 20th-century landings (Koo 1970; Joseph 1972; van Winkle et al. 1977; Wilk 1977; Mercer 1985, 1987). Causes of long-term fluctuation in the abundances of these species are still not fully explained, though they also apparently reflect recruitment in large part.

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