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TR EL-82-4

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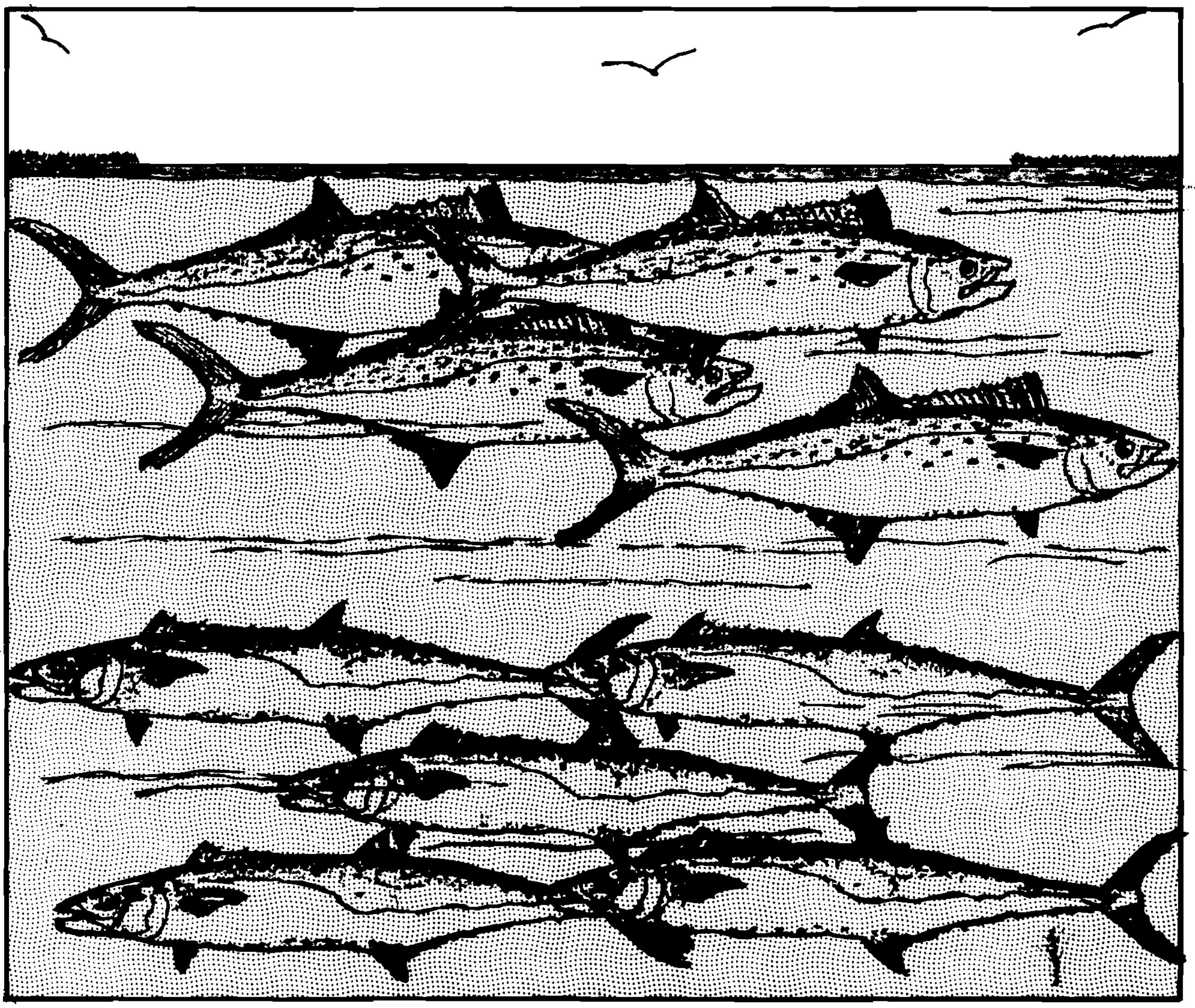
KING AND SPANISH MACKEREL



Fish and Wildlife Service
U.S. Department of the Interior

Coastal Ecology Group
Waterways Experiment Station
U.S. Army Corps of Engineers

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Species Profiles: Life History and Environmental Requirements of Coastal Fishes and Invertebrates (South Florida)

KING MACKEREL AND SPANISH MACKEREL

by

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PREFACE

This species profile is one of a series on coastal aquatic organisms, principally fish, of sport, commercial, or ecological importance. The profiles are designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the species and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. Each profile has sections on taxonomy, life history, ecological role, environmental requirements, and economic importance, if applicable. A three-ring binder is used for this series so that new profiles can be added as they are prepared. This project is jointly planned and financed by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

Suggestions or questions regarding this report should be directed to one of the following addresses.

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CONVERSION TABLE

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
kilometers (km)	0.6214	miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees	1.8(°C) + 32	Fahrenheit degrees

U.S. Customary to Metric

Multiply	By	To Obtain
inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
acres	0.4047	hectares
square miles (mi^2)	2.590	square kilometers
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees	0.5556(°F - 32)	Celsius degrees

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TABLES

ACKNOWLEDGMENTS

We are grateful for reviews by J. Connor Davis, Florida Marine Fisheries Commission; Roy Williams, Florida Department of Natural Resources; Dr. Bill Seaman, University of Florida; and staff of the National Marine Fisheries Service Laboratory in Panama City, FL.

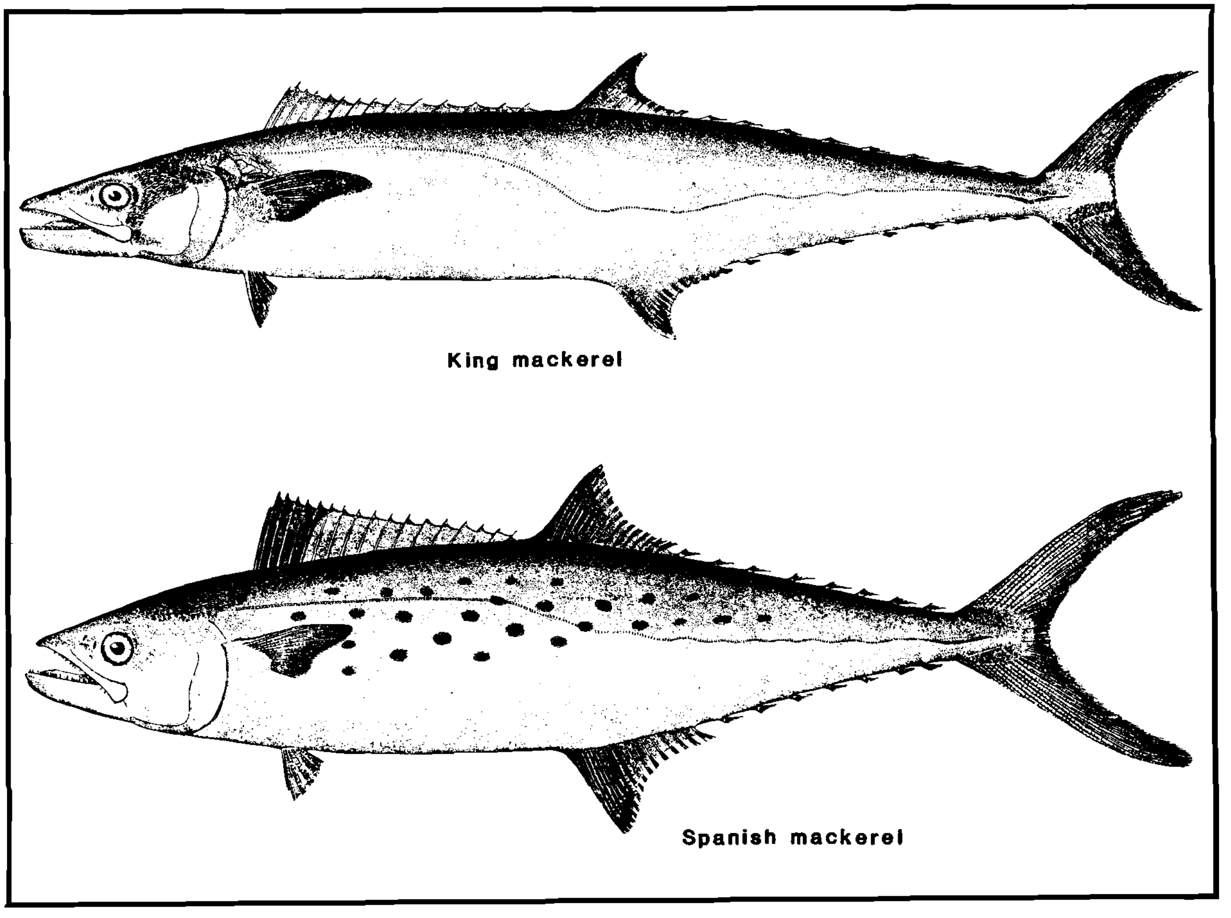

Figure 1. King and Spanish mackerel (from Goode 1884).

KING MACKEREL AND SPANISH MACKEREL

NOMENCLATURE/TAXONOMY/RANGE

Scientific name..*Scomberomorus cavalla* (Cuvier)
Preferred common name... king mackerel (Figure 1)
Other common names.......... kingfish, kings, serucho
Scientific name......... *Scomberomorus maculatus* (Mitchill)
Preferred common name......... Spanish mackerel (Figure 1)
Class.................... Osteichthyes
Order..................... Perciformes
Family.................... Scombridae

Geographic range: King mackerel inhabit Atlantic coastal waters from the Gulf of Maine to Rio de Janeiro, Brazil, including the Gulf of Mexico and the Caribbean Sea (Briggs 1958; Beaumariage 1973). They are concentrated off the coast of the Carolinas in the spring, summer, and fall; in the northern Gulf of Mexico from Texas to northwest Florida in summer; and off southern Florida and Louisiana in winter. The distributions and concentrations in south Florida are shown in Figure 2.

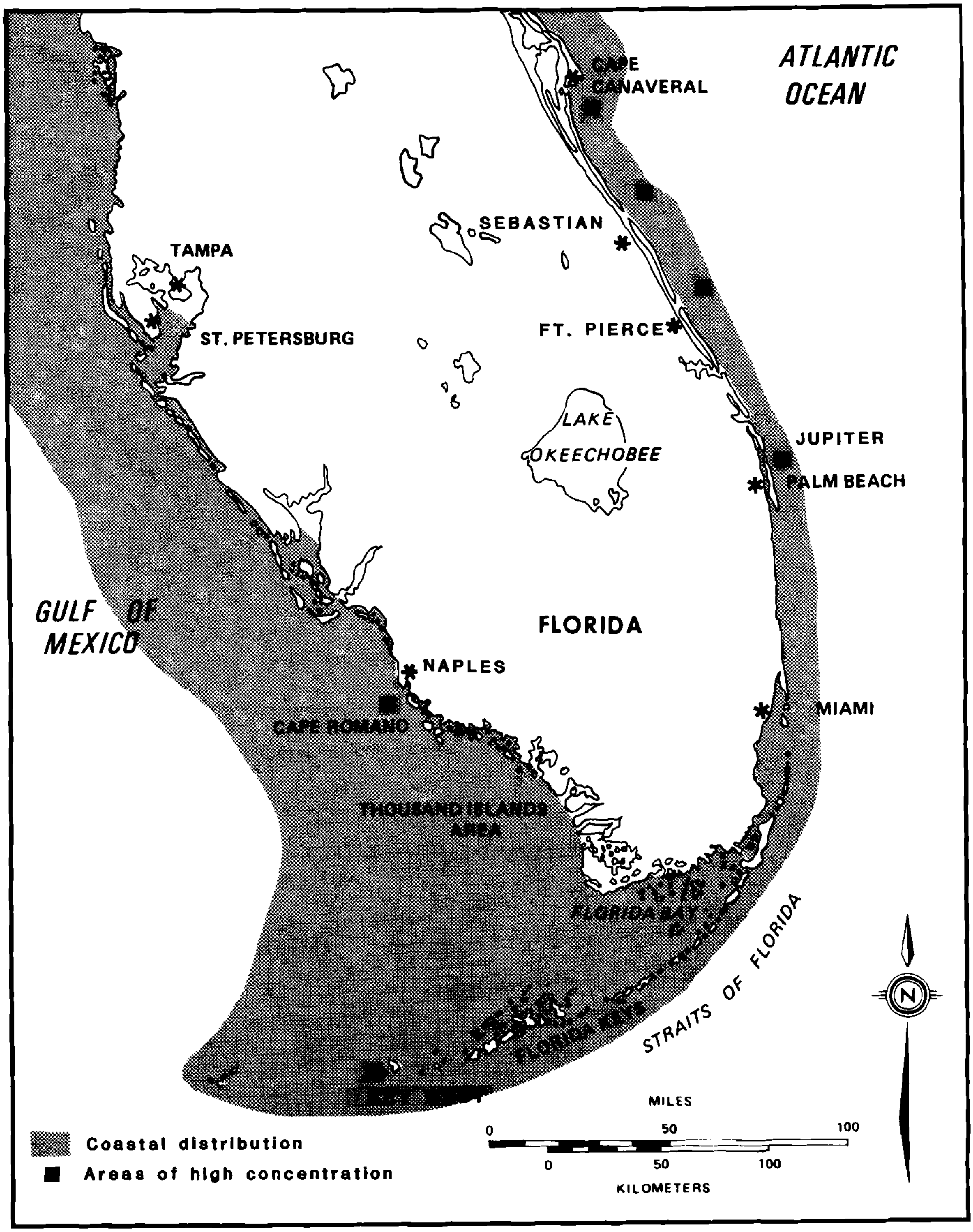

Figure 2. Distribution of mackerel along the coast of South Florida.

Spanish mackerel inhabit coastal waters of the western Atlantic Ocean from the Gulf of Maine to the Yucatan Peninsula (Collette et al. 1978). They are common as far north as Chesapeake Bay in summer (Bigelow and Schroeder 1953). Large schools are common in south Florida waters in late fall and winter (Figure 2).

MORPHOLOGY/IDENTIFICATION AIDS

King Mackerel

The elongated, fusiform, compressed body of king mackerel is 4.25 to 5.00 times as long as the head, and 5.50 to 6.25 times as long as it is deep (Berrien and Finan 1977a). They have two dorsal fins, the second followed by eight or nine finlets. The lateral line, which abruptly curves downward below the second dorsal fin, distinguishes the king mackerel from the Spanish mackerel and the cero mackerel (S. regalis). The caudal peduncle has a large fleshy keel. The body is entirely scaled with rudimentary scales, except for most of the pectoral fin. The mouth is large and oblique with the maxillary reaching posteriorly to slightly beyond the eye orbit. Each side of the jaw has about 30 strongly compressed triangular teeth. This species gets considerably larger than the Spanish mackerel.

The dorsal surface of the king mackerel is black with iridescent hues of green and blue. The lateral and ventral sides are silvery white. The lateral yellow spotting on the young is almost always absent on mature specimens (Berrien and Finan 1977a).

Spanish Mackerel

Spanish mackerel have compressed, elongated bodies about 4.5 to 5.0 times as long as they are deep. The first dorsal fin is triangular; the second fin is concave and originates a short distance in front of the anal fin, which is similar in form and size. These are followed by eight or nine dorsal and anal finlets. The lateral line is wavy, and the caudal peduncle is keeled. The caudal fin is lunate, and the pectorals are not covered with scales. See Table 1 for other key diagnostic characters.

Spanish mackerel are dark blue or blue-green above, pale and silvery below. Their sides are marked with many small, oblong, dull orange or yellowish spots that are prominent both above and below the lateral line. The membrane is black on the anterior one-third of the first dorsal fin and the posterior is greenish-white. The second dorsal and the pectoral fins are pale yellow with dusky edges. The anal and ventral fins are white (Berrien and Finan 1977b).

REASON FOR INCLUSION IN SERIES

King and Spanish mackerel support commercial and sport fisheries of major importance. Both species inhabit coastal waters but Spanish mackerel usually come closer to shore, e.g., along the beaches and in the outer waters of estuaries. In the summer, large solitary king mackerel are sometimes captured off piers and near deepwater inlets. Juvenile king mackerel sometimes mix with schools of Spanish mackerel. Both species feed principally on estuary-dependent species such as menhaden (Brevoortia spp.) and anchovies (Anchoa spp.). Excessive alterations of estuaries could reduce the production of coastal forage fish on which king and Spanish mackerel feed.

LIFE HISTORY

Seasonal Distribution and Populations

King mackerel. Extensive tagging studies indicate that there are at

Table 1. Meristic characteristics of mackerels in Florida (Mago-Leccia 1958).

Characteristic		King mackerel	Spanish mackerel	Cero mackerel
Total number of vertebrae		42-43	52-53	47-49
First closed haemal arch at vertebra number		10	13-15	12
First haemal spine at vertebra number		18-19	22-24	20-21
Dorsal spines		15-16	16-18	16-18
Dorsal rays		16-17	15-18	16
Dorsal finlets		8-9	8-9	8-9
Anal spines		2	2	2
Anal rays		14-17	15-17	14-15
Anal finlets		8-10	8-9	8
Gill rakers	Upper limb	1	2-3	3-4
	Angle	1	1	1
	Lower limb	6-7	10-12	11-13
	Total	8-9	13-15	15-18

least two migratory groups of king mackerel. Those tagged in the winter south of Cape Canaveral, Florida, usually moved southward through the Florida Keys, entered the Gulf of Mexico in late winter and spring, and then continued northward along the west Florida Continental Shelf. Some were recaptured as far west as Texas and a few as far south as Veracruz and Yucatan, Mexico. These western migrants, some tagged off the coasts of Texas and northwest Florida in the summer, returned to south Florida in the winter (Williams and Taylor 1978; Williams and Sutherland 1979; Sutherland and Fable 1980).

A second group of king mackerel, tagged in the spring off southeast Florida, moved northward in the summer along the Atlantic coast to the Carolinas. One was recaptured as far north as Chincoteague, Virginia. King mackerel tagged in South Carolina in the spring generally moved south in May through August and were recaptured in Florida that summer. In the fall they migrated to the northern limit of their distribution, and many were recaptured in North Carolina (Williams and Sutherland 1979; Williams and Godcharles 1983).

Preliminary electrophoretic analyses of 48 enzymes extracted from king mackerel tissues (heart, liver, eye, and muscle) give evidence that there are two populations of king mackerel. Variation of two alleles for the peptidase with glycylleucine-2 locus gave the greatest differences between South Carolina and Texas specimens; however, other loci were minimally polymorphic and of limited value for separating populations (May, unpubl. MS.). Homing tendencies are additional evidence of two populations. After a year or more of freedom, king mackerel usually are recaptured at or near their release site at about the same time of year they were first tagged (Williams and Godcharles 1983).

Spanish mackerel. Spanish mackerel are also migratory, generally moving northward each spring, spending summer in the northern part of their range, and migrating south in fall. In spring, summer, and fall, they are most abundant in the northern Gulf of Mexico and along the east coast of the United States up to Virginia (Wollam 1970; Dwinell and Futch 1973; Powell 1975). Their major wintering grounds are off south Florida, but some overwinter off the east coast of Mexico (Mendoza 1968; Sutherland and Fable 1980).

Spanish mackerel from different geographic areas may mix in south Florida during the winter. In summer, the south Atlantic and eastern Gulf of Mexico populations spawn in isolation in the northern parts of their ranges (Wollam 1970). Electrophoretic patterns of two hemoglobin phenotypes demonstrated that northwestern gulf fish are distinct from fish captured along the U.S. east coast (Skow and Chittenden 1981).

Spawning

King mackerel. This species spawns in the coastal waters of the northern Gulf of Mexico, and off the south Atlantic coast (Dwinell and Futch 1973; McEachran et al. 1980; Burns 1981; Powles, unpubl. MS.). Because of a protracted spawning season, larvae have been collected by sampling gear from May through October. Catches were highest in September. The paucity of larvae in the eastern Gulf of Mexico south of Cape San Blas, off the Yucatan Channel and southeast Florida, indicates minimal spawning in these waters (Wollam 1970; Houde et al. 1979; Burns 1981).

King mackerel larvae were discovered off northwest Florida and Texas between the Middle and Outer (35-183 m) Continental Shelf (Dwinell and Futch 1973; McEachran et al. 1980). Larvae captured near Palm Beach, Florida, were closer to shore than those captured farther north off Cape Canaveral, Florida, Savannah, Georgia, and Cape Fear, North Carolina. North of Cape Canaveral, larvae were found near or off the shelf along the 200 m depth contour and near the Gulf Stream (Wollam 1970; Burns 1981; Powles, unpubl. MS.).

Further evidence of protracted spawning for king mackerel is the holding of vitellogenic eggs (eggs with forming yolk) from May through October (Beaumariage 1973). Multiple spawning is suggested by bimodal distributions of mean oocyte diameter of yolkbearing vitellogenic (stage 4) eggs. The first mode was in late May through early July and the second was in late July and early August. The appearance of spent males from September through December coincided with a commensurate absence of vitellogenic eggs beginning in August, suggesting a final climactic spawn.

Spanish mackerel. Spanish mackerel also spawn over a protracted season (Powell 1975). Ripe females have been collected from April through September in Florida waters (Klima 1959; Powell 1975; Finucane and Collins, unpubl. MS.). Larvae have been collected from spring until late summer in the eastern Gulf of Mexico (Dwinell and Futch 1973; Houde et al. 1979), and from May through mid-September from Cape Fear, North Carolina, to Cape Canaveral, Florida (Powles, unpubl. MS.).

The onset of spawning progresses from south to north. Spawning begins in April in the Carolinas, in mid-June in Chesapeake Bay, and from late August to late September off Sandy Hook, New Jersey, and Long Island, New York (Earll 1883). Beaumariage (1970) reported that few mackerel spawned at water temperatures below 26 °C. In Texas, mackerel spawned when water temperatures exceeded 25 °C and at salinities between 30 and 36 ppt (Hoese 1965). Spanish mackerel apparently spawn at night (Earll 1883; Smith 1907).

Collections of small larvae indicate that Spanish mackerel spawn over the Inner Continental Shelf in waters 12-34 m deep (McEachran et al. 1980). In the northeastern Gulf of Mexico off northwest Florida, most larvae were collected in water shallower than 13 m, although some were in water as deep as 91.5 m (Dwinell and Futch 1973). All larvae collected along the west coast of Florida by Houde et al. (1979) were taken inside the 50 m depth contour; most were within the 20 m contour.

Maturity and Fecundity

In south Florida, most male king mackerel probably spawn in their fourth year of life (Age III) when about 718 mm fork length (FL); most females spawn at Age IV when about 857 mm FL (Beaumariage 1973). Finucane et al. (unpubl. MS.) reported mature females about 600 mm FL distributed from Texas to the Carolinas, with egg count estimates ranging from 69,000 (446 mm FL, Age I, 0.68 kg) to 12,207,000 (1,489 mm FL, Age XIII, 25.6 kg). The best indicator of fecundity is the total weight of the fish (Finucane et al. unpubl. MS). Fecundity-weight equations are listed in Table 2.

Spanish mackerel in south Florida become sexually mature in their second and third year of life (Ages I and II) when about 250 to 350 mm FL. In southeast Florida, the length of most mature males and females ranges between 325 and 349 mm FL; all fish larger than 375 mm FL were mature. Klima (1959) found mature females as small as 250 mm FL and mature males between 280 and 340 mm FL. He estimated that most of these fish were 1 or 2 years old. On the other hand, Powell (1975) reported that Klima overestimated all ages by one year because he misread the first annulus; therefore, fish less than 1 year old may have been mature. Many Age I fish had ripe oocytes, but observations in the April-September spawning season suggested that the eggs of Age I fish were not advanced enough to be spawned that season (Powell 1975). Spanish mackerel Age III and older constitute the bulk of the spawning stock.

The fecundity of Spanish mackerel (Table 2) in southeast Florida increases with increasing length and weight (Finucane and Collins, unpubl. MS.). Egg number estimates ranged from 194,000 to 1,491,000 for females 354 to 664 mm FL. Earll (1883) reported 1.5 million eggs from a 6-lb (2.7-kg) female collected from Chesapeake Bay.

Eggs, Larvae, and Juveniles

Examination of king and Spanish mackerel larvae 2.0 to 2.9 mm standard length (SL) offered diagnostic aids for separating the larvae based on pigment (melanophore) differences in the jaw, head, and nape areas (Richardson and McEachran 1981). The myomere counts, mouth, teeth, preopercular spines, fin elements, and pig-

Table 2. Regressions of fecundity (F) on total weight (TW) and fork length (FL) for king mackerel (Finucane et al., unpubl. MS.) and Spanish mackerel; r is the correlation coefficient (Finucane and Collins, unpubl. MS.).

Equation	$100r^2$	Number of fish
KING MACKEREL (SOUTHEAST U.S.)		
$F = 1.854 \times 10 \ (TW)^{1.361}$	85.6	65
$F = 4.391 \times 10^{-6} \ (FL)^{3.974}$	82.0	64
SPANISH MACKEREL (SOUTHEAST FLORIDA)		
$F = 9.076 \times 10^{2} \ (TW)^{0.919}$	94.1	11
$F = 1.027 \times 10^{-2} \ (FL)^{2.863}$	92.5	11

mentation of larger king mackerel larvae (3.3 to 17.0 mm SL) were described by Wollam (1970). King mackerel eggs have not yet been described.

King mackerel. Because most king mackerel larvae are collected near the surface, the refinement of quantitative sampling techniques to collect larvae 3 mm SL (about 3 days old) would aid in the delineation of spawning grounds (McEachran et al. 1980). In the gulf, mackerel larvae have been taken at surface salinities and temperatures from 27 to 36 ppt and 26 to 31 °C, and in the south Atlantic between 30 and 37 ppt and 22 to 28 °C (Dwinell and Futch 1973; Powles, unpubl. MS.).

Spanish mackerel. The eggs and newly hatched larvae of Spanish mackerel have been described by Ryder (1882). The eggs are pelagic, smooth, and transparent, with a single oil droplet. Eggs are round and about 1 mm (0.9 - 1.3 mm) in diameter; the perivitelline space (the clear space inside the egg between the chorion and the oil globule) is about 0.1 mm across, and the oil globule is 0.25 mm in diameter. Hatching takes place after about 25 h at a temperature of 26 °C (Smith 1907). Larvae longer than 3 mm SL were described by Wollam (1970). Most larvae have been collected in coastal waters of the Gulf of Mexico (Wollam 1970; McEachran et el. 1980) and the east coast of the United States (Powles, unpubl. MS.).

Juvenile Spanish mackerel have been collected from low salinity estuaries and high salinity beach waters. A Spanish mackerel 58 mm long was collected from Sabot Pond, Louisiana, at a salinity of 0.2 ppt (Kelley 1965). Juveniles (133 to 158 mm SL) were collected along high salinity (33.8 ppt) beaches and low salinity (12.8 to 19.7 ppt) bayous in Tampa Bay, Florida (Springer and Woodburn 1960). Apparently, some juvenile Spanish mackerel use estuaries as nursery grounds, but most stay nearshore in open beach waters.

Longevity and Growth

King mackerel. Although Beaumariage (1973) estimated age, growth, and mortality of king mackerel, recent estimates (Johnson et al. 1983) are probably more accurate because the data base included more of the larger and older king mackerel collected from North Carolina to Texas. Most of Beaumariage's (1973) specimens came from winter collections in South Florida. The mean back-calculated fork lengths are listed in Table 3. The von Bertalanffy growth equation is as follows:

$$l_t = L_\infty(1 - \exp(-K(t - t_0)))$$

where l_t is length at age t, L_∞ is asymptotic length, K is the growth coefficient, and t_0 is the age when the theoretical length is zero (Table 4).

Both Beaumariage (1973) and Johnson et al. (1983) aged king mackerel by using otoliths. Although

Table 3. Mean back-calculated fork lengths (mm) of king mackerel (Beaumariage 1973; Johnson et al. 1983) and Spanish mackerel (Kilma 1959; Powell 1975). Beaumariage's lengths were converted to fork lengths using his relation FL = 1.096(SL) - 17.143. Powell's lengths were converted by using his relation FL = 1.073(SL) + 2.427. Lengths for female king mackerel reported by Johnson et al. (1983) excluded Louisiana specimens.

Age	Males		Females	
	Beaumariage (1973)	Johnson et al. (1983)	Beaumariage (1973)	Johnson et al. (1983)
King mackerel				
I	457	414	491	434
II	643	613	703	652
III	705	689	793	747
IV	752	734	857	807
V	795	777	928	854
VI	822	809	986	899
VII	839	851	1033	939
VIII		897		998
IX		943		1021
X				1034

Age	Males		Females	
	Kilma (1959)	Powell (1975)	Kilma (1959)	Powell (1975)
Spanish mackerel				
I	178	337	186	373
II	309	421	348	481
III	404	460	464	542
IV	492	490	582	580
V	512	511	602	622

there was good correlation between the growth of otoliths and length of fish, neither study clearly demonstrated that opaque otolith growth rings were valid indicators of age (Powers and Eldridge, unpubl. MS. a).

Females live longer than males and usually grow faster after Age II (Table 3). The oldest females collected were 14 years of age or older: a 1.4 m FL fish from Louisiana (Johnson et al. 1983) and a 90 lb (40.8 kg) fish from Key West (Beaumariage, unpubl. data). The oldest male (979 mm SL) was 12 years old (Johnson et al. 1983).

King mackerel growth is highly variable. For example, females 850 to 899 mm FL could be 1 to 8 years old; males about the same size could be 3 to 8 years old. Johnson et al. (1983) suggested that compensatory growth occurs in "slow growing" fish during their second year when their growth increment surpasses that of "fast growers." Nevertheless, "slow growing" mackerel remain smaller than "fast growers" throughout their lives.

Equations relating weight to length of king and Spanish mackerel are listed in Table 5. The total annual mortality estimate by Johnson et al. (1983) was 0.37; Beaumariage (1973) reported 0.54.

Spanish mackerel. The growth of larval and juvenile Spanish mackerel has not been measured in the laboratory. The protracted spawning season makes it difficult to estimate growth from length distributions. Hildebrand and Cable (1938) collected larvae 4 mm long as early as June off North Carolina; some juveniles were 80 mm long by October.

By determining age and growth from otoliths in south Florida, Powell (1975) and Klima (1959) reported that females grow faster than males (Table 3). The average length of Age II fish reported by Klima (1959), however, is about equal to the average length of Age I fish reported by Powell (1975). One author probably misread the first annulus. Growth parameters for each sex are in Table 4.

Spanish mackerel of the same age are smaller in the southwestern Gulf of Mexico than in south Florida (Powell 1975). Mendoza (1968) and Doi and Mendizabal (1979) also used otoliths to determine age, but the data for both sexes were combined. Mendoza (1968) reported average fork lengths (FL) of 333, 408, 471, 543, and 593 mm for Ages II-VI, respectively, and an estimated asymptotic length of 860 mm FL. Estimated average total lengths (TL) reported by Doi and Mendizabal (1979) for Ages I-VI were 262, 426, 475, 512, 575, and 638 mm, respectively.

The life span of Spanish mackerel is about 5 to 8 years (Klima 1959; Powell 1975; Doi and Mendizabal 1979). The total annual mortality rate based on Powell's (1975) data was estimated at 0.62 (GM&SAFMC 1982), which approximates the rate calculated by Doi and Mendizabal (1979) for Spanish mackerel taken off the Mexican coast (0.59). Weight-length relations for Spanish mackerel are given in Table 5.

COMMERCIAL AND SPORT FISHERIES

King Mackerel

Florida has historically produced about 90% of the king mackerel commercial landings in the United States (Table 6). The species is also highly regarded as a sport fish. Sport fishermen in the south Atlantic region are estimated to have caught 598,000 king mackerel in 1979 and 1,370,000 in 1980. In the gulf, about 600,000 were taken in 1979 and 1 million in 1980 (Trent et al. 1983). At times, keen competition for this resource has led to serious user conflicts.

Table 4. Von Bertalanffy growth parameters for king mackerel (Beaumariage 1973; Johnson et al. 1983) and Spanish mackerel (Powell 1975). Johnson et al. did not include large, mostly female fish captured off Louisiana in data used to estimate growth parameters. Beaumariage's and Powell's estimates of asymptotic length (L_∞) were converted to fork lengths by using their length-length regressions (Table 3). K is the growth coefficient.

Species and sex	Growth parameters K	L_∞(mm FL)	t_0(years)	Source
King mackerel				
Males	0.35	903	-2.50	Beaumariage 1973
	0.28	965	-1.17	Johnson et al. 1983
Females	0.21	1,243	-2.40	Beaumariage 1973
	0.29	1,067	-0.97	Johnson et al. 1983
Spanish mackerel				
Males	0.48	555	-1.12	Powell 1975
Females	0.45	694	-0.78	Powell 1975

Table 5. Length-weight relations for king mackerel and Spanish mackerel. Weights (W) are in grams and lengths (L) in millimeters.

Species and sex	Length measure*	Number of fish	$W = aL^b$ a	b	Source
King mackerel					
Males	SL	237	1.330×10^{-5}	2.9372	Beaumariage 1973
	FL	701	0.8064×10^{-5}	2.9928	Johnson et al. 1983
Females	SL	292	3.907×10^{-6}	3.1256	Beaumariage 1973
	FL	2,023	0.8801×10^{-5}	2.9827	Johnson et al. 1983
Spanish mackerel					
Males	SL	135	1.1519×10^{-5}	2.9822	Powell 1975
Females	SL	217	4.7491×10^{-6}	3.1373	Powell 1975

*SL = Standard length
FL = Fork length.

Major commercial catches along the Florida east coast are centered between Cape Canaveral and Palm Beach, and on the west coast from Key West to Naples (Beaumariage 1973). Although king mackerel support a year-round fishery, most are caught in winter and early spring. The percentages of the total catch taken from 1950 to 1974 along the east coast of Florida were 67% by trolling, 29% by runaround gill nets, and 4% by handlines. The percentages for the west coast were 56% for runaround gill nets, 34% for trolling, 6% for handlines, and 4% for other methods (Trent et al. 1983). Purse seining has recently been permitted in Federal waters (GM&SAFMC 1982).

Major changes in the locations and the intensity of fishing in Florida have taken place since about 1960. The east coast center of production has gradually shifted northward from Dade County toward Volusia County and a spring fishery of major importance has developed off Palm Beach County near Jupiter and Juno (Williams and Godcharles 1983). As a result of higher dockside prices, fishing efforts increased sharply: from 1969 to 1977 there was a three-fold increase in hook-and-line vessels, 100 to 300, and gill net vessels, 12 to 33 (GM&SAFMC 1982). By 1983, the number of gill net vessels had risen to about 80, and the larger net boat fleet had moved onto fishing grounds that had formerly been used principally by trollers and handliners. In addition, the net fleet has increased its efficiency through the use of spotter airplanes, monofilament net construction, larger and deeper nets mechanically retrieved by power rollers, and electronic equipment.

Spanish mackerel. This species is of major commercial importance in south Florida (Klima 1959; Powell 1975). The main fishing areas are the Florida Keys and the Atlantic coast between Palm Beach and Cape Canaveral. Small numbers are caught as an incidental or supplemental commercial species off the coasts of Alabama, Mississippi, Louisiana, North Carolina, and, to a smaller extent, Georgia and South Carolina.

Spanish mackerel are primarily captured with gill nets deployed from small boats 20 to 22 ft long, and with power rollers used on large boats 30 to 60 ft long. Since 1976, commercial production on the gulf coast has fluctuated between 1.5 and 3.5 million lb, and production on the Atlantic coast has fluctuated between 3.4 and 11 million lb (Table 6). The causes of fluctuation in catch cannot be identified because there are no catch-per-unit-of-effort data.

Spanish mackerel also are an important species for the private boat and charter boat sport fishery along the gulf and south Atlantic coasts. Most anglers fish from private boats, although good catches are made from charter boats, fishing piers, and beach fishing (Deuel 1973).

The limited sport statistics suggest that 1979 commercial landings on the Atlantic coast were double the sport catch. On the gulf coast, however, the sport catch was probably 50% higher than the commercial catch (GM&SAFMC 1982).

Fisheries Management Plan. The Fishery Management Plan (FMP) for coastal pelagic fish species, including mackerel, was implemented in March 1983 by the Gulf of Mexico and South Atlantic Fishery Management Councils (GM&SAFMC). Quotas based on theoretical yields partitioned according to historical landings were established for the commercial hook-and-line (3,877,200 lb), net (5,122,800 lb), and sport (28,000,000 lb) fisheries, and were in effect from 1 July 1982 to 30 June 1983. In May 1983, the commercial hook-and-line fishery was officially closed when that quota was attained. This early closure was

Table 6. Florida commercial landings (thousands of pounds) of king and Spanish mackerel in the Gulf of Mexico and along the Atlantic coast, 1960-83 (NMFS Annual Landings).

	Gulf of Mexico		Atlantic	
Year	King mackerel	Spanish mackerel	King mackerel	Spanish mackerel
1960	1,785	5,435	1,807	2,282
1961	1,683	3,988	2,076	3,158
1962	2,021	6,869	2,076	2,578
1963	2,817	5,405	2,173	2,123
1964	1,314	3,880	2,020	2,002
1965	1,898	4,883	2,549	2,901
1966	2,633	7,004	1,782	2,181
1967	3,084	5,867	2,988	1,802
1968	3,604	7,066	2,586	4,406
1969	3,242	8,175	2,943	2,359
1970	2,372	8,100	4,338	3,574
1971	2,738	7,383	2,907	2,582
1972	1,378	6,532	3,489	3,369
1973	2,217	6,194	3,712	3,203
1974	6,133	8,267	4,267	2,346
1975	2,622	5,621	3,697	5,145
1976	2,801	7,783	4,821	9,589
1977	4,950	2,393	3,236	10,987
1978	1,745	1,478	3,402	3,424
1979	1,691	1,946	3,346	4,886
1980	3,002	1,770	3,073	9,811
1981	3,073	3,550	4,858	4,174
1982	1,966	3,287	4,383	3,759
1983	1,250	3,287	3,066	5,945

attributed to increased catches in North Carolina (0.7 million lb) and Louisiana (1.2 million lb). These new developments in conjunction with decreasing catches in south Florida are currently under review by the GM&SAFMC. Recent studies suggest that increased catches are related to strong year classes, that more than one migratory group exists, and that a maximum sustainable yield of 37.7 million lb may have been overestimated (Powers and Eldridge, unpubl. MS. a, b; Williams and Godcharles 1983).

A maximum sustainable yield of 27 million lb for Spanish mackerel was established by the fisheries management plan (GM&SAFMC 1982). Sport and commercial catch statistics from the National Marine Fisheries Service reveal that only about half of the maximum sustainable yield was landed in 1979.

ECOLOGICAL ROLE

Food Habits

King and Spanish mackerel juveniles and adults are primarily pelagic carnivores. Analysis of the stomach contents of 84 juvenile king mackerel (103-309 mm FL) from Cape Canaveral, 130 Spanish mackerel (117-432 mm FL) from Cape Canaveral, and 214 Spanish mackerel from Galveston Bay revealed that juveniles of both species were principally piscivorous, but king mackerel showed a greater preference for invertebrates. Anchovies (Anchoa spp.), menhaden (Brevoortia spp.), and Atlantic thread herring (Opisthonema oglinum) were the dominant forage of the mackerels. Much less common were mugilids, sciaenids, carangids, and eleotrids. Squid was the major invertebrate prey for both species. Juveniles fed heavily on anchovies, as shown by their frequency of occurrence (19%-39%) and volume (30%-54%) in mackerel stomachs. The body shape of anchovies appears to make them highly suitable prey for juvenile mackerel (Naughton and Saloman 1981).

King mackerel feed mostly on schooling fish, secondarily on crustaceans, and minimally on mollusks. The dominant prey by number (59%) were clupeids (Atlantic thread herring) and scaled sardines, Harengula jaguana. The minor fish prey (8%) were species of Carangidae, Lutjanidae, Pomadasyidae (Haemulidae), Sparidae, and Triglidae. Invertebrates, particularly squid and shrimps, made up 33% of the diet (Beaumariage 1973).

In south Florida, the king mackerel fed primarily on the ballyhoo, Hemiramphus brasiliensis, followed by lutjanids (five species), clupeids, scombrids, mugilids (two species), and serranids (Saloman and Naughton 1983a). The invertebrates eaten were mostly penaeid shrimp and some squid and nematodes. In east central Florida, clupeids (principally the Spanish sardine, (Sardinella aurita) were the dominant fish prey. Other prey were anchovies, mullet, flying fish, drum, and jacks. Squid was the major invertebrate food; others were nematodes, penaeid shrimp, and isopods. Most fish eaten by adult king mackerel were about the same size: 100 to 150 mm FL (Saloman and Naughton 1983a).

The food of adult king and Spanish mackerel is similar. Klima (1959) examined 190 Spanish mackerel stomachs and reported that 76% contained herringlike fishes, principally the scaled sardine and Atlantic thread herring. Shrimp (Penaeus spp.), mullet (Mugil spp.), needlefish (Strongylura spp.), and anchovies were less abundant. In Texas, Miles and Simmons (1951) examined 2,274 Spanish mackerel stomachs containing food, and found that 30% contained menhaden. Kemp (1950), also working in Texas, reported the contents of 611 Spanish mackerel stomachs: 13% contained shrimp; 5%, squid; 9%, ribbonfish; 1%, menhaden; 1%, other species; and the remainder, unidentifiable. The round scad (Decapterus punctatus) was also listed as a food of the Spanish mackerel (Anderson and Gehringer 1957).

Stomachs of 6,933 Spanish mackerel (64% were empty) were examined from the northern Gulf of Mexico, from east central Florida, and from the Carolinas. In volume, anchovies made up 96% of the food in Texas and 99% in east central Florida (Saloman and Naughton 1983b). Anchovies also made up 94% of the diet by number in Louisiana and 98% in North and South Carolina. The predominance of anchovies, herring, and small jacks in the Spanish mackerel diet demonstrates major predation on small, schooling pelagic fishes.

Predators

Larvae and juveniles of king and, principally, Spanish mackerel have been identified as prey for the little tunny, Euthynnus alletteratus, and dolphin, Coryphaena hippurus (Carlson 1952; Klawe 1961; Dragovich 1969; Rose and Hassler 1974). Relatively large king and Spanish mackerel are eaten by pelagic sharks, little tunny, and dolphins. The bottlenose dolphin (Tursiops truncatus) interferes with commercial fishing by pirating king mackerel hooked on trolling lines and in nets (Cato and Prochaska 1976). Sharks sometimes interfere with gill net sets by eating mackerel caught in the mesh. The most common shark species are the tiger shark, Galeocerdo cuvieri; bull shark, Carcharhinus leucas; dusky shark, C. obscurus; smooth hammerhead, Sphyrna zygaena; shortfin mako, Isurus oxyrinchus; lemon shark, Negaprion brevirostris; and porbeagle, Lamna nasus (Bigelow and Schroeder 1948; Clark and von Schmidt 1965; GM&SAFMC 1982).

ENVIRONMENTAL REQUIREMENTS

Temperature

Temperature and salinity are believed to be the most important factors governing the distribution of the two mackerels. Their northern range extends only to the 20 °C isotherm within the 18 m depth contour (Munro 1943; Berrien and Finan 1977a). Their northern range limit is in the vicinity of Block Island, Rhode Island (Beaumariage 1970). During years of warm water temperatures, Spanish mackerel have been reported as far north as North Bay, Massachusetts (Arnold 1951). According to Earll (1883), water temperatures of 21 to 27 °C are preferred by the Spanish mackerel; rarely are they observed in waters cooler than 18 °C.

The arrival of king mackerel off west central Florida in the spring depends on changes in water temperature and on the preceding winter's air temperature (Williams and Taylor 1980). Furthermore, sport catch data from northwest Florida indicate that catch-per-hour is usually higher following warm winters and lower following cold winters (Fable et al. 1981).

Salinity

All life stages of king and Spanish mackerel usually inhabit waters within salinities of 32 to 36 ppt. Spanish mackerel usually avoid freshwater or low salinities near the mouths of rivers (Earll 1883). Exceptions were reported by Tagatz and Dudley (1961), who collected young Spanish mackerel in a salinity of 4.7 ppt in the Neuse River, North Carolina. Other investigators have reported juveniles in low salinities (17.8 ppt, Springer and Woodburn 1960; 0.2 ppt, Kelley 1965).

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15. Supplementary Notes

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16. Abstract (Limit: 200 words)

This Species Profile on king and Spanish mackerel summarizes the taxonomy, morphology, distribution, life history, fishery descriptions, ecological role, and environmental requirements of these coastal pelagic fish to assist environmental impact assessment. King and Spanish mackerel support major commercial and sport fisheries in south Florida. In 1974-83, Gulf of Mexico and Altantic commerical landings of king mackerel declined from 10.4 to 4.3 million lb.; Spanish mackerel have fluctuated between 4.9-17.4 million lb. Both inhabit coastal waters, but Spanish mackerel are generally found closer to beaches and in outer estuarine waters. Both species feed principally on estuarine-dependent species. They are highly migratory, exhibiting seasonal migrations to winter feeding grounds off south Florida and summer spawning/feeding grounds in the northern Gulf of Mexico and off the Atlantic coast of the Southeastern U.S. Spawning occurs from March/April through September/October between the middle and Outer Continental Shelf (35-183 mi) for king mackerel and the inner shelf (12-34 mi) for Spanish mackerel. King mackerel reach sexual maturity in their 3rd and 4th years and Spanish, between their 2nd and 3rd. Female king mackerel live longer and grow larger and faster than males. Spanish mackerel live to 8 years; females also grow faster than males. King and Spanish mackerel feed principally on schooling fishes. Larvae and juveniles of both species are prey to little tunny and dolphin; adults are prey for sharks and bottlenose dolphin. Temperature and salinity are important factors regulating mackerel distribution.

17. Document Analysis a. Descriptors

Growth
Feeding habits
Temperature
Salinity
Life cycles
Marine fishes
Animal migrations

b. Identifiers/Open-Ended Terms

King mackerel
Scomberomorus cavalla
Spanish mackerel
Scomberomorus maculatus
Ecological roles
Environmental requirements

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
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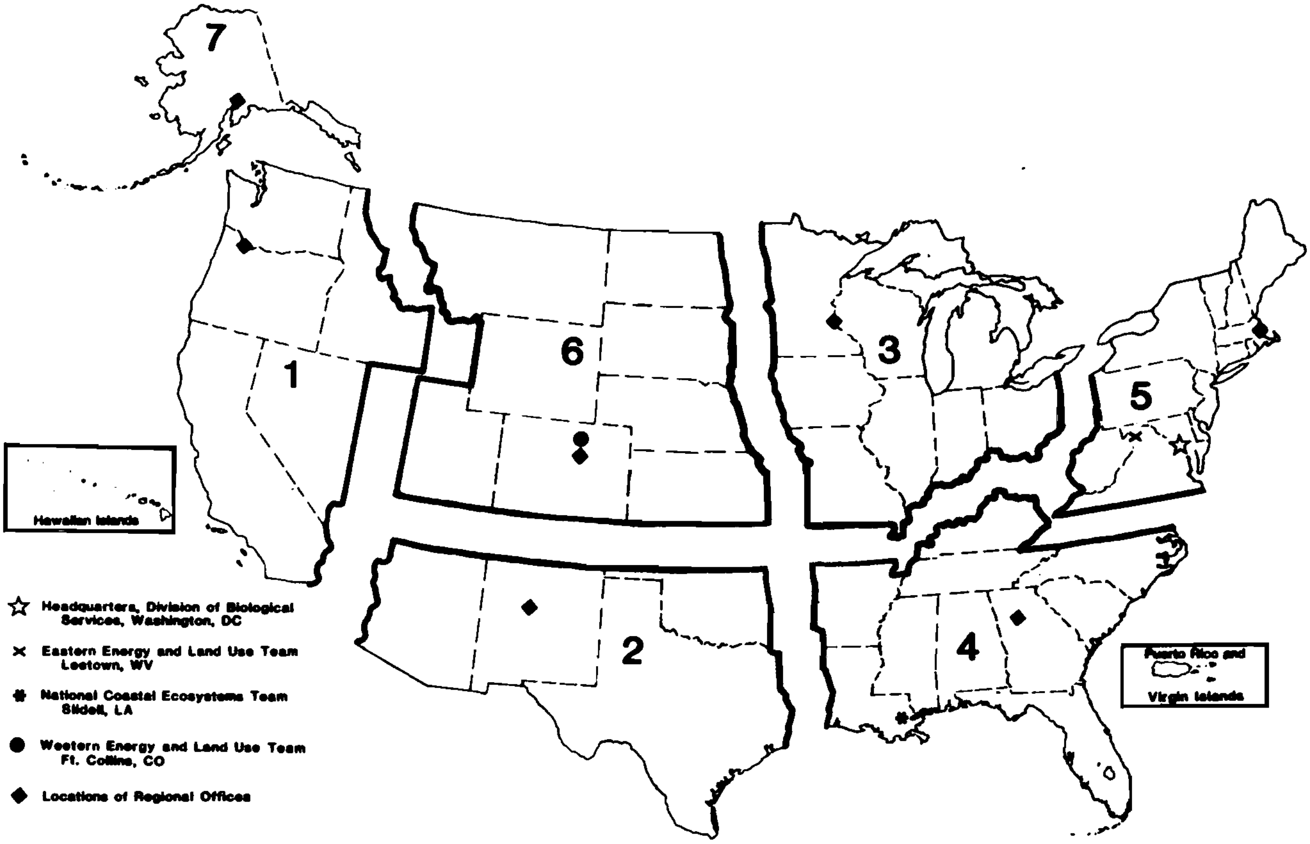

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