Nation's principal conservation agency, the Depart-
the Interior has basic responsibilities for water,
life, mineral, land, park, and recreational re-
Indian and Territorial affairs are other major
of America's "Department of Natural Resources."
partment works to assure the wisest choice in
all our resources so each will make its full
on to a better United States -- now and in the future.

P

Importance of the Worldwide Hake, *Merluccius*, Resource

By

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ABSTRACT

Aspects of hake taxonomy, biology, and world fisheries are reviewed from the literature. Of the 11 nominal hake species, 6 represent a substantial segment of the total gadoid species landed in the world and play an important role in world fisheries economy. The historical development of the fishery for six species of hake is discussed.

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INTRODUCTION

Hakes of the genus *Merluccius* (fig. 1) are represented in all coastal areas throughout the Atlantic and Pacific Oceans, except the northwest Pacific, and their increasing importance in the world fisheries has resulted in a proliferation of literature describing the biology and the fisheries of various species. We have reviewed pertinent literature with the aim of summarizing the general biology of the commercially important species and the development of current hake fisheries.

Figure 1.—Photograph of an adult Pacific hake taken off the Washington coast (BCF staff photo).

TAXONOMIC STATUS

Of the several commercial codlike species taken from the cooler waters of the Northern and Southern Hemispheres, the genus *Merluccius* has rapidly become important in world fish catches. Marshall (1966) provided the most recent interpretation for the systematic position of merlucciid fishes, distinguishing family Merlucciidae from other groups of anacanthine fishes: *Melanonus*, Muraenolepidae, Bregmacerotidae, Gadidae, Moridae, and Macrouridae. The reader is referred to Svetovidov (1948) and Norman (1966) for other systematic reviews of merlucciid fishes.

Norman (1937) recognized seven species of worldwide hake:

1. *M. merluccius* (Linnaeus) - Europe, North Africa
2. *M. hubbsi* Marini - Eastern South America
3. *M. productus* (Ayres) - Northeastern Pacific
4. *M. gayi* (Guichenot) - Southeastern Pacific
5. *M. bilinearis* (Mitchill) - Northwestern Atlantic
6. *M. capensis* Castelnau - South Africa
7. *M. australis* (Hutton) - New Zealand, South America

Ginsburg (1954) increased the number of species to 11 by recognizing 2 previously described ones and describing as new 2 more. He recognized *M. albidus* from the northwestern Atlantic, formerly in the synonymy of *M. bilinearis;* and *M. angustimanus* from the central Pacific, formerly in the synonymy of *M. gayi.* He described *M. magnoculus* from the Gulf of Mexico and *M. polylepis* from the tip of South America (the latter had been recorded from South America as the New Zealand species *M. australis*).

Including and subsequent to Ginsburg's (1954) work, descriptions have been made of species, subspecies, and independent stocks of hake off the European, African, and North American continents (see Cadenat, Doutre, and Franca in Cabo, 1965). Cabo (1965) recognized and provided a summary of 8 species and 10 subspecies of hake throughout the world.

The taxonomy of *Merluccius* remains unclear. Svetovidov (1948) pointed out that by existing standards of evaluation, species referable to Merlucciidae lack the distinctive characters of other gadoid species and even subspecies. He stated that, within the limits of their recorded range, forms of this genus apparently are not isolated from nearby forms. This lack of isolation helps to maintain a close systematic identity, and in reality there may be fewer than three worldwide species (Baxter and Pruter[1]).

Lacking the necessary evidence to evaluate published work, we arbitrarily follow Cabo's (1965) summary, with minor modifications (table 1; fig. 2).

Table 1.—Species of genus *Merluccius*, their common names, and area of occurrence

Species	Common name	Area of occurrence (fig. 1)
M. merluccius	European hake	Europe and North Africa (including the Mediterranean and adjacent waters)
M. capensis	Cape hake (Stockfish)	South Africa
M. bilinearis	Silver hake	Atlantic coast of the United States and Canada
M. albidus	Offshore hake	Atlantic coast of the United States
M. magnoculus	--	Gulf of Mexico
M. hubbsi	Argentine hake (Merluza)	Argentina
M. polylepis	--	Chile and Tierra del Fuego
M. gayi	Chilean hake	Chile
M. angustimanus	Panamanian hake	Southern California to Panama
M. productus	Pacific hake	Baja California, Pacific coast of the United States and Canada
M. australis	New Zealand hake	New Zealand

ASPECTS OF HAKE BIOLOGY

The biological similarity among hake species is as remarkable as their alleged systematic closeness.

SCHOOLING BEHAVIOR

Hake tend to form large schools over the Continental Shelf and are found usually near the bottom during daylight (fig. 3). Their appearance in schools appears to be related to availability of food. Hickling (1927) elaborated on the availability of European hake as related to euphausiid, *Meganyctiphanes norwegica*, concentrations. Alton and Nelson (1970) have also reported on the availability of Pacific hake related to the species of forage organisms.

DIEL MOVEMENT AND FEEDING BEHAVIOR

Hake undertake diel vertical migrations in which they move away from the seabed at night and return to the bottom near dawn. This migration is associated directly or indirectly with feeding behavior. Hickling (1927) reported that European hake move off bottom at night in apparent pursuit of euphausiids and other food organisms, which themselves undertake nocturnal migrations. Rattray (1947), Davies (1949), and Jones (1967) report the same behavior for cape hake; Bigelow and Schroeder (1953) and Leim and Scott (1966) for silver hake; Angelescu and Fuster de Plaza (1965) for Argentine hake; and Poulsen (1958) and Vestnes, Strom, and Villegas (1965) for Chilean hake.

The feeding behavior of hake clearly demonstrates their opportunistic habits. Bigelow and Schroeder (1953) reported on the opportunistic feeding behavior of silver hake, and Best (1963) on Pacific hake. In line with this theory, Alton and Nelson (1970) have suggested that the predominance of a single food organism in the stomachs of Pacific hake reflects more on the availability of that organism than selection of any particular species.

[1] Baxter, J. L., and A. T. Pruter. 1965. Background resume for Pacific hake workshop meeting. Bureau Commercial Fisheries Exploratory Fishing and Gear Research Base, 2725 Montlake Blvd. E., Seattle, Wash. 98102. Unpublished manuscript.

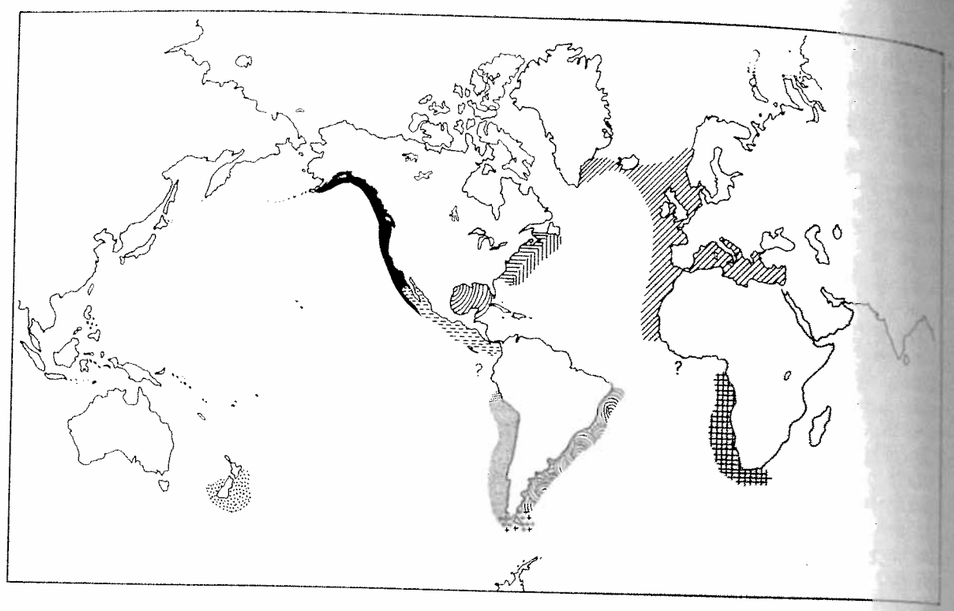

Figure 2.—Worldwide distribution of hake, genus *Merluccius*, modified after Cabo (1965).

SEASONAL AND DEPTH MIGRATIONS

Nearly all commercially important hake species exhibit a seasonal onshore-offshore depth migration. Generally, adult and juvenile European hake move inshore during the spring, adults for spawning and juveniles for feeding. After spawning the adults move back into deep water and are later joined by the juveniles in wintering areas (Hickling, 1927). Although European hake usually move into shallow water to spawn, Hickling (1927; 1930) stated that some adults spawn in deep water. Adult silver hake and merluza display a bathymetric pattern similar to that of the European hake. It is likely, however, that merluza spend more time in the deepwater portion of their depth range than do European hake because of the long spawning period of merluza (Hart, 1947; Bigelow and Schroeder, 1953; Angelescu, Gneri, and Nani, 1958; Fritz, 1960; de Ciechomski, 1967). Cape hake and apparently Pacific hake exhibit a reversal of the seasonal spawning cycle outlined above. These two species apparently spawn offshore in deep water during the winter (Rattray, 1947; Roux, 1949; Dreosti,

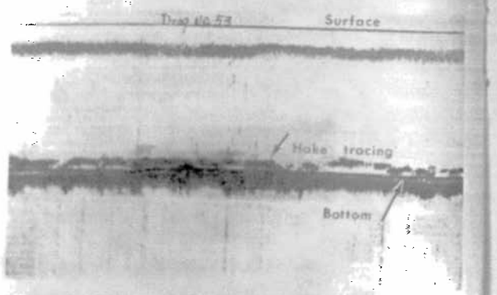

Figure 3.—Echogram showing concentrations of Pacific hake off the Washington coast (BCF Staff photo).

1967; Best and Nitsos;[2] Jones, 1967; Nelson, 1967). The migratory habits of the Chilean hake are unique among hakes in that sexually mature specimens of intermediate length move offshore to spawn during the spring and subsequently return to shallow water (Poulsen, 1958; Vestnes, Strom, and Villegas, 1965; Lengerich N., 1965).

Circumstantial evidence suggests that Pacific hake undertake a latitudinal seasonal movement in addition to the apparent depth migration. During the fall the bulk of the population shifts toward the south, off California, and then returns to more northerly waters of Oregon and Washington during the late spring, summer, and early fall (Nelson, 1967; Tillman[3]). Leim and Scott (1966) suggested the same type of migration for the silver hake. Irrespective of their spawning migrations, however, the presence of Pacific hake inshore appears to coincide with feeding activity in upwelling productive areas (Tillman, see footnote 3).

REPRODUCTIVE BEHAVIOR

Unlike inshore demersal schools of Pacific hake, offshore spawning populations are often found concentrated or dispersed at intermediate depths within the water column and apparently do not exhibit marked diel vertical movements. A physiological change might be responsible for this lack of diel movement, which has been observed for both the coastal and Puget Sound populations of Pacific hake (Nelson, 1967).

Hickling (1927) and Hart (1947), respectively, stated that the European and Argentine hakes stop feeding before spawning and feed ravenously afterward. This behavior corresponds to observations on spawning populations of hake in Puget Sound (Nelson, 1967).

In spawning schools of Pacific hake sex ratios favor males. Tillman (see footnote 3) pointed out that the percentage of males in spawning populations may be twice that of inshore, feeding populations for coastal Pacific hake. Larkins, Shippen, and Waldron[4] found similar sex ratios for spawning Pacific hake in Puget Sound and offered the explanation that males concentrate on the spawning grounds while the females are transient (i.e., the latter arrive, ripen, spawn, and then move out).

With the exception of the two dominant South American species, reports indicate that hakes have brief annual spawning seasons variable by species throughout the year. Most species spawn from spring to early fall (Hickling, 1933; Raitt, 1933; Bigelow and Schroeder, 1953; Fritz, 1960; Leim and Scott, 1966; Jones, 1967; Marak, 1967). The European hake in the Adriatic, cape hake, and the Pacific hake, however, spawn during winter (Ahlstrom and Counts, 1955; Paul, 1960; Basioli, 1965; MacGregor, 1966). Hickling (1927) suggested that the spawning time of geographically distinct populations of European hake varies clinally by latitude — the more northern populations spawn later in the year than the southern. The same phenomena has been reported for the Pacific hake (Larkins et al., see footnote 4).

The Argentine and Chilean hake appear to spawn continuously or several times each year. Although the Argentine hake shows a pronounced increase in reproductive activity from November to February (Hart, 1947; Angelescu, Gneri, and Nani, 1958; de Ciechomski, 1967), and the Chilean hake, a pronounced peak during October and November (Poulsen, 1958; Fischer, 1959), both appear to spawn from July through April.

EGG AND LARVAL DEVELOPMENT

The European hake (Graham, 1956) cape hake (Matthews and de Jager, 1951), silver hake (Bigelow and Schroeder, 1953), Chilean hake (Poulsen, 1958), and Pacific hake (Ahlstrom and Counts, 1955) apparently produce transparent, spherical pelagic eggs that hatch

[2] Best, E. A., and R. J. Nitsos. 1966. Length frequencies of Pacific hake *(Merluccius productus)* landed in California through 1964. California Department of Fish and Game, Fisheries Laboratory, Terminal Island, Calif. Unpublished manuscript, 7 pp.

[3] Tillman, Michael Francis. 1968. Tentative recommendations for management of the coastal fishery for Pacific hake, *Merluccius productus* (Ayres), based on a simulation study of the effects of fishing upon a virgin population. Masters thesis. University of Washington, 197 pp.

[4] Larkins, Herbert, Herbert H. Shippen, and Kenneth D. Waldron. 1967. Features of a northern Puget Sound hake population. Bureau of Commercial Fisheries Biological Laboratory, Seattle, Wash. Unpublished manuscript, 19 pp.

into pelagic larvae. The incubation period of the eggs is from 2 to 14 days. Graham (1956) reported that eggs of European hake hatch 10 to 14 days after fertilization. Artificially fertilized and reared eggs of cape hake hatched after 2 days of incubation (Matthews and de Jager, 1951). Bigelow and Schroeder (1953) assumed that the incubation period of silver hake eggs was 2 days at 44.6° to 55.4° F., whereas Marak (1967) concluded that the incubation period of offshore hake eggs was 6 to 8 days. Chilean hake eggs required 4 days to hatch when artificially incubated at 54.5° to 59.0° F. (Poulsen, 1958).

Newly hatched larvae of hake generally are undeveloped. Pacific hake emerge before a functional mouth develops and before the ocular pigment appears (Ahlstrom and Counts, 1955). The time between hatching and the development of a functional mouth is 7 to 14 days for the European hake (Graham, 1956), 36 hours for the cape hake (Matthews and de Jager, 1951), and 4½ days for the Chilean hake (Fischer, 1959). During the early stages of their postembryonic existence hake are apparently sustained by nutrients from their large yolk-sacs.

LENGTH OF PELAGIC EXISTENCE

The length of pelagic existence for young hake varies among species. The eggs and larvae of the European and cape hake have prolonged pelagic existence; they settle to the bottom at the end of their second year of life (Hickling, 1933; Rattray, 1947; Graham, 1956). Among other hake species, however, a long pelagic life is not apparent. Silver hake descend to the bottom near the end of the first summer or during the first autumn, after they complete their larval development (Bigelow and Schroeder, 1953; Fritz, 1960). Young Chilean hake spend 2 to 3 years in deep water where they are spawned then move shoreward to enter the demersal inshore population (Poulsen, 1958). Juvenile Pacific hake apparently have a pelagic existence for at least 1 or 2 years (Tillman, see footnote 3).

GROWTH

Generally, male hake grow more slowly than females. For European hake the differential growth rate between males and females does not become readily apparent until the third year of life (Bagenal, 1954). The growth rates of silver and Chilean hakes are comparable to that of the European hake (Bigelow and Schroeder, 1953; Poulsen, 1958), whereas cape hake grow more slowly than do the other species (Jones, 1967). The length at maturity of Chilean hake varies clinally by latitude — shorter toward the north (Poulsen, 1958). Best (1963) stated both sexes of Pacific hake mature at about the same age and length (3-4 years at 15.75 inches); Tillman (see footnote 3) indicated that Pacific hake exhibit sex-specific rates of growth in which females ultimately become larger than the males.

SIZE COMPOSITION

Studies have shown that hake separate according to size. Tillman (see footnote 3) reported that only mature Pacific hake are found at the northern end of their distribution (excluding Puget Sound), whereas mature as well as younger and smaller specimens appear more southerly. Reports on other hake populations indicate that the largest specimens are generally in deeper waters (Bagenal, 1954). Poulsen (1958) reported that small and very large Chilean hake are found offshore in deep water, whereas medium to large specimens predominate in coastal waters.

HISTORICAL DEVELOPMENT OF THE WORLD HAKE FISHERIES

Relatively large commercial fisheries have been established for at least six different kinds of hakes, whereas the five species listed below are generally unreported in world fishery statistics.

1. Offshore hake, *Merluccius albidus* (Mitchill).

   Distribution.—Along the Atlantic coast of the United States from Georges Bank southward, overlapping areas occupied by the silver hake beyond the 50-fathom isobath (Cabo, 1965; Leim and Scott, 1966; fig. 2).

2. *M. magnoculus* Ginsburg.

   Distribution.—Gulf of Mexico (Ginsburg, 1954; fig. 2).

3. *M. polylepis* Ginsburg. - (including records of *M. australis* (Hutton) from South America).

   Distribution.—Off Chile and the tip of South America (Ginsburg, 1954; fig. 2).

4. Panamanian hake, *M. angustimanus* Garman.

   Distribution.—Ranges north along western Central and North America, from the Gulf of Panama into the Gulf of California (Lavenberg and Fitch, 1966) to offshore from Puristima, Mexico, (Cabo, 1965) northward to Del Mar, Calif., (Ginsburg, 1954; fig. 2).

5. New Zealand hake, *M. australis* (Hutton)

   Distribution.—Known from Chatham Island, South Island of New Zealand and northward to East Cape on North Island (Hart, 1948; fig. 2).

EUROPEAN HAKE FISHERY

Species: *Merluccius merluccius* (Linnaeus) - including subspecies *M. m. atlanticus* Cadenat; *M. m. mediterraneus* Cadenat; *M. m. senegalensis* Cadenat; *M. m. candenati* Doutre.

The European hake fishery was simultaneously developed by several western European nations, and European hake was an important constituent of the diet for people throughout western Europe during the latter half of the past century (Hart, 1948). By the turn of the century, its popularity decreased in Britain when the church relaxed emphasis on lenten fare and improved fishing technology provided greater quantities of more choice gadoid species from northern waters. This decline of the hake popularity reversed when modern trawling, especially steam trawling, began to overexploit nearby fishable stocks, and when fried-fish shops improved the demand for cod-like fishes (Hart, 1948).

France, Portugal, and Spain, unable to capitalize on distant fisheries, relied on the local hake resource, particularly throughout the Mediterranean (Hart, 1948). At the beginning of World War I European hake stocks were greatly reduced. During the war, however, these stocks showed signs of recovery, and catches began to increase. The cycle of depletion and recovery was repeated up to and during World War II, (Hickling, 1946; Hart, 1948; fig. 4). Since then hake landings have decreased in the United Kingdom to a level comparable with Italy (fig. 4).

Italy's 1958 entry into the fishery illustrates the expansion and shift of effort from traditional European grounds to areas off the coast of Africa and adjacent Mediterranean countries (Hart, 1948; Food and Agriculture Organization of the United Nations, 1966). Spain, Portugal, and France lead the western European nations in hake landings, apparently as the result of greater effort on the new fishing grounds (fig. 4).

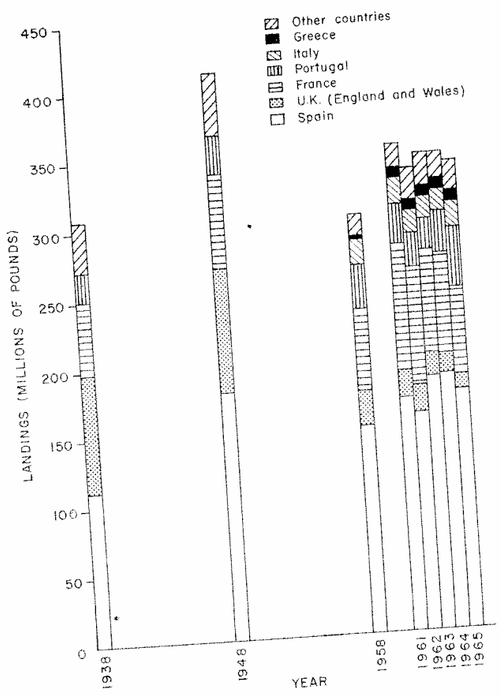

Figure 4.—Landings of European hake, *M. merluccius*, by country (Food and Agriculture Organization of the United Nations, 1966).

Fishing Methods and Fleet

The European hake fishing has kept pace with modern technology. During the early stages of the fishery handlines and nets were used. Fish taken by handlines brought higher prices than those taken by nets (Hart, 1948). Handlines continue to provide high-quality hake in Spain (Capont, 1961), and a midwater longline fishery has been reported off Tarbert (Bagenal, 1954). Trawlers have been modified in various ways and have evolved from smacks to the modern refrigerated vessels that constitute today's offshore fleets (Grzywaczewski, Huelle, Szmid, and Swiecicki, 1959; Cutting, 1961; Remy, 1961; Capont, 1961; Houk, 1961). To harvest African hake stocks, some western European nations have designed large offshore trawlers that have a greater range and can remain at sea for longer periods than their predecessors. This change has created a need for more skillful crews and more elaborate holding facilities than for vessels participating in the shore-based fishery (Grzywaczewski et al., 1959; Cutting, 1961). The distant-water trawlers are capable of refrigerating and salting fish, whereas the shore-based boats essentially haul fresh (iced) fish, thus limiting their operational time to 2 to 3 weeks.

On-deck processing of freshly caught hake has been vastly improved on vessels fishing off the northeastern Africa coast. Hake in these waters have a protozoan parasite that destroys muscle tissue soon after capture (Cutting, 1961; Cabo, 1965). Unless properly dressed and frozen before rigor mortis, the flesh becomes "pulpy" and unpalatable.

Distribution and Major Fishing Grounds

The European hake ranges from Norway and the Skagerrak and from west of Scotland, southward along the edge of the European Continental Shelf to Dakar on the coast of Senegal — a local race is reported from Cape Verde. It is common throughout the Mediterranean, and an occasional fish is caught off Iceland and Greenland and in the southern North Sea (Norman, 1937; Hart, 1948; Bagenal, 1954; fig. 2). Hart (1948) suggested that the wide range probably results from the diverging current systems off the west coasts of Europe and North Africa; to the north are relatively warm currents that move northward off Europe, whereas a relatively cold current flows southward along the northwestern Africa coast.

Major fishing effort is expended on concentrations that occur along the west coasts of Scotland, Ireland, and the northwest coast of Africa, at depths to 300 fathoms (Graham, 1956; fig. 2) and in the Mediterranean (Hart, 1948; fig. 2).

Management

Because of international participation in the western European hake fishery, cooperation of all nations using these stocks is necessary for effective management. Unlike other international fisheries, full cooperation was not achieved until the stocks were seriously depleted (Hickling, 1946; Graham, 1956; Engholm, 1961). During the 1930's, British biologists unilaterally adopted a scheme of regulating mesh sizes as a means of managing the hake fishery (Graham, 1956). This management practice was designed to increase the size of the stocks and their subsequent yield by increasing the survival of the youngest age groups (Gulland, 1956; Engholm, 1961). The scheme was approved in principle by an international conference held in 1936 and 1937, and adopted by the International Conference on Overfishing in 1946. The latter conference established a Permanent Commission with powers to define and enforce regulatory measures. In 1954 a minimum mesh size was adopted and was required for boats fishing between lat. 48° N. and 62° N. and long. 42° W. and 32° E. In 1956 the minimum mesh size was again increased following selectivity experiments by the International Council for the Exploration of the Sea, the scientific body adopted by the Permanent Commission as its investigative arm (Engholm, 1961).

Increased use of European hake stocks from traditional areas together with fishing on new grounds created a need for the Northeast Atlantic Fisheries Convention in 1959. This meeting resulted in the expansion of the management area southward to lat. 36° N. and eastward to include the north coast of the Soviet Union (fig. 2). The Permanent Commission was given power to regulate by other measures,

such as seasonal restrictions, area closure, or catch quotas. The traditional European hake grounds are now regulated by an international convention; new grounds, however, are excluded and management in these areas is at the discretion of the participating countries (Engholm, 1961; fig. 2).

CAPE HAKE OR STOCKFISH FISHERY

Species: *Merluccius capensis* Castelnau - including *M. m. polli* Cadenat; *M. m. paradoxas* Franca.

At the end of the 19th century, South Africa began the fishery for cape hake or stockfish. A new inland market created by technological advances in cold storage facilities and improved railway transportation led to the import of steam trawlers from the United Kingdom (Dreosti, 1961).

The cape hake, despite its poor keeping quality, is the most valuable commercial species landed in the Union of South Africa (Food and Agriculture Organization of the United Nations, 1966). Fish are headed, gutted, and iced for fresh fish markets; heads and offal are reduced to white-fish meal; and vitamin A is extracted from the livers (Dreosti, 1961). The best of the trawl-caught fish are filleted and smoked. In addition quantities are salted, dried, and canned (Dreosti, 1961). Smoked fillets and frozen blocks of hake are exported to European markets (Marchand, 1935; Pacific Fisherman, 1966). During the last decade, quick-freeze plants have been developed to produce home convenience products, such as frozen fillets and fish sticks (Dreosti, 1961).

The cape hake fishery began off Cape Peninsular and then moved northward to the Luderitz grounds (about 800 miles north of Cape Town) as foreign vessels began to participate in the fishery. Part of the South African fleet was diverted to the northern grounds but there the catch rates declined and the fishery was not profitable (Jones, 1967; fig. 2). The fleet soon returned to the Cape region.

Landings of cape hake have increased steadily during recent years (fig. 5). In the early 1960's Japanese and Spanish exploratory vessels appeared along the western coast of Africa, preceding the beginning of a large

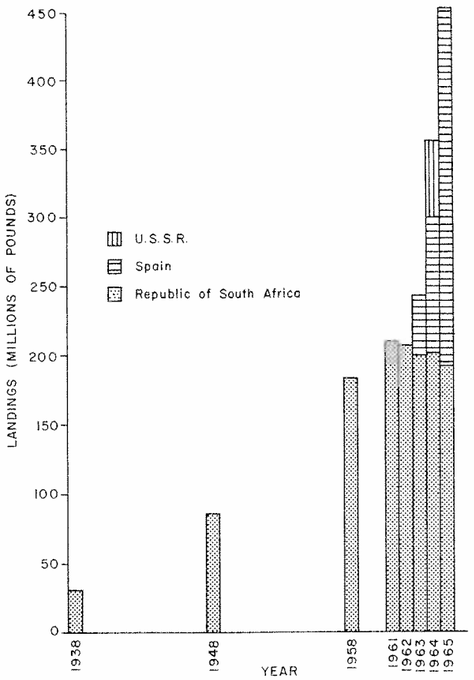

Figure 5.—Landings of cape hake, *M. capensis*, by country (Food and Agriculture Organization of the United Nations, 1966).

foreign fishery for hake off the continent. Soon the U.S.S.R., Israel, West Germany, Portugal, Poland, and Greece joined the foreign fleet. As a result the total landings have increased from 100,000 tons in 1961 to over 200,000 tons in 1965 (Jones, 1967; fig. 5).

Fishing Methods and Fleet

During the early developmental stage of the cape hake fishery, bottom trawlers competed with handliners in shallow water (40-80 fathoms) for the resource, but now trawlers completely dominate the fishery and a considerable portion of the catch comes from 100 to 300 fathoms (Marchand, 1935; Smith, 1961). Jones (1967) reported that most of the South African fishing fleet is equipped primarily for a nearshore fishery, whereas the foreign fleets are equipped for an offshore fishery and have

large freezer trawlers with or without factory facilities.

Distribution and Major Fishing Grounds

The cape hake ranges from Port Elizabeth in the southeast, off South Africa, over the Agulhas Bank in the south, and northward along the west coasts of South and Southwest Africa to about southern Angola (Jones, 1967; fig. 2). Under the influence of the cold, northward flowing Benguela Current, this hake is most abundant on the west coast and ranges as far north as Angola, lat. 10° S. The warm, southward flowing Mozambique Current limits its northern range on the east coast to only as far north as Natal, lat. 28° S. (Hart, 1948).

Management

The cape hake fishery is regulated only by the South African Government. For local trawlers minimum cod end mesh size is in effect and no hake may be discarded at sea (Jones, 1967). Apparently the international fishery uses the same mesh size as the South African fishery (Jones, 1967).

SILVER HAKE FISHERY

Species: *Merluccius bilinearis* (Mitchill).

Prior to the mid-19th century the silver hake or whiting was discarded as trash because of its poor keeping qualities. Silver hake did not salt well, and the flesh became soft and tasteless unless refrigerated or eaten very soon after capture (Jensen, 1967). In about 1840 the New England fisherman began catching silver hake for the local fresh fish markets; later it was used as bait in a hook and line fishery for spiny dogfish, which was intended for guano and oil (Jensen, 1967). A limited fishery for hake continued during the 1920's, mostly to supply fried-fish shops in north-central United States. An active food fishery began in the 1930's when a market for frozen hake was developed (Jensen, 1967). This market continued to grow, and by 1940 nearly half of the annual catch was being frozen and represented as much as 11 percent of the total frozen fish produced in the United States (Hart, 1947).

In recent years, silver hake have been made into meal for the animal food and other industrial markets (Fritz, 1960; Jensen, 1967), but human consumption still accounts for the greatest proportion of the U.S. catch. Silver hake are frozen in the round, headed and gutted, or filleted (Fritz, 1960).

Product diversification provided the basis for the expansion of the fishery into the second most important industrial species on the east coast (Fritz, 1960). The entry of the U.S.S.R. in 1962 further expanded the fishery, which is now the world's largest hake fishery in weight landed (fig. 6). The United States landings have remained relatively constant during the last decade, but the Soviet high-seas fleet now catches over six times that amount (fig. 6).

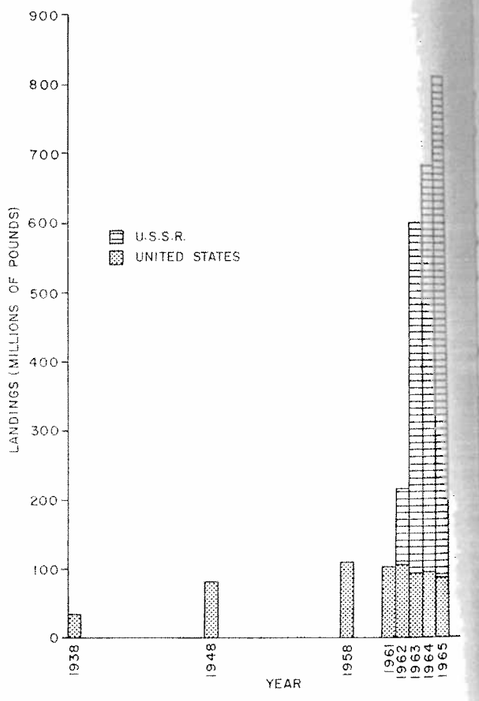

Figure 6.—Landings of silver hake, *M. bilinearis*, by country (Food and Agriculture Organization of the United Nations, 1966).

Fishing Methods and Fleet

The silver hake fishery began inshore with pound and trap nets. As the market grew during the 1930's, the New England trawl fishery expanded to meet increased demands for frozen hake (Hart, 1947; Fritz, 1960). During the 1940's, an increasing number of U.S. trawlers began to harvest hake along the entire coast, inshore as well as offshore (Taylor, Bigelow, and Graham, 1957; Fritz, 1960). The Soviet effort is strictly a high-seas operation. To compete with Soviet fishing the United States fleet has undertaken a program of gear and vessel modernization.

Distribution and Major Fishing Grounds

The silver hake ranges along the Atlantic coast of Canada and the United States from the southern and eastern part of the Gulf of St. Lawrence and southern Newfoundland to off South Carolina (Ginsburg, 1954; Leim and Scott, 1966; fig. 2). Hart (1948) linked the northerly, abundant part of the distribution with the major hydrographic feature of the area, the Labrador Current. The silver hake is caught commercially along the inshore waters of the North Atlantic coast over Georges Bank, rarely in depths over 100 fathoms (Fritz, 1960; Leim and Scott, 1966).

Management

Should it become necessary, in face of the intensified effort by the Soviets and United States, the ICNAF (International Convention on Northwest Atlantic Fisheries) has the authority to apply regulatory measures to conserve the silver hake stocks within the ICNAF area (Engholm, 1961).

ARGENTINE HAKE OR MERLUZA FISHERY

Species: *Merluccius hubbsi* Marini.

The fishery for the merluza or Argentine hake began in the 1920's as a small, shallow-water trawling industry at the mouth of the Rio de la Plata. Landings were first marketed in Montevideo, then in Buenos Aires, following the failure of the Uruguayan enterprise (Hart, 1947, 1948). From its inception, the fishery for merluza was based on a fresh-fish market (Anonymous, 1961), but its growth was limited by two factors — merluza were infested with a protozoan parasite, which affected their keeping quality (Angelescu et al., 1958), and investment capital was not available for the fishery. Thus the technology required for proper delivery and storage of high-quality seafood products did not develop. A flourishing fresh-fish market, however, did develop in Buenos Aires where quality fish could be obtained from nearby fishing grounds (Anonymous, 1961).

Although the industry was technologically depressed in its early stages, refrigeration and quick-freeze facilities have become available within the last decade, and the city of Mar del Plata has become a center for frozen fish (Anonymous, 1961). At first frozen fillets were used for local consumption (Anonymous, 1961), but later, additional quantities were prepared for export to the United States as frozen fish blocks (Pacific Fisherman, 1966). Total catches have continued to increase in recent years (fig. 7).

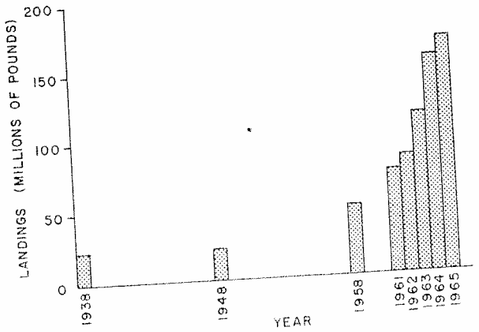

Figure 7.—Landings of merluza, *M. hubbsi*, in Argentina (Food and Agriculture Organization of the United Nations, 1966).

Fishing Methods and Fleet

The merluza is caught principally by the Argentine trawl fleet, which is relatively small and is divided between an inshore and an offshore operation. Vessels in the coastal fishery have 44 to 130 gross tonnage, whereas the offshore trawlers have 144 to 372 gross tonnage (Anonymous, 1961). To supply increased market demands, the offshore fleet tried new

large catches of merluza when the gear was fished off bottom. Occasionally two-boat trawling has been undertaken (Argentina, Secretaria de Marina Servicio de Hidrografia Naval, 1966).

Distribution and Major Fishing Grounds

Hart (1947), Angelescu et al. (1958), and Cabo (1965) set the Straits of Magellan and Tierra del Fuego as the southernmost limit of merluza distribution. It mixes there with the Chilean hake, *M. gayi* and *M. polylepis* (Cabo, 1965) and ranges north along the east coast of South America to the convergence of the inshore Falkland and offshore Brazil currents (Hart, 1948). This convergence of northerly flowing cold water and southerly flowing warm water varies seasonally but generally occurs at about lat. 30° S. off southern Brazil (fig. 2).

Most of the fishing is on the Bonaerense section of the northern Argentine Continental Shelf (Anonymous, 1961). Exploratory surveys have shown that the species is abundant as far south as the southern Patagonian region (lat. 50-54° S.); however, insufficient local markets and inadequate technology have limited the fishery to the northern region (lat. 42-46° S.) (Hart, 1946). The present deepwater fishery operates in depths between 55 and 135 fathoms (Angelescu et al., 1958; Angelescu and Fuster de Plaza, 1965).

Management

Despite recent attempts to increase production of merluza, the stocks of hake off Argentina appear to be sufficient to withstand the present fishing effort and are in little danger of overexploitation (Pacific Fisherman, 1966).

CHILEAN HAKE FISHERY

Species: *Merluccius gayi* (Guichenot) - including *M. gayi peruanus* Ginsburg and *M. g. gayi* (Guichenot).

During the 1940's the Chilean hake was marketed only as a fresh food item (Lengerich N., 1965). In the mid-1950's the demand for fish meal became so great that the demands of the fresh market were not filled. German fishing vessels with modern trawl gear were called in by fish meal plants to supply the increased demand (Poulsen, 1958). In the early 1960's a large reduction industry developed in two areas: a site in northern Chile produced fish meal for export, and another in central Chile prepared fish meal for feeding to local pigs and poultry. Landings show the rapid development of these industries (fig. 8).

The Chilean Government imposed catch limits that suppressed the meal industry (Tilic and Maschke, 1965). Although a market exists, the supply continues to lag behind demand (Tilic and Maschke, 1965; Tilic and Mery, 1966). As a result of these production limits the Chilean hake industry is now seeking a greater economic return by processing frozen hake and fish protein concentrate, and deemphasizing reduction. New plants are freezing hake for export; more plants are being built for this purpose. With existing production quotas, investors believe that they will receive greater economic return by supplying the frozen fish market than the fish meal market (Tilic and Maschke, 1965).

In Quintero, Chile, a plant uses hake to produce fish protein concentrate and canned fillets (Institute of Marine Resources, 1965). The high-quality, inexpensive, flourlike concentrate derived from hake is suitable as a human diet supplement. The product is odorless and tasteless and can be readily transported and

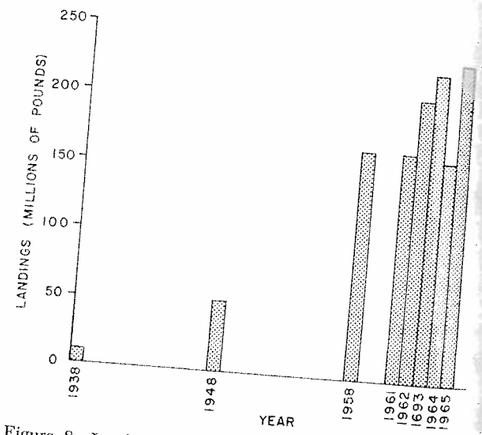

Figure 8.—Landings of Chilean hake, *M. gayi*, in Chile (Food and Agriculture Organization of the United Nations, 1966).

stored for use in programs supported by the National Health Service of Chile (Allen, 1963). Because Chile is relatively poor in protein (Tilic and Maschke, 1965), this new use of hake may bring about another possible change in emphasis on the use of hake.

Fishing Methods and Fleet

Before 1951 the hake fishery consisted of Chilean fishermen working from small boats with nets or hook and line. The Chilean hake fishery is principally land-based and is now operated by fewer than 50 trawlers of less than 110-gross ton capacity (Institute of Marine Resources, 1965). An inshore, summer fishery is operated by small boats using handlines (Vestnes, Strom, and Villegas, 1965).

Distribution and Major Fishing Grounds

Influenced by the cold, northerly flowing Peru Current, the Chilean hake is distributed along much of the west coast of South America. Hart (1948) set the northern limit at Paita in northern Peru at lat. 4° S., and Cabo (1965) set the southern extreme of its distribution at the Straits of Magellan and Tierra del Fuego. In the south the Chilean hake apparently intermingles with other hake species (fig. 2).

Throughout its range, the Chilean hake is known to be concentrated only in northern and central Chile where it is the basis of an extensive trawl fishery (Hart, 1948; fig. 2). Although the complete depth distribution is not known, dense schools of Chilean hake are fished between 28 and 83 fathoms (Poulsen, 1958). Large stocks of hake have been reported from the southern region; this area, because of its wide Continental Shelf, offers promising trawling grounds (Institute of Marine Resources, 1965). The Chilean Government is now studying the feasibility of developing the potential to the south (Vestnes, Strom, and Villegas, 1965; Vestnes, Strom, Saetersdahl, and Villegas, 1965; Vestnes et al., 1966; Del Solar, 1968).

Management

Owing to the rapid development of the hake fishery during the late 1950's, landings became so large that extinction of the hake stocks was feared by the Chilean Government. Although this fear was unfounded biologically, it continued to exist, and in 1961 limits were imposed on production of the fish meal plants as a means of conserving the stocks (Tilic and Maschke, 1965).

PACIFIC HAKE FISHERY

Species: *Merluccius productus* (Ayres).

Until recently, fishermen regarded the Pacific hake as an abundant nuisance. The presence of hake has been evident for at least the past one thousand years (Soutar, 1967). Fishermen trawling for other species often have shifted to grounds with no large schools of hake (Jones, 1960) and gill netters have been plagued by surface-feeding schools at night (Clemens and Wilby, 1961). Exploratory surveys by the United States and the Soviet Union showed that Pacific hake was a large undeveloped resource, and that it was the most abundant gadid (by weight) in the northeastern Pacific Ocean. The U.S. estimate of the standing stock of Pacific hake in waters from Oregon to British Columbia is about 1.5 billion pounds (Alverson, 1968). Alverson, Pruter, and Ronholt (1964) showed in trawl surveys off Oregon and Washington that the hake was the most abundant species at depths between 50 and 99 fathoms and was always one of the three most abundant species taken between 100 and 299 fathoms.

CalCOFI (California Cooperative Oceanic Fisheries Investigations) surveys off the California coast showed that hake larvae represent 19 percent of the total larvae taken for a 15-year period (Ahlstrom, 1954) and rank second in abundance to northern anchovy larvae (Ahlstrom, 1965; MacGregor, 1966). A standing stock of 4 to 8 billion pounds of hake has been estimated from these surveys (Ahlstrom, 1968).

Obviously industry did not bypass the hake resource for lack of abundance. In northern California, a small industry based on incidentally caught trawl species ground and froze fish to be fed to pets and fur-bearing animals (Best, 1959; Nitsos and Reed, 1965). Hake accounted for about 25 percent of the total California animal food catch (Radcliffe, 1920; Best, 1961;

fig. 9). During the 1930's, the use of Pacific hake for pet and mink food declined. Bones were difficult to grind up and often became lodged in the throats of animals fed processed or raw hake (Baxter and Pruter, see footnote 1). A diet high in raw hake caused "cotton-fur", an abnormality of domestic fur bearers, which resulted in an economic loss to the farmer (Stout, Oldfield, and Adair, 1960). Unless hake were heated and treated with acid, they had to be mixed with other types of food. This requirement limited the amount of hake that could be used in the animal food industry.

The development of the Pacific hake fishery, like other hake industries, required costly handling procedures or special refrigeration equipment to provide a palatable product for the fresh or frozen markets. Without such treatment, Pacific hake will have poor texture and flavor (Paul, 1960; Heimann, 1963; Ahlstrom, 1965). An infestation of myxosporidian parasites apparently causes enzymatic proteolysis and a softening of the infected tissue shortly after the death of the fish (Patashnik and Groninger, 1964; Baxter and Pruter, see footnote 1).

A new industry for Pacific hake began in 1965. Figure 9 provides catch data for the Pacific hake from its use in a multispecies animal food industry to the new technologically

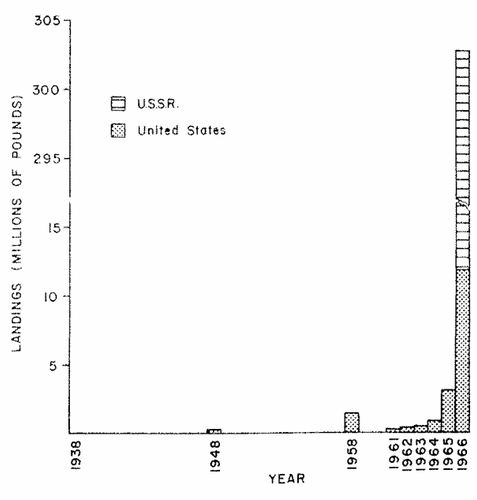

Figure 9.—Landings of Pacific hake, *M. productus*, by country (Lyles, 1968).

advanced fishery off Washington and Oregon jointly enjoyed by the Americans and Soviets. Unlike the development of other world hake resources, this industry grew rapidly following extensive research. The intensive fishing effort was prompted by the increased demand for fish meal in the United States and food fish in the Soviet Union (Nelson, 1967). Further interest in Pacific hake resulted when the U.S. Food and Drug Administration approved regulations governing interstate sale of fish protein concentrate as a diet supplement for human consumption.

Fishing Methods and Fleet

The fishery on Pacific hake has been exclusively by trawling. At the beginning of the fishery off Washington, Oregon, and British Columbia, a technologically advanced extraction process was developed (Hipkins, 1967; Johnson and High, 1970; and Nelson, 1970). Large schools were located by the use of echo sounders, and catches were made with midwater trawls (McNeely, Johnson, and Gill, 1965; Hipkins, 1967; Nelson, 1967). Small multipurpose United States trawlers and large distant-water Soviet vessels now participate in the fishery.

Distribution and Major Fishing Grounds

The Pacific hake ranges from the Gulf of Alaska to the Gulf of California and occurs from shallow shelf waters to depths of 490 fathoms (De Witt, 1952; Clemens and Wilby, 1961; Nelson, 1967). It mixes with the Panamanian hake throughout the southern extent of its distribution (fig. 2). According to Alverson et al. (1964), major concentrations appear to be associated with the California undercurrent system, which lies between lat. 23° and 48° N., of the Pacific coast of North America (Sverdrup, Johnson, and Fleming, 1961). In the northerly part of its range the Pacific hake seldom is taken and throughout much of the Gulf of Alaska it is apparently replaced by Pacific cod and walleye pollock (Alverson et al. 1964).

The Pacific hake fisheries are concentrated in waters off the northern California, Oregon, and Washington coasts and in the inland waters of Puget Sound. Most of the catch is taken at depths of 35 to 80 fathoms (Hipkins, 1967; Nelson and Larkins, 1970).

Management

The Pacific hake fishery has not yet become complicated by conservation management problems. In joint Soviet-American meetings, biologists agreed upon a range of yield estimates in which the upper limit exceeds the landings currently taken by both fleets (Alverson and Larkins, 1969).

THE WORLDWIDE HAKE RESOURCE

In the past decade, codlike fishes contributed about 12 percent to the total world fishery landings and were second only to herringlike fishes (Food and Agriculture Organization of the United Nations, 1966). Hake of the genus *Merluccius*, in turn constituted nearly 15 percent of the 1965 total codlike fish production and has had steadily increasing landings since 1938 (table 2). Important hake fisheries occur off the coasts of Europe, North and South Africa, and North and South America.

Table 2.—Contribution by hake to the world production of codlike species

Year	Codlike fishes	Hake	
	Millions of pounds	*Millions of pounds*	*Percent*
1938	742,950.2	408.1	5.5
1948	795,860.6	654.1	8.2
1958	989,865.4	818.2	8.3
1961	1,113,323.0	904.5	8.1
1962	1,221,348.4	1,049.6	8.6
1963	1,309,532.4	1,530.7	11.7
1964	1,327,169.2	1,703.8	12.8
1965	1,424,171.6	2,012.4	14.1

Source: Food and Agriculture Organization of the United Nations (1966)

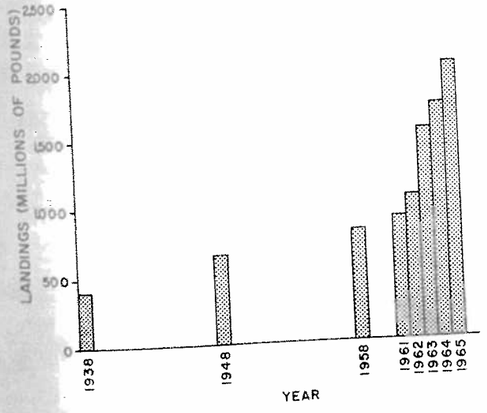

Figure 10.—World hake production, 1938-65.

Hake landings continue to increase worldwide; in 1965 the total production was over 2 billion pounds (table 2, figs. 10 and 11) for a value of nearly $60 million (fig. 12). The massive Soviet offshore fleet fishing silver hake was primarily responsible for the most recent escalation in landings (fig. 11). Excluding its value to the U.S.S.R., hake have contributed

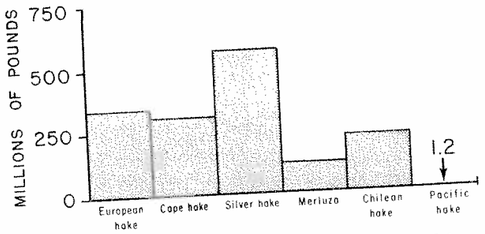

Figure 11.—Annual average hake production by fishery 1962-65.

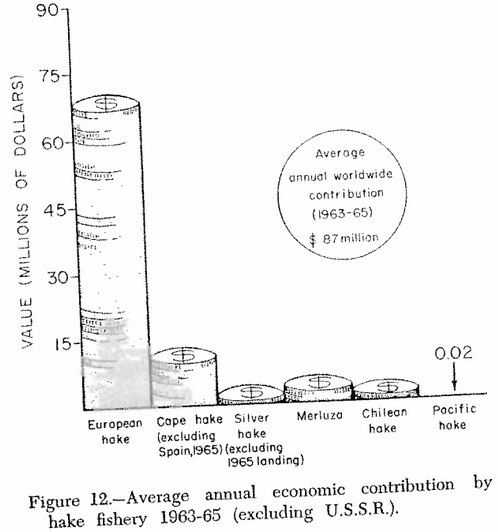

Figure 12.—Average annual economic contribution by hake fishery 1963-65 (excluding U.S.S.R.).

an average of $87 million annually to the world market, 1963-65 inclusive (fig. 12). Its value in the U.S.S.R. must be enormous to warrant the operation of a costly high-seas fleet.

SUMMARY

1. Eleven nominal species of hake are recognized in this paper. Further study may result in fewer valid species.

2. Hake are represented in all coastal areas of the Atlantic and Pacific Oceans in both hemispheres except the northwest Pacific.

3. Biologically and taxonomically, hake throughout the world are remarkably similar.

4. Hake essentially concentrate seasonally and migrate geographically and bathymetrically or both.

5. The Pacific hake and possibly the silver hake give indications of a latitudinal seasonal migration.

6. With the exception of the South American species, hakes have a relatively short spawning season.

7. The transparent hake egg is pelagic and spherical.

8. Pelagic larvae emerge 2 to 14 days after fertilization and have nonfunctional mouths.

9. European and cape hake exhibit a prolonged pelagic existence, settling to the bottom at the end of their second year of life. Other hake species assume a demersal way of life before 2 years of age. Males grow slower and mature at a smaller size than do females.

10. With the exception of Chilean hake, the largest individuals occur primarily in deep, offshore waters. Larger individuals of the Pacific hake are found at the northerly part of their onshore range.

11. With the exception of the European hake fishery which was carried on by several nations, fisheries on other hake species have been initially harvested by nearby shore-based fisheries.

12. As traditional hake fishing grounds have become overexploited, many nations have turned to resources farther afield. Russia and Spain have become dominant in the Atlantic; also, the Soviets undertake large-scale fishery operations in the Pacific.

13. Hake are taken by a variety of harvesting techniques; however, electronic detection and guided trawling have emerged as the most efficient. Improved processing techniques and larger, more sophisticated modern vessels have escalated hake landings.

14. European, cape, and Chilean hake fisheries have been variously influenced by fishery management. The European hake has been managed internationally, whereas the cape and Chilean hakes have been managed locally. The remaining three hake fisheries have not been managed, and catches reflect a balance between supply and demand.

15. Gadoid fishes (including hake) rank second in world landings of species groups and play an important role in world fisheries economy.

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