Silver Hake: A Description of the Stocks Comprising the Management Unit

by

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Stock Identification

The silver hake (*Merluccius bilinearis* Mitchell) is a widely distributed species with a range extending from the Newfoundland Banks to the Bahamas (Domanevsky and Nozdrin, 1963), but found most plentifully off the New England coast (Figure 1). The upper limit of this species' depth range is the high tide line and catches have been made in water as deep as 730 m on the continental slope off New England (Bigelow and Schroeder, 1953).

Bottom trawl surveys conducted primarily in the fall and spring have documented that silver hake have wide distribution and depth ranges throughout the year, with only the concentrations of fish varying from season to season. As a whole, these fish overwinter in the deeper waters in the Gulf of Maine and along the continental slope from Georges Bank to Cape Hatteras. There appears, however, to be small numbers of year-round inshore residents, regardless of the major seasonal hydrographic changes. Schaefer (1960) indicated that he used fish caught between December and May along the beach in New Jersey in his study of growth and feeding habits in silver hake. During the warmer spring and summer months the surveys have indicated a very widespread distribution of fish in both deep and shoal waters with no major concentrations in any particular depth (Figures 2 and 3). Catches from these surveys show a continuous distribution of fish from Georges Bank to the Hudson Canyon with no clear-cut demarcation between stocks on Georges Bank and in the Gulf of Maine and one extending from Cape Cod-Cape Hatteras during any season. There does exist, however, some evidence that several discrete stocks of silver hake may exist off the eastern coast of the United States.

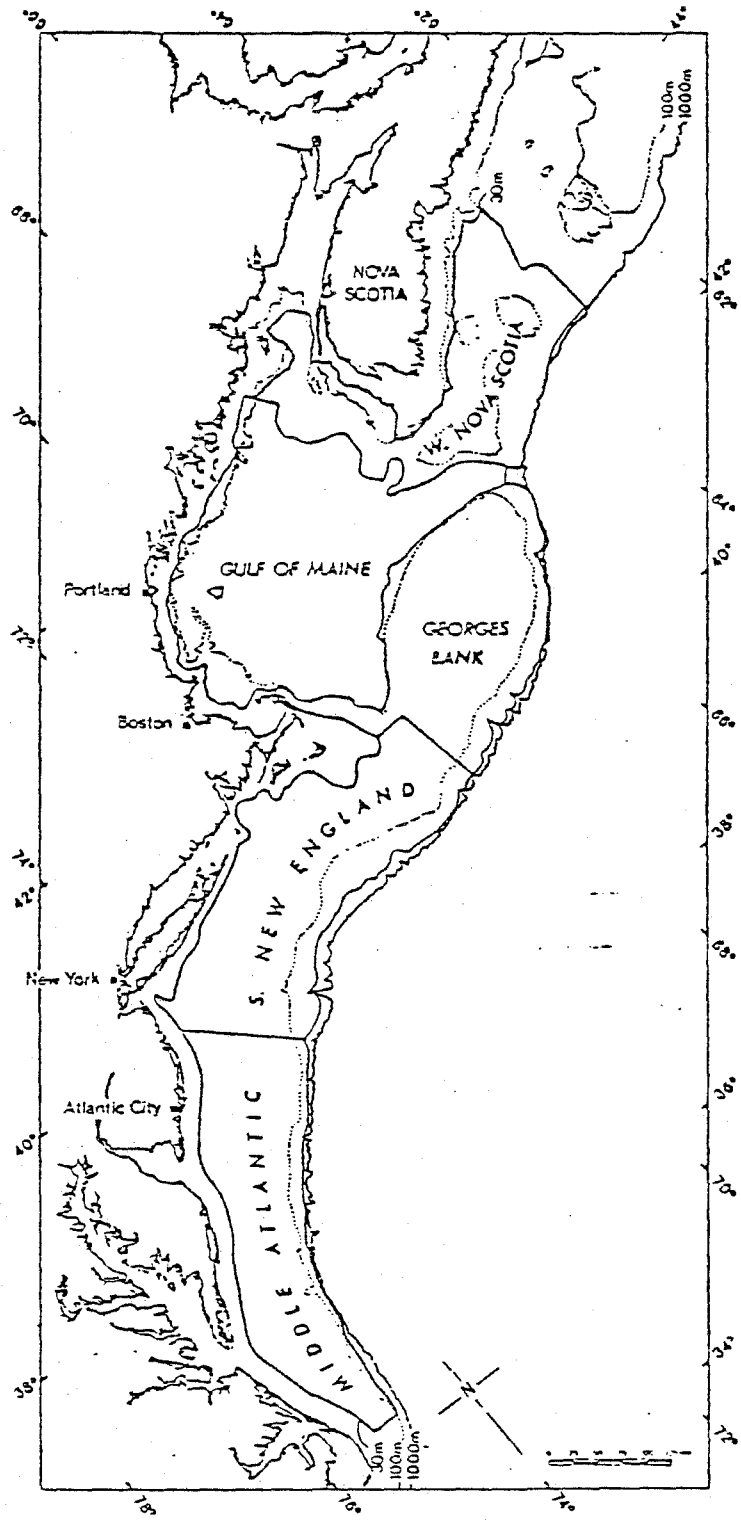

Figure 1. Areas sampled in annual bottom trawl surveys.

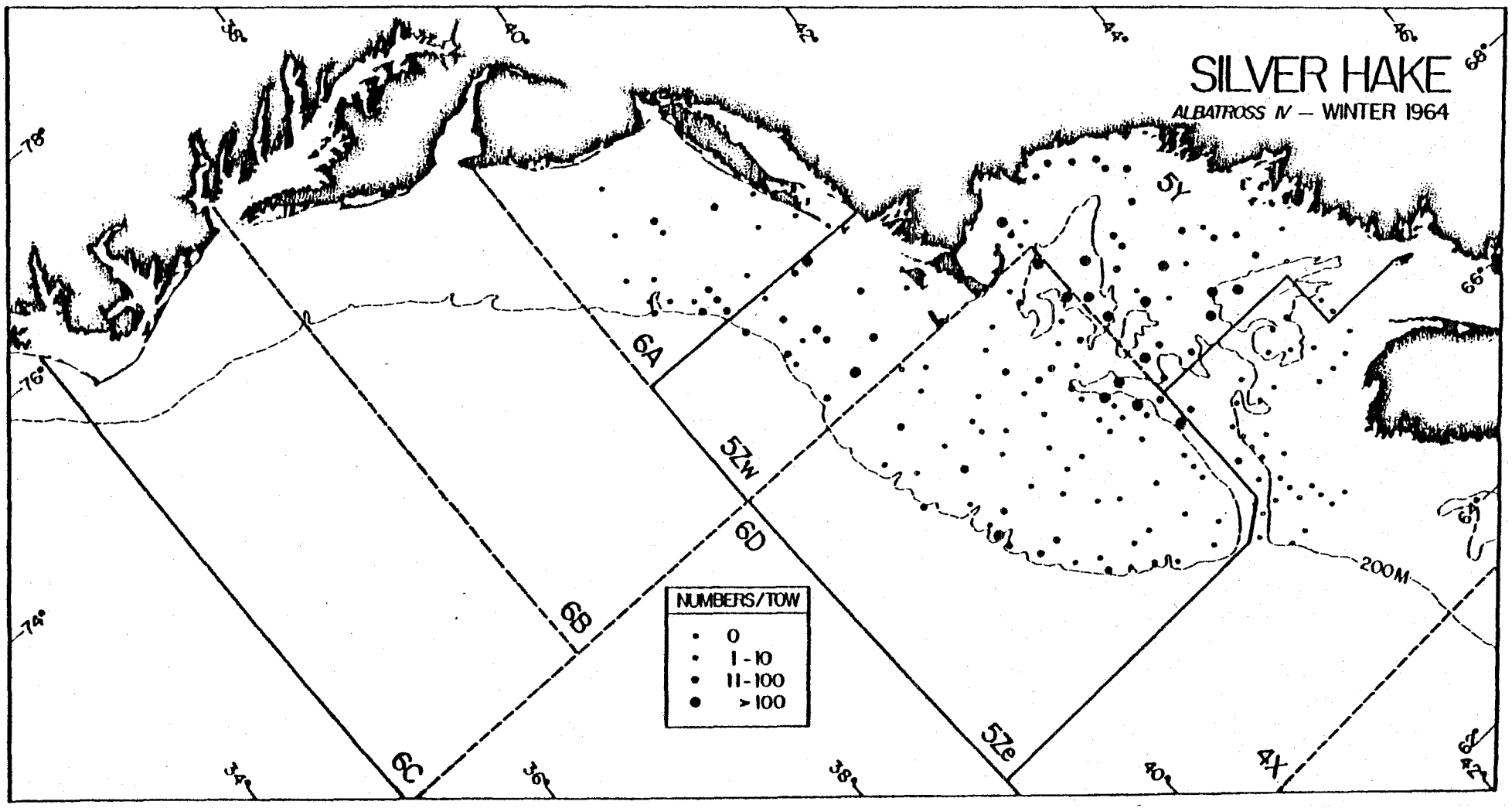

Figure 2. The distribution of silver hake catches (no./tow) during the winter 1964 (16 January - 15 February) ALBATROSS IV groundfish survey. (From Anderson, 1974).

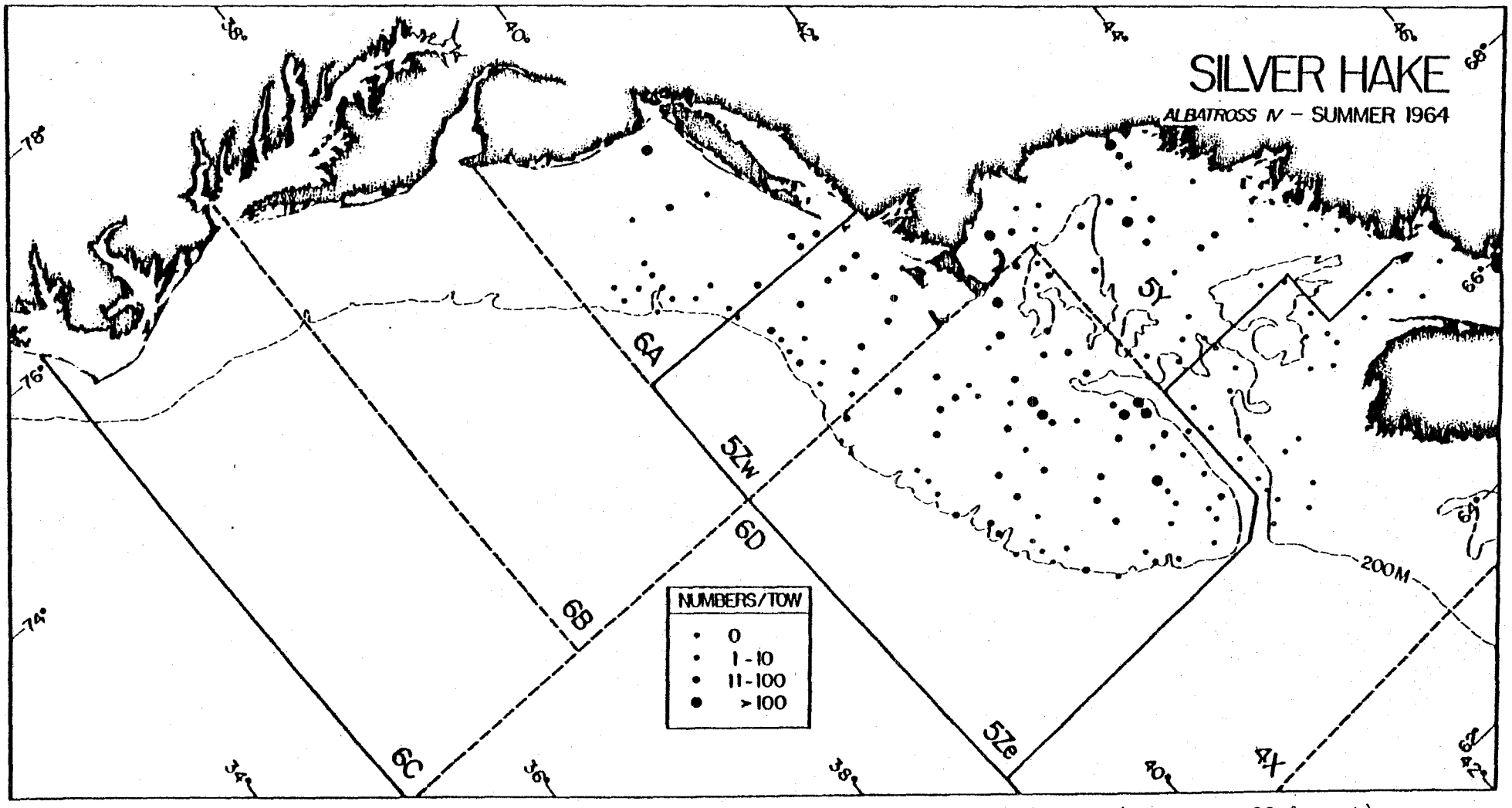

Figure 3. The distribution of silver hake catches (no./tow) during the summer 1964 (27 July - 22 August) ALBATROSS IV groundfish survey (From Anderson 1974).

Conover et al. (1961) examined morphometric characteristics of 1,265 fish from the Gulf of Maine, both inshore and offshore, and south of Cape Cod, Massachusetts, to New Jersey. Approximately 40 percent of those fish measured from the offshore waters of the Gulf of Maine, were collected on the northern edge of Georges Bank. The characteristics studied were, head length, length of the pelvic fin, length of the first ventral fin, and eye diameter, all as functions of body length. In all cases, there were no statistically significant differences in the characteristics between fish collected in the Gulf of Maine, and those on the northern edge of Georges Bank. There were also no differences found between fish collected in the Southern New England area and those from the Middle Atlantic. There were, however, highly significant differences between fish collected in the Gulf of Maine-northern Georges Bank area, and those collected in Southern New England and Middle Atlantic waters. The study suggested that two distinct stocks populate the region, one in the Gulf of Maine, including northern Georges Bank, and another from Southern New England to New Jersey with Nantucket Shoals considered to be somewhat of a dividing line between the two stocks.

Konstantinov and Noskov (1969), examined the blood serum and erythrocyte antigens of silver hake using fish collected in the Sable Island, Georges Bank, and Middle Atlantic states areas. Their report indicated that a separate stock could be distinguished in each area, with the division of the Georges Bank and Middle Atlantic stocks in the Nantucket Shoals area. They also found that the stocks from the Georges Bank and Middle Atlantic areas intermixed during the fall and winter. During their study period,

14 percent of the Middle Atlantic stock was found on Georges Bank and 35 percent of the Georges Bank stock was intermixed with the Middle Atlantic stock. Additionally, it was found that the blood serum antigens from fish collected in each area differed slightly by sex, age, and size during the study period.

Nichy (1969) examined fish from Southern New England and the Gulf of Maine and found a difference in otolith zonal formation and length at age between young fish in both areas. He suggested using $41^{0}30'$N latitude as the division line between what he considered the two stocks occupying those areas.

Tagging studies on the eastern coast of the United States between Massachusetts and New Jersey, and also in the Gulf of Maine began in 1946 and continued with limited success until 1958. Between 1945 and 1956, approximately 2,100 fish were tagged using otter trawls and trap nets, and a variety of tags. Those studies produced only a 0.6 percent rate of recapture (Fritz 1959, 1962, 1963, and unpublished data). During 1957-1958, approximately 2,200 fish were tagged using a modified version of the tag judged to be superior in the previous attempts. The methods of capture in this study were otter trawls, trap nets, and hook and line. The rate of recapture was 6.0 percent, but all fish were recaptured within 65 km of the tagging site and due to the restricted area, no conclusions could be drawn concerning stock movement or identification.

The current stock delineations, using the standard ICNAF areas 5Y (Gulf of Maine), 5Ze (Georges Bank), and 5Zw+6 (Southern New England - Middle Atlantic) as stock boundaries may appear to be somewhat unrealistic in that they divide a major overwintering area in the Gulf of Maine roughly

in half, as indicated from fall and winter bottom trawl surveys (Anderson, 1974). These boundaries were originally chosen because catch statistics reported by the foreign fishing fleets had no finer breakdown, and the general feeling among participating scientists was that the ICNAF divisions did, in fact, somewhat define the stock boundaries.

None of the previously mentioned studies have definitively determined the stock identity of the silver hake inhabiting the waters between Cape Hatteras and the Gulf of Maine. Based on the USA bottom trawl survey data, Nichy's (1969) otolith zonal formation data, and the morphometric studies carried out by Conover et al (1961), it appears possible that there exists two stocks, one in the Gulf of Maine, including northern Georges Bank, and one extending from southeastern Georges Bank to Cape Hatteras. The large percentage of mixing reported by Konstantinov and Noskov (1969) would tend to infer this also.

An argument contrary to the division of fish populating Georges Bank into two discrete stocks might include data indicating that the fish from the northern and southern overwintering grounds intermix during the warmer months and, therefore, are not reproductively isolated.

Until definitive studies can be carried out, including tagging and possibly a morphometric study including fish from the Gulf of Maine, both inshore and offshore, northern Georges Bank, southern Georges Bank, Southern New England, and the Middle Atlantic, the serious problems and difficulties encountered in accurately apportioning catch data to specific stocks, indicates that the assessment management units should remain the same.

Early Life History

Sexual maturity in silver hake is initiated at age 2 and all fish are capable of spawning in the third or fourth year of life. Bigelow and Schroeder (1953) indicated that silver hake in the Gulf of Maine were probably mature at age 2. In the Georges Bank area, Sauskan (1964) stated that during 1962-1963, first time spawners were 29-33 cm in length, age 2-3 fish. Doubleday and Halliday (1975), examining fish collected on the Scotian Shelf during 1971-1974 indicated that all males greater than 25 cm and all females greater than 30 cm were sexually mature. These fish were also age 2 and older. It is assumed that silver hake populating the Southern New England and Mid-Atlantic waters are also sexually mature at about age 2-3.

Sauskan and Serebryakov (1968), in an in depth study of the reproduction and development of silver hake, indicate various stages in the development of the gonads and subsequent egg and larval development. During the first three years of life, the ovaries of silver hake contain oocytes in what is termed a "lesser" growth phase. This phase consists of protoplasmic cell growth with oocyte diameters ranging between .01 and .17 mm. During this period, the ovaries have a threadlike appearance. A characteristic of individuals reaching sexual maturity is a change in growth from "lesser" to "greater", which includes the deposition of yolk material and terminates in a full-sized oocyte or egg. This period of so-called "greater" growth can be further divided into a series of stages leading to the actual spawning of ripe eggs.

On the overwintering grounds during the winter and spring, the gonads of the female silver hake increase in size and change in color from yellowish to a rose pink. At this time, the oocytes of the first generation increase in size and by the end of spring are clearly discernable, approximately .50 mm in diameter.

In late spring, the first evidence of asynchronous egg development and ovulation becomes apparent. Between May and August, the ovaries are yellow or dark orange in color, and three generations of oocytes are distinguishable under microscopic examination. The first generation of oocytes have diameters between .48 and .78 mm, the second generation between .25 and .48 mm, and the third generation, .01 - .25 mm. During these summer months (before the first batch of eggs is spawned) the abdomen becomes swollen with the gonads almost completely filling the body cavity, making up approximately 35% of the total body weight. After the first batch of eggs is spawned, the gonads shrink and make up approximately 4.5 - 5% of the body weight; the abdomen of the fish is not swollen, but the gut walls appear stretched. About half of the annual production of eggs is spawned in the first batch with the remainder being divided between the second and third batches. Fahay (1974) confirmed these findings with data from ichthyoplankton surveys conducted between Martha's Vineyard and Cape Lookout, North Carolina, in 1966.

Sauskan and Serebryakov (1968) also reported that females, 25-30 cm in length, averaged 343,000 eggs per spawning season, and females 30-35 cm long averaged 391,700 eggs.

By late summer, after the second generation of oocytes has been released, the gonads shrink to approximately half their weight before the release of the first generation eggs. Third generation oocytes reach full size in early fall and are shed between September and November. After this stage, the gonads account for only 1.5 - 2.0% of the total body weight and any unshed oocytes are apparently resorbed.

The asynchronous ovulation of the female silver hake is not paralleled by an asynchronous spermatogenesis in the male. Sperm are released over a long period from May to late autumn, but especially in June and August.

The testes also go through distinguishable stages of maturity, also reported by Sauskan and Serebryakov (1968). On the overwintering grounds, between early winter and spring, the testes undergo a change from a brownish threadlike appearance measuring up to 2 mm in diameter to enlarged, whitish, scalloped organs, typical throughout the Gadidae.

Throughout the spawning season, sperm are released gradually, beginning in the caudally located lobes of the testes and proceeding forward. It may be noted that the caudal lobes may indeed be free of sperm even before those lobes located nearer the head of the fish have reached the running stage.

By autumn, the testes are considerably reduced in size and become brownish again. Whether or not any unreleased sperm are resorbed is still in question.

When spawned, silver hake eggs are spherical, almost transparent and contain one oil droplet. The eggs are pelagic and the oil droplet is oriented on the upward pole of the egg, with the embryo developing on the opposite,

downward pole. The average egg diameter reported by Sauskan and Serebryakov (1968) was .85 mm, by Kuntz and Radcliffe (1917), .88 - .95 mm, and by Fritz (1962) .79 mm. The range in variation reported by Sauskan and Serebryakov (1968), between .70 mm and 1.11 mm is the widest range of all species of hake that have been investigated. The incubation period was reported by Kuntz and Radcliffe (1917) to be 48 hours, though no accompanying temperature was given.

Newly hatched larvae range in size from 2.8 mm (Kuntz and Radcliffe, 1917) to 3.2 mm (Fritz, 1962). Ahlstrom and Counts (1955), studying the Pacific hake (M. productus), noted that newly hatched embryos have unpigmented eyes, no jaws, and the oil droplet is located behind a large yolk sac. The embryo apparently lives off stored yolk for a period of time until it reaches at least 9 mm in length, when the jaws become sufficiently developed to support active external feeding. This same development pattern most likely applies to M. bilinearis also.

Sauskan and Serebryakov (1968) noted that incompletely formed larvae, 9.9 mm in length, have a broadened body, an embryonic fin fold between the first and second dorsal fins, rays beginning to develop in most fins, and the caudal end of the notochord curved upward. By the time the larvae reaches a length of 15.3 mm, the body is elongate, the fin fold between the first and second dorsal fins is very narrow and dorsal pigmentation is more intense.

At the fry stage, approximately 22.5 mm, the larval characteristics have almost completely disappeared. The first and second dorsal fins are

not joined and the pelvic fin extends slightly beyond the anus. Larval pigmentation is lost, with color more uniformly diffused.

Pelagic life continues for two months, after which the larvae, measuring about 17-20 mm (notochord length), decend to the bottom (Fahay, 1974). Bigelow and Schroeder (1953) reported that juvenile silver hake move to deep water after their first summer and migrate inshore the following year as mature fish in the Gulf of Maine. During the first summer, the eggs and larvae drift in a southwesterly direction carried by the prevailing currents to a maximum distance from the spawning sites of between 77 km (Fahay, 1974) to 111 km (Sauskan and Serebryakov, 1968).

Bigelow and Schroeder (1953) reported that silver hake eggs and larvae were found on the Nova Scotia Banks, with their eastern limit being the Sable Island area. They also reported the southern limit to be Cape May, New Jersey. Silver hake eggs and larvae have been taken from Georges Bank from May to November (Marak and Colton, 1961; Sauskan and Serebryakov, 1968). Fahay (1974) reported collecting eggs and larvae from south of Martha's Vineyard and the Nantucket Shoals area, with some taken as far south as Virginia. He noted that the heaviest concentrations were found between Nantucket Shoals and the Hudson Canyon. Large catches were found in the northern portion of the study area, Nantucket Shoals, early in the season with smaller catches occurring further south probably due to the smaller number of adults populating that area.

Spawning areas for the silver hake include the coastal region of the Gulf of Maine from Cape Cod to Grand Manan Island, with the area on the

eastern side of Cape Cod north to Cape Ann being the most important (Bigelow and Schroeder, 1953). On Georges Bank, the major spawning grounds are the southeastern and southern slopes although silver hake can be taken in most parts of the bank all summer and some spawning must occur in these other parts as well. Sauskan and Serebryakov (1968) reported that in some years spawning does take place on the northern edge of Georges Bank.

Spawning also takes place in the area of Nantucket Shoals and south of Martha's Vineyard and as far south as Cape Hatteras (Fahay, 1974). Indeed 88% of the total number of eggs taken in ichthyoplankton surveys conducted in 1966 between Martha's Vineyard and Cape Lookout, North Carolina, were collected between Martha's Vineyard and Montauk Point, Long Island. The densest concentration of larvae was found between Nantucket Shoals and the Hudson Canyon, also indicating that the New York Bight may be a prime spawning ground and nursery area.

Spawning takes place from May to November (Bigelow and Schroeder, 1953; Marak and Colton, 1961; Marak et al., 1962; Sauskan and Serebryakav, 1968; Colton and St. Onge, 1974; Fahay, 1974), with optimum spawning taking place in July and August in the Gulf of Maine, and June - July along the continental shelf. Bigelow and Schroeder (1953) indicated that the lowest temperatures at which spawning takes place in the Gulf of Maine are between 5° and $7^{o}C$ with a maximum temperature of $13^{o}C$. Sarnits and Sauskan (1967) reported that the optimum spawning temperature on Georges Bank is 10° - $12^{o}C$, and the optimum incubation temperature ranges from 13° - $16^{o}C$. The lowest temperature at which normal development takes place is $10^{o}C$, and the maximum temperature

is $21^{o}C$ (Bigelow and Schroeder, 1953). Fahay (1974) reported that eggs were found in waters with surface temperatures ranging between $13^{o}C$ and $22^{o}C$ and larvae in waters between 9° and $26^{o}C$.

Age and Growth

Growth is rapid in the first several years of life and is sexually dimorphic, with females growing much faster and attaining greater lengths than males (Schaefer, 1960; Nichy, 1969; Almeida, 1978). Spring and autumn bottom trawl survey data indicate that females grow to a maximum length of 66 cm and have a maximum age of 15 years. The survey data also show that males grow to a maximum length of 41 cm and a maximum age of nine years. Bigelow and Schroeder (1953) reported that silver hake from the Gulf of Maine attained a maximum weight of 2.3 kg.

The von Bertalanffy (1938) growth equation has been fitted to spring and autumn bottom trawl survey length at age data for the years 1973-1976 (Almeida, 1978). In the Southern New England-Middle Atlantic region (sexes combined, n = 3344), the equation obtained was:

$$\ell_t = 46.08\ (1-e^{-.4156(t-.2730)});$$

with ℓ = length in cm, and t = age in years. In the Georges Bank region (sexes combined, n = 1681) the resultant equation was:

$$\ell_t = 50.72\ (1-e^{-.2462(t+.6208)});$$

and the equation obtained for the Gulf of Maine area (sexes combined, n = 3858) was:

$$\ell_t = 65.41\ (1-e^{-.1818(t+.2746)}).$$

The length-weight relationship, an equation derived using spring and autumn bottom trawl survey data, is:

$$W = 5.93229 \times 10^{-6} L^{3.04990}$$

where W = weight in kg, and L = length in cm.

A comparison of length-frequency distributions and the preceding growth equations indicates a difference in growth rates between fish found in the Gulf of Maine, Georges Bank, and Southern New England - Middle Atlantic areas, with fish populating the more northern regions growing slightly faster and attaining greater lengths than those found further south. Indeed, both the oldest fish, and the largest fish ever reported were taken in the Gulf of Maine.

A new and more accurate method of reading thin sections of silver hake otoliths was begun in 1975 and the results indicate a substantial difference between fish aged in the US and those in the USSR. The effect of the new U.S. method was to age fish of a given length younger than in previous years, indicating that the catch of fish from those years was younger than reported.

Silver hake are fully recruited into the commercially exploitable stocks by age 3, although in all years, age one fish are also reported taken in the annual catch.

Ecological Relationships

A relatively limited number of papers has been published discussing the feeding habits and predator-prey relationships of the silver hake. Silver hake have been identified as playing an important role in the food web in that it preys and is preyed upon by other commerically important species such as cod, pollock, mackerel, herring, squid, red hake, flounders, and other silver hake.

Silver hake are extremely voracious fish, armed with numerous sharp teeth and the ability to swim very swiftly. In their search for prey, they do not confine themselves to bottom or surface dwelling species and wander over large areas. Fritz (1962) reported sighting these fish feeding on silversides at the surface along beaches and they have been known to strand themselves on beaches while chasing herring in the autumn.

Feeding intensity is greatest in the spring and late autumn, with very little feeding taking place during the spawning season or during the winter months. Rikhter (1968) did report that much feeding does take place in the Hudson Canyon region during the winter and Vinogradov (1972) substantiated this, although neither author indicated which species were being preyed upon. Vinogradov (1972) also indicated two daily peaks in feeding intensity, one at approximately midnight, during which the major food species were bottom

dwellers, and again around noon, when pelagic species were more well represented in the stomachs examined. Bowman (1975) found no diurnal differences in food habits using data obtained from spring and autumn research vessel trawl surveys between 1969 and 1972.

There also appears to be definite feeding patterns based on the size and age of silver hake. Those fish, ranging from less than 20 cm to approximately 45 cm consume a very large quantity of euphausids with those fish larger than 45 cm feeding almost exclusively on fish.

Bowman (1975) compared the feeding habits of both sexes of silver hake and found that in all areas except Georges Bank males ate a higher percentage of crustaceans at all length intervals than did females who ate fish almost exclusively at older ages.

Papers discussing and listing the species composition of the silver hake diet include those by Jensen and Fritz (1960), Schaefer (1960), Fritz (1962), Domanevsky and Nozdrin (1963), Dexter (1969), Vinogradov (1972), Maurer (1975), Bowman (1975), and Langton and Bowman (1977). The following is a condensed summary, by areas, of the conclusions of the above listed papers.

In the Middle Atlantic silver hake feed primarily on herring, myctophids, shad, silversides, some amphipods, and shrimp. In Southern New England waters, mackerel becomes an important species in the diet along with other gadids, butterfish, shrimp, and euphausids. Important fish species on Georges Bank are mackerel, herring, yearling hake, and yearling cod. The dominant invertebrate species included squid, euphausids, and gammarids.

In the Gulf of Maine, herring and mackerel again are important food species, although Dexter (1969) indicated that in 1959, sand launce made up 53% of the silver hake diet. On the Scotian Shelf, Vinagradov (1972) and Jensen and Fritz (1960) reported that euphausids were the highly dominant species for all silver hake although gadids, including young silver hake, and shrimp were included in its diet. Sand launce is also eaten by silver hake in that region.

Population size and especially survival rate in any given areas depend to some degree upon food supply, and the abundance of fish in an area may be limited depending upon the relationship between the species and its feeding area (Dementeva, 1953: Nikolsky, 1958). Multi-species relationships are now being more closely examined by the National Marine Fisheries Service to develop a more reasonable overall view of the ecological relationships between the commercially important species and their environment.

General Condition of the Habitat

Within the distributional range of the silver hake, from the Gulf of Maine to Cape Hatteras, there are two hydrographically distinct regions separated by the Nantucket Shoals.

In the Southern New England - Middle Atlantic region, the continental shelf extends 20 mi seaward off Cape Hatteras and continually widens to about 100 mi off Cape Cod. In this region, the bottom consists of sand

with areas of sand-gravel and sand-shell out to the edge of the shelf, at a depth of 200 m. The slope area, where silver hake overwinter close to the bottom is made up of silt and silty sand.

The northern region is characterized by a deep, centrally located cold basin in the Gulf of Maine nearly isolated from the Atlantic by Georges and Browns Banks.

The bottom composition of the coastal waters north of Cape Ann to southwestern Nova Scotia is rock and rock-gravel. The sediments in the central basin of the Gulf of Maine are silt and silty-sand, similar to the slope of the continental shelf. On Georges Bank, the bottom is made up of sand and sand-gravel, while the slope is again silt and silty-sand.

Salinities close to the coast in the Southern New England - Middle Atlantic area are about 32°/oo, increase to 34-35°/oo near the edge of the shelf, and exceed 36.5^{o}/oo close to the Gulf Stream. On Georges Bank and in the Gulf of Maine, salinities average 32-35°/oo but are lower inshore and vary with depth and the intrusion of more saline slope water.

The general circulation pattern in the Southern New England - Middle Atlantic region is primarily in a southwesterly direction throughout the year. There is, however, some reversal of flow inshore, along the Middle Atlantic states in the summer and fall. A limited reversal in flow may also occur at the northern and southern extremities during the winter and spring.

In the Gulf of Maine, the circulation is characterized by a counter-clockwise eddy which is predominant during most of the year. Its waters generally spill onto Georges Bank along the northern slope and onto the Nantucket Shoals via the Great South Channel.

An anticyclonic or clockwise eddy develops on Georges Bank in the spring and lasts through summer. By autumn, the drift is predominantly south and westerly and this flow persists through winter.

The annual planktonic cycle is typical of the temperate zone in that its abundance is at a minimum during the winter and at a maximum during the summer. Low levels persist in the winter due to cold surface water temperatures and low solar radiation levels. In the spring, when conditions improve, a phytoplankton bloom occurs, and by summer, the zooplankton reach their maximum abundance due to the high levels of phytoplankton which are their predominant food. By late summer, the phytoplankton are at levels approaching their winter minimums, but in autumn, another moderate bloom takes place when nutrients are brought to the surface due to unstable water column conditions as the water temperature decreases. During this time, the zooplankton levels are decreasing, primarily due to predation by fish larvae and fry.

Environmental Factors Affecting Distribution

The most important environmental factor governing the distribution of adult silver hake is temperature. Seasonal migrations apparently are governed by changing temperatures, with fish moving from the relatively warm shoal water where they remain in the spring and summer, to the deeper slope waters in the winter. Although silver hake may be found in water ranging in temperature from 4-18°C (Bigelow and Schroeder, 1953), in July - August, 1962, Domanevsky and Nozdrin (1963), observed that the greatest

abundance of silver hake were found on southeastern Georges Bank at depths between 90 - 110 m and temperatures of 7 - 11°C. Ripe and maturing silver hake were found concentrated on the southeastern slope of Georges Bank between April and June, 1962 and 1963, at depths of 85 - 200 m with near bottom temperatures of 10 - 12°C. Post-spawning feeding concentrations were also found on the northern part of Georges Bank at depths of 40-110 m and temperatures of 6 - 10°C (Sarnits and Sauskan, 1976; Sauskan, 1964). Edwards (1965) reported that silver hake tend to prefer warmer water as the size of the fish increases, and that only young-of-the-year fish were taken in the relatively cold shoal water below 9°C during 1956-1958.

Bottom composition does not directly affect the distribution and abundance of the pelagic silver hake but probably does secondarily affect this species in that prey species such as the bottom spawning sea herring, which is fed upon heavily during its spawning period, use sand or sand-gravel bottom types as spawning grounds.

Langton and Bowman (1977) indicate that although red and silver hake have similar distribution ranges and migration patterns, competition between adults of the two species is at a minimum. Major components of the adult red hake diet consist of crustaceans, namely amphipods, crabs, and shrimp, whereas the adult silver hake prey largely on fish, namely herring, mackerel, silver hake, and other Gadids.

Circulatory patterns during the spawning season of silver hake may have an affect on the distribution of eggs and larvae. During the incubation

period, which lasts up to two months, eggs and larvae may drift up to 111 km. (Sauskan and Serebryakov, 1968), carried by the prevailing currents in and around the spawning areas.

In the Southern New England and Middle Atlantic region, eggs spawned between Nantucket Shoals and the Hudson Canyon drift in a west-southwesterly direction. Those eggs spawned on the southern and southeastern slopes of Georges Bank may drift in an easterly direction toward the Southern New England waters or towards the north and then east, caught in the Georges Bank gyre.

The most important spawning area in the Gulf of Maine, in the coastal waters between Cape Cod and Cape Ann, is also an area of divergence in the circulatory pattern of the Gulf. The southerly flow of water on the western side of the Gulf separates north of Cape Cod, with some water entering Cape Cod Bay, some flowing south past the outer Cape toward Nantucket Shoals, and some flowing east toward the northern edge of Georges Bank. During the prime spawning period in the summer months, there is also an upwelling that occurs in this area (J. Colton, personal communication). This upwelling causes much of the southerly flow to divert to the east toward the northern edge of Georges Bank and would tend to minimize the amount of eggs and larvae spawned in the Gulf of Maine to drift onto the Nantucket Shoals and Southern New England waters.

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