



Description. Slender, five to six times as long as deep; body rounded in front of vent but flattened sidewise behind it, with large, flat-topped head occupying about 25% TL; large eyes (Fig. 119). Lower jaw projecting beyond upper; wide mouth armed with two or more rows of sharp recurved teeth, which also occur on vomer. First dorsal fin originates close behind gill openings, roughly an equilateral triangle in shape and separated by a short space from second dorsal fin. Second dorsal fin about four times as long as first dorsal, but hardly more than half as high, and deeply emarginate two-thirds of the way back, with rear section higher. Anal fin corresponds in height and shape to second dorsal, under which it is located. Caudal fin square-tipped when widespread; otherwise its rear margin weakly concave. Pectoral fins rather narrow, their tips slightly rounded, and extending far enough to slightly overlap second dorsal. Pelvic fins situated slightly in front of pectorals and perceptibly shorter than the latter. Lateral line prominent, appearing double (Scott and Scott 1988).

Meristics. First dorsal fin with 1 spine and 10-12 rays; second dorsal fin rays 37-42; anal fin rays 37-42; total caudal fin rays 34-37; lateral line scales 101-110; gill rakers on first arch 16-20; precaudal vertebrae 26-29 + 27-29 caudal = 53-57 total (Markle 1982; Cohen et al. 1990)

Color. Silver hake are dark gray above with five to seven irregular, darkened vertical bars on the sides. They have a silvery iridescent cast, as the name implies, or golden reflections. The lower part of the sides and belly are silvery. The inside of the mouth is dusky blue; the lining of the belly is black or brown speckled with black. They are brightly iridescent when taken from the water, but fade soon after death.

Size. Maximum size about 760 mm TL and about 2.3 kg. A 760-mm TL individual caught on *Delaware II* cruise 78-06, station 421 at 43°28' N, 66°26' W was the largest taken by the NEFSC surveys, 1963-1986. The largest individuals from 54 bottom trawl surveys ranged from 490 to 760 mm TL. The all-tackle game fish record is 2.04-kg fish caught in Perkins Cove, Dgunquit, Maine, in August 1995 (IGFA 2001).

Distinctions. Presence of two separate and well-developed dorsal fins, both of them soft-rayed, the second much longer than the first, combined with location of the pelvic fins anterior to the pectoral fins distinguish silver hake from all other Gulf of Maine fishes except true hakes and offshore hake. They differ from the former by the lack of a chin barbel and the ordinary shape of the pelvic fins, which in true hakes are attenuated into long feelers. They are distinguished from the latter by having more gill rakers (16-20 vs. 8-11) and fewer lateralline scales (101-110 vs. 104-119).

Habits. The lowest temperatures in which silver hake have been taken by NEFSC trawling surveys 1963-1986 are 3°- 6°C. Most winter and spring records for silver hake have been from areas where the bottom temperature was warmer than 6°C. Maximum temperatures ranged from 7° to 17°C. Similarly, they were not reported in any numbers where the water was warmer than 18°C (Bigelow and Schroeder). More detailed habitat requirements are given in Morse et al. (1999).

Silver hake are strong, swift swimmers, well-armed with teeth and extremely voracious. Although they do not form definite schools, multitudes of them often swim together. Silver hake are said to rest on the bottom by day, on sandy or pebbly bottom or on mud but seldom over rocks. Adults observed from the deep-sea submersible *Alvin* were seen 2 m or so off the bottom or resting in shallow depressions at depths of 37-46 m during the day (Edwards and Emery 1968). Young-of-the-year silver hake, 1.5-5.0 cm TL, occurred at higher densities on bottoms with greater amphipod tube cover at a 55-m site in the Mid-Atlantic Bight (Auster et al. 1997). Observations at other sites showed that young-of-year silver hake occurred only on silt-sand bottom with amphipod tubes at bottom temperatures of 8.7°- 11.4°C. Adults hunt by night, and it is usually at night that they run into the shallows and enter traps. Their movement off bottom at night also makes them more available to bottom trawls (Bowman and Bowman 1980). Silver hake are wanderers, independent of depth within wide limits. Sometimes they swim close to the bottom, sometimes in the upper levels of the water, their vertical movements being governed chiefly by their pursuit of prey: Their upper limit is the tide line; at the other extreme they were caught down to 400 m in 54 NEFSC bottom trawl surveys. There are reports as deep as 900 m (Scott and Scott 1988), but it seems likely that such deep records were based on misidentified specimens of *M. albidus*.

Food. Silver hake are crustacean/fish predators with a size-dependent shift in predation from crustaceans to fishes at about 20-25 cm (Langton 1982). Silver hake less than 1 year old feed primarily on copepods, amphipods, euphausiids, and small decapod shrimps (Bowman 1981; Bowman et al. 2000). Euphausiids (mostly *Meganyctiphanes*) are an especially important food (about half of the diet) at about 15 cm in FL. Shrimps such as *Pandalus*, *Dichelopandalus*, *Crangon*, and *Pasiphaea* are regular prey in the Gulf.

When silver hake reach 20 cm, they begin to depend more on fishes and squids for food, which together make up about 80% of their diet (Langton and Bowman 1980; Bowman 1984; Bowman and Grosslein 1988). Fish species preyed upon include anchovies, herrings, silver hake, lanternfishes, Atlantic mackerel, sand lance, butterfish, and any other small fishes abundant in a particular area. Bigelow and Schroeder reported that Vinal Edwards observed cunner, sand lance, scup, silversides, and smelt in the diet of fish collected near Woods Hole. In the offshore waters of the Gulf of Maine, herrings, mackerel, sand lance, and silver hake are the principal fish prey: Cannibalism is common, especially in the Mid-Atlantic area.

Composition and quantity of food consumed differs between males and females of the same size. Females tend to eat more food and take primarily fishes as prey: Males have much larger proportions of crustaceans in their stomachs than females (Bowman 1984). As growth is directly related to food intake, it is not surprising that females grow faster than males (Penttila and Dery 1988).

Silver hake feed mainly at night from just after dusk until predawn. Intensive feeding occurs between dusk and midnight, and during the spring they may also feed around noon. In spring, just prior to summer spawning, they eat larger quantities of food. During spawning food intake is curtailed; in autumn it increases again, although not to the extent of spring. Over the winter months feeding is reduced compared to the spring and autumn (Bowman 1984). The average daily ration has been estimated at 2.9-3.2% of the body weight for hake smaller than 20 cm and 0.8-2.2% for fish larger than 20 cm (Durbin et al. 1983). From the point of view of total food consumption, silver hake represent one of the most important predators in the Mid-Atlantic Bight (Grosslein et al. 1980). Lists of prey species and further details of silver hake feeding are given by Langton and Bowman 1980; Bowman and Michaels 1984; and Bowman et al. 2000.

Diet overlap calculated as the percentage similarity between the diets of silver hake and 16 other northwest Atlantic fishes showed that the greatest overlap in diet was among species of gadoid fishes rather than between gadoids and fishes of other orders (Langton 1982). The greatest overall potential for interaction exists between smaller stages of silver hake (11-30 cm) and slightly larger (16-65 cm, depending on species) stages of gadids such as white hake, red hake, spotted hake, and pollock, largely owing to predation on the euphausiid *Meganyctiphanes norvegica* and the shrimps *Dichelopandalus leptocerus* and *Crangon septemspinosa* (Langton 1982).

Predators. Silver hake are preyed upon by numerous other fishes, and older silver hake commonly eat juvenile silver hake. A partial list of fishes that eat silver hake includes spiny dogfish, little skate, goosefish, pollock, cod, haddock, spotted, red, and white hakes, Acadian redfish, sea raven, bluefish, mackerel, swordfish, and flounders (Maurer and Bowman 1975; Bowman and Michaels 1984;

Bowman et al. 2000). Silver hake are also common prey of harbor porpoise in the Gulf of Maine (Cannon et al. 1998).

Parasites. Helminths (Scott 1987, most severe infestations marked *), four Digenea: **Derogenes varicus*, *Hemiurus levinseni*, *Lecithaster gibbosus*, and *Podocotyle atomon*; one Monogenea: *Anthocotyle merluccii*; two cestodes: **Cleistobothrum crassiceps* and *Grillotia* sp. (larvae); three nematodes: *Anisakis* sp., *Capillaria gracilis*, and **Hysterothylacium aduncum*; and three copepods: *Caligus curtus*, *C. elongatus*, and *Chondrocanthus merluccii*.

Breeding Habits. Median length at maturity for female and male silver hake from the Gulf of Maine-northern Georges Bank stock was 23.1 and 22.3 cm, respectively (O'Brien et al. 1993). Stock abundance was the most important predictor of sexual maturation of 2- and 3-year-olds in the northwest Atlantic between 1973 and 1990 (Helsler and Almeida 1997). Median age at maturity for both sexes was 1.7 years. Average fecundity is 343,000 eggs in females 25-30 cm and 391,700 eggs in females 30-35 cm (Sauskan and Serebryakov 1968). Silver hake are serial spawners; three successive generations of oocytes develop in the ovary and all are spawned in a single season (Sauskan and Serebryakov 1968).

Concentrations of spawning stock of silver hake in the Gulf of Maine were located in the coastal area between Cape Cod and Grant Manan Island (Almeida 1987). Major spawning grounds on the continental shelf are along the southeastern and southern slopes of Georges Bank (Sauskan and Serebryakov 1968), around Nantucket Shoals, and south of Martha's Vineyard (Fahay 1974) as far as Cape Hatteras (Anderson 1982: Map 32). Significant spawning also occurs in inshore waters of the Gulf of Maine during the summer (Berrien and Sibunka 1999).

Egg and larval collections show that spawning extends throughout the year but eggs are most abundant from May to November (Berrien and Sibunka 1999). The earliest egg record north of Cape Cod was 11 June; egg production is at its height in July and August; and 22 October appeared to be the latest date. Spawning occurs near the bottom, but has been recorded from surface to bottom both inshore and offshore (Sauskan 1964) at salinities of 31.5-32.5 ppt (Svetovidov 1962).

Early Life History. The eggs are buoyant, transparent, 0.82- 1.00 mm in diameter, perivitelline space 0.05-0.13 mm, with a single yellowish or brownish oil globule 0.19-0.34 mm (Markle and Frost 1985: Table 3). Incubation is rapid, 48 h at Woods Hole (Kuntz and Radcliffe 1917) and 39 h at 22.1°C in the Mid-Atlantic Bight (Kendall and Naplin 1981). Larvae are 2.64-3.52 mm long at hatching. The vent is located on one side near the base of the larval finfold, and the trunk behind the vent is marked with two black crossbars. Dorsal, anal, and caudal fins assume their definite outlines by the time the fish is 10-11 mm long, and larvae of 20-25 mm begin to resemble their parents (Bigelow and Schroeder). Silver hake can be distinguished from offshore hake, with which they occur in some places, by the scarcity or lack of pigment on the paired fins and by the two major melanophores found laterally on the trunk. In the latter the paired fins are usually heavily pigmented and the posterior lateral flank melanophores dominate the anterior. In larger offshore hake larvae, a line of dense large spots covers the flank (Fahay 1983). Silver hake have more total caudal fin rays than offshore hake (34-37 vs. 40, Markle 1982: Table 6).

Larvae drift at the surface or in undercurrents and are present down to 40 m. In the Mid-Atlantic Bight, most larvae occurred at 30 m during the day but at 15 m during the night, implying that they avoided the net during the day or migrated upward at night (Kendall and Naplin 1981). They are inshore in Maine during August and September (Graham and Boyar 1965). Juveniles are reported to associate with jellyfish. They become benthic at 17-20 mm according to Fahay (1974), but Fritz (1965) and Bigelow and Schroeder reported they descend to the bottom at 25-75 mm in autumn. They overwinter in deep depressions (Bigelow and Schroeder). Vertical distribution of young-of-the-year silver hake on the Scotian Shelf (Koeller et al. 1986) showed that they were present throughout the water column with relatively high concentrations above the thermocline; they were not caught during the day because they migrated to the bottom before dawn. This behavior begins when the fish are 20-30 mm long and continues throughout life. Cumulative distribution plots of juvenile silver hake catches during the years 1973-1976 by *Albatross IV* are given in Bowman et al. (1987).

Calanoid copepods are the primary food of larval silver hake and metamorphosed juveniles (19-40 mm). At lengths greater than 40 mm, more noncopepod items such as amphipods, mysids, and euphausiids are included in the diet although calanoid copepods are still important. At sizes over 46 mm, cannibalism became evident and increased in importance. Juveniles did not feed on other fishes, probably because juveniles of other fish species were rare at this time. An abrupt change in feeding pattern occurs as larvae metamorphose into juveniles, and a strong diel vertical migration pattern begins in which juveniles are near the bottom during the day and throughout the water column at night (Koeller et al. 1989).

Age and Growth. Silver hake produce daily growth rings on their otoliths, and both fast-growth zones and slow ones (spawning zones) are apparent (Pannella 1971). Based on otolith analysis (Hunt 1980), there is very rapid growth during the juvenile stage and a divergence between males and females greater than 25 cm, with females growing faster. Observed maximum growth for males and females was 37 and 65 cm, respectively (Ross and Almeida 1986), and the maximum age appears to be 14 years (Penttila et al. 1989). The first annulus is the most difficult to determine. Growth is faster in the Gulf of Maine than further south (Fig. 120). Growth rates in the northern Georges Bank-Gulf of Maine stock appear to be density-dependent after the fish become piscivorous (Ross and Almeida 1986). Weight was inversely correlated with the estimate of stock density for all ages, although it was lower for fish of age-group 2 than for older ones.

General Range. Atlantic coast of Canada and the United States, from Belle Isle Channel (52° N) to the Bahamas; most common from southern Newfoundland to South Carolina (Cohen et al. 1990: Fig. 730).

Occurrence in the Gulf of Maine. Silver hake are familiar all around the Gulf of Maine (Map 13) from Cape Cod to the Bay of Fundy and to the west coast of Nova Scotia, but their center of abundance is in the southwestern part of the Gulf. Distribution in the Mid-Atlantic Bight is shown in Anderson (1982: Map 32), for the Gulf of Maine in Halliday et al. (1986).

Migrations. Silver hake migrate seasonally; inhabiting waters shallower than 90 m in summer and autumn and deeper offshore

waters in winter and spring (Anderson 1982). They also move north and south (Fritz 1962). Water temperature appears to be an important factor governing timing of migration and fish distribution. Silver hake prefer progressively warmer waters as they increase in size in the first year of life (Edwards 1965).

Importance. Silver hake are a delicious fish if eaten fresh; however they soften so fast that there was no regular market demand for them and those caught incidentally were thrown overboard or used as fertilizer (Bigelow and Schroeder). A commercial market first developed in the 1920s as fillets for fried fish shops. They were also used for canned pet food and fish meal (Anderson et al. 1980). They have an enzyme system that causes rapid breakdown of flesh after capture, which renders them unsuitable for fillets after frozen storage. Commercial processing trials have shown that they make excellent surimi when processed without belly flaps, and this should enhance their market value (Lanier 1984).

Following the arrival of distant-water fleets in 1962, total landings increased rapidly to a peak of 94,500 mt in 1964 dropped sharply in 1965, and declined for 13 years, reaching their lowest level (3,400 mt) in 1979 (Mayo 1998a). Landings increased slightly during the early 1980s and have varied between 4,400 and 6,800 mt since 1987 (Fig. 121). Neither the Gulf of Maine-Northern Georges Bank nor the Southern Georges Bank-Mid-Atlantic stocks can support increased fishing, and both stocks must be considered fully exploited.

The Canadian-directed silver hake fishing activity developed from 1987 to 1996 (Showell and Cooper 1997) and became a commercial fishery in 1995-1996 in Emerald and La Have basins.

Trawler discards of silver hake in the northern shrimp fishery in the 8- to 31-cm size range indicate that 93% per tow was discarded, and this could have a negative effect on the species in the Gulf of Maine (Howell and Langan 1992). Regulations have been implemented to reduce finfish by-catch in the shrimp fishery.

There is a recreational hook-and-line fishery for silver hake from southern Massachusetts to New Jersey. They rank 10th as a sport fish, because even though they bite greedily; they put up only feeble resistance when hooked (Bigelow and Schroeder). They are caught on rod and reel in the fall at night off docks and piers (Fritz 1962).

Stocks. Two distinct stocks of silver hake are recognized (Mayo 1998a; Bolles and Begg 2000): Gulf of Maine-northern Georges Bank and southern Georges Bank to the Mid-Atlantic area. The Gulf of Maine stock differs from populations south of Cape Cod morphometrically (Conover et al. 1961); head length and pelvic fin length are significantly different between the two groups. Growth patterns of otoliths of immature silver hake (ages 0 and 1) from the Gulf of Maine and southern New England waters differ in growth increments (Nichy 1969). Biochemical analysis indicates significant differences in the enzyme systems of spawning silver hake (Schenk 1981). Use of a statistical technique (discriminant analysis) based on 13 morphometric characters, bottom trawl survey data, and commercial fishery catch statistics support earlier conclusions that there are two distinct stocks, one on northern Georges Bank and the Gulf of Maine and another from southern Georges Bank south to Cape Hatteras (Almeida 1987). The greatest group separation occurs during spawning season. Some mixing occurs on Georges Bank and Nantucket Shoals, but the shoal part of Georges Bank appears to separate the two stocks.