BIOLOGY OF OFFSHORE HAKE, *MERLUCCIUS ALBIDUS*, IN THE GULF OF MEXICO[1]

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ABSTRACT

Biological data of the offshore hake, *Merluccius albidus*, in the Gulf of Mexico are presented and compared with those of other species of *Merluccius*. The species has been found from Georges Bank to Rio de Janeiro, Brazil, in 192 to 1,170 m. In the Gulf of Mexico it occurs in greatest abundance in the De Soto Canyon area in depths of 350 to 1,000 m.

Merluccius albidus are segregated by size and sex on the continental slope with juveniles, males, and young females found in depths less than 550 m and large, mature females found in depths exceeding 550 m. Mature males were smaller than females and grew at a reduced rate following the onset of sexual maturity.

Males and young females were found on the upper slope and older mature females found on the lower slope. Spawning appeared to take place on or near the bottom in 330 to 550 m. Spawning in the southern latitudes appears to occur from late spring to early fall and may be more protracted at the southern limits of its range. Eggs and the earliest larval stages have been described only for *M. albidus* from New England.

Merluccius albidus are opportunistic feeders preying primarily on fishes, squid, and crustaceans. Fishes make up about 75% of their diet, with species of Merlucciidae and Myctophidae consumed most frequently. Prey species exhibited diel movement, but the similarity between day and night catch rates of *M. albidus* suggests that offshore hake do not move far off the bottom in pursuit of prey.

Density estimates suggested a small population of *M. albidus* in the northern Gulf of Mexico. *Merluccius albidus* stocks in 370 to 730 m on the De Soto Canyon slope north of Tampa, Fla., are estimated to be a minimum of 3.3 × 10^6 kg.

Species of the genus *Merluccius* are distributed worldwide in temperate and tropical waters but are exploited primarily in temperate seas. Aspects of their biology, distribution, and utilization have been reported by numerous authors (Hickling 1927, 1933; Bigelow and Schroeder 1953, 1955; Graham 1956; Fritz 1960; Lozano Cabo 1965; Marak 1967; Botha 1969, 1971; Grinols and Tillman 1970; and Nelson and Larkins 1970). Northern Gulf of Mexico *Merluccius* are considered to be divergent forms of *M. albidus* (Karnella 1973). Several of the above authors have commented on the similarity in life history patterns of various species of *Merluccius*. Offshore hake, *M. albidus*, display some of these same patterns, indicating that aspects of their life histories are similar to those documented for other species.

Biological data concerning *M. albidus* are sparse. Those reported in this paper are limited primarily to the Gulf of Mexico. This study is a composite of published accounts, data acquired during resource assessment, gear evaluation and general exploratory cruises, and results of biological studies conducted by personnel of the Southeast Fisheries Center Pascagoula Laboratory, National Marine Fisheries Service (NMFS), NOAA.

MATERIAL AND METHODS

Specimens were collected with a variety of bottom trawls (Table 1) equipped with mud rollers, loop chain, floats, and usually a tickler chain. The larger trawls (38 to 60 m headrope) were fished with wooden bracket doors and ground cables whereas the smaller trawls (12 and 22 m headrope) utilized wooden chain doors. Mesh size on the larger trawls was 7.6 cm in the wings and body, 5.1 cm in the throat, and 4.5 cm in the cod end; smaller trawls had 5.1-cm mesh throughout with 3.8 cm in the cod end. In October 1971, a 22-m trawl with a 1.3-cm inner liner was used to collect juvenile *M. albidus*. Rough bottom areas were fished with a 12-m flat or semiballoon trawl and smooth areas with larger trawls (22 to 68 m).

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TABLE 1.—Trawling gear used by the RV *Oregon II* during slope fishery surveys in the Gulf of Mexico and Caribbean Sea from June 1969 through September 1973.

Trawl size (headrope length) (m)	(feet)	Door size (length × width) (m)	(feet)	Type of door
12	40	2.4 × 1.03	8 × 3.33	Wooden chain
22	71	3 × 1.12	10 × 3.67	Wooden chain
38	125	3 × 1.22	10 × 4	Iron bound wooden bracket
40	130	3 × 1.22	10 × 4	Iron bound wooden bracket
46	150	3 × 1.22	10 × 4	Iron bound wooden bracket
58	191	3 × 1.22	10 × 4	Iron bound wooden bracket
62	204	3 × 1.22	10 × 4	Iron bound wooden bracket
68	224	3 × 1.22	10 × 4	Iron bound wooden bracket

TABLE 2.—Gonad classification code — modified from Nikolsky (1963).

U-1	Gonads undeveloped, vestigial tubes, sex determination impossible by gross examination
Female:	
F-2	Immature gonads, sex determinable by gross examination, gonads very small, uninflated
F-3	Developing gonads, small yellow or white with no eggs visible to the naked eye
F-4	Maturing gonads, filled with opaque yellow to yellowish-orange eggs detectable by the naked eye
F-5	Ripe gonads, ovaries with translucent yellowish-white to whitish-green eggs easily expelled from the genital opening by lateral pressure on the gonads
F-6	Spent gonads, ovaries collapsed and bloodshot with some eggs being reabsorbed
Male:	
M-2	Immature gonads, sex determinable by gross examination, testes very small, uninflated
M-3	Developing gonads, inflated to the same degree as those of F-3 females and white or whitish-pink in color
M-4	Maturing gonads, inflated to same degree as those of F-4 females and milky white without free running milt
M-5	Ripe gonads, fully developed with free running white milt
M-6	Spent gonads, collapsed and bloodshot

Specimens were measured at sea to the nearest millimeter standard length (SL). Additional specimens were frozen for processing ashore, and were measured in standard, fork, and total lengths (SL, FL, and TL) for computation of a conversion curve and were also processed for length-weight relationship, gonad maturation, and stomach content data. Gonad maturation stages were classified by a scheme modified from that by Nikolsky (1963) and are listed in Table 2. Ovaries were weighed to the nearest 0.1 g. Otoliths removed from selected specimens (one specimen per centimeter SL) were prepared and evaluated following Jensen (1965). Morphometric and meristic measurements were taken as defined by Ginsburg (1954).

Age-class lines were computed using techniques described by Harding (1949) and Cassie (1954) and compared with ages determined from length-frequency data.

Weights were recorded to the nearest ounce on specimens larger than 200 mm SL and to the nearest 0.1 g on smaller fish. The method of least squares using the log transformation of the general equation $W = aL^b$ was used to compute the length-weight equations for males, females, and sexes combined.

The sample design for RV *Oregon II* cruise 27 allowed for equal effort per stratum regardless of stratum size, because distributional patterns and abundance levels of *M. albidus* were undefined. The sample area (Figure 1) on the De Soto Canyon slope north of Tampa, Fla., was divided into four 90-m depth strata ranging from 370 to 730 m. Each stratum was then further subdivided into 2.5 × 15 nautical mile sample sites (12,874 hectares per site). The entire sampling area of 84 sites totaled 1,081,416 hectares. Five sample sites were randomly selected within each 90-m depth stratum from a number table; however, only four sites were sampled in stratum 4 due to a malfunction of the trawl. No special consideration in site selection was given to latitude.

Each sample site was fished with a 40-m trawl (Table 1) for 5 h at 3 knots with a 2.5:1 scope ratio (i.e., 2.5 m of wire out for each meter of depth). Drag distance was variable because of changes in the surface and bottom currents. Area swept in hectares per drag was computed by measuring the distance between the starting and ending point of each tow and multiplying by a conversion factor. An XBT (expendable bathythermograph) probe was dropped at the start and finish of each station.

Standing stock estimates were computed using an "area-swept" method. This method is computed as follows:

$$SS_i = (\bar{P}_{wi})(A_i) \quad (1)$$

where SS_i = standing stock estimate in the ith area

$\bar{P}_{wi}$ = average population expressed as kilograms per hectare in the ith area

A_i = total bottom area within the ith area.

$$SS_{tot} = \sum_{i=1}^{4} SS_i$$

where SS_{tot} = total standing stock estimate expressed as kilograms

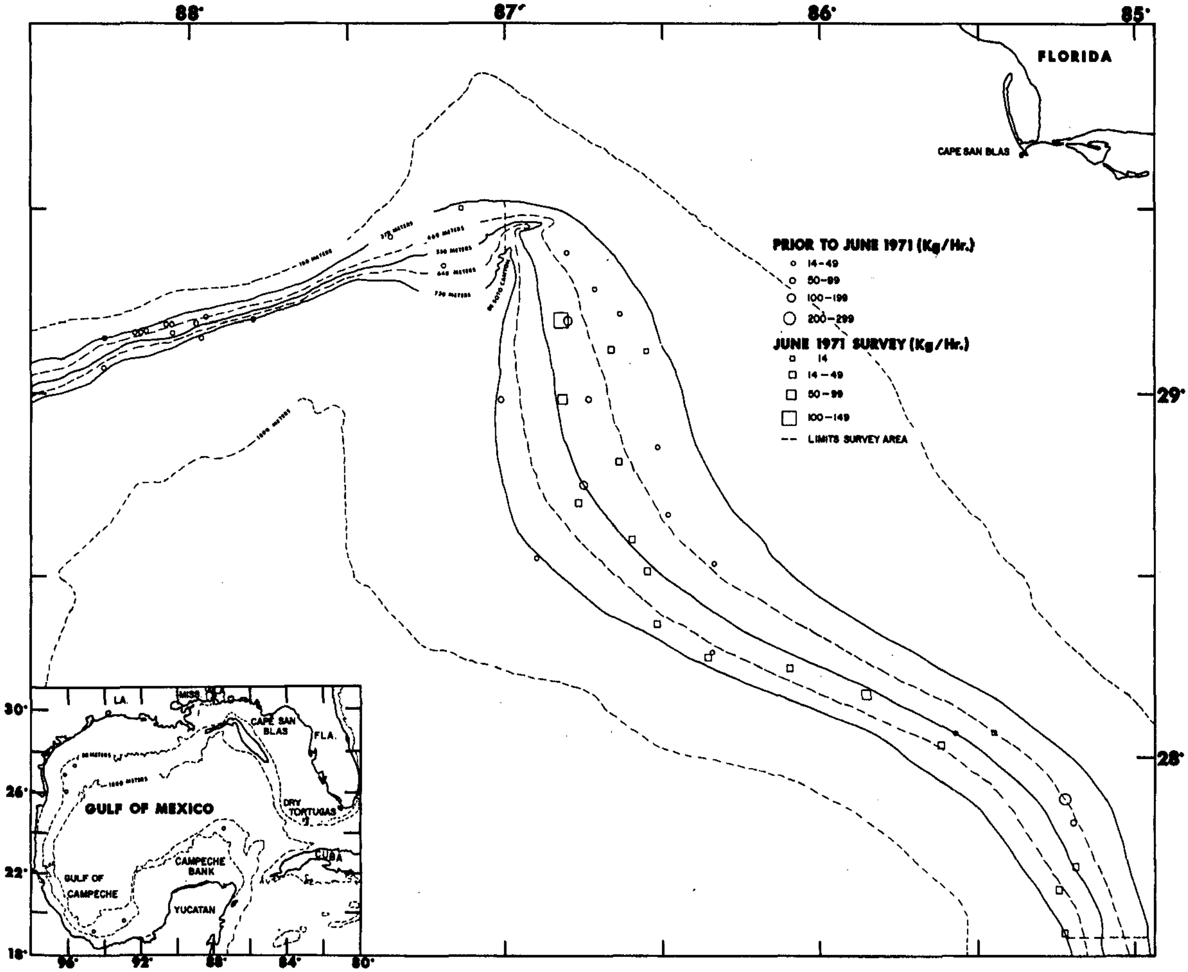

FIGURE 1.—Northeastern section of the Gulf of Mexico showing stations on De Soto Canyon slope north of Tampa, Fla., made during the June 1971 finfish survey and the Mississippi Delta slope; insert of entire Gulf of Mexico identifying all stations between 1950 and 1971 where the catch rate of *Merluccius albidus* exceeded 14 kg/h.

SS_i = the computed standing stock estimates for each area.

Confidence intervals were calculated using the weighted pooled variance method described by Snedecor and Cochran (1967):

$$S_{\bar{x}_{tot}} \sqrt{w_i^2 \, s_i^2/n_i} \qquad (2)$$

where $S_{\bar{x}_{tot}}$ = standard error of the mean
$\bar{x}_{tot}$ = mean density (kilograms/hectare) weighted by area
w_i = weighting factor based on sample size, i.e., $w_i = n_i/N$
s_i^2 = variance of density estimate for ith stratum.

The weighted pooled variance was used to reduce the variation associated with different sample sizes within each stratum.

DISTRIBUTION AND ABUNDANCE

The range of *M. albidus* in the western Atlantic extends from lat. 41°N off Georges Bank (Bigelow and Schroeder 1955) to the Orinoco Delta and possibly to the vicinity of Rio de Janeiro (Cervigon 1966). Bigelow and Schroeder (1955) reported a depth range of 92 to 1,170 m for *M. albidus* on the New England slope with approximately 75% of the population residing in depths of 185 to 550 m. *Merluccius albidus* are seldom caught by commercial hake fishermen in New England (Fritz

1960), suggesting a low population level, unavailability to the fleet, or lack of recognition by the fishermen. However, mixed commercial concentrations of *M. albidus* and *M. bilinearis* were found south of Hudson Canyon on the edge of the shelf by the RV *Albatross III* (Edwards et al. 1962) and on Georges Bank by West German stern trawlers (Mombeck 1971).

Exploratory fishing data from the Pascagoula data files showed that *M. albidus* composed 25% of the total finfish available to trawl gear between 350 and 1,000 m on the Mississippi slope and 60% between 450 and 730 m on the west Florida-De Soto Canyon slope. Several large catches containing individual fish weighing in excess of 0.45 kg have been made by NMFS vessels.

In the Gulf of Mexico, *M. albidus* have been taken at depths of 142 to 1,100 m. Between 1950 and 1971, NMFS vessels caught *M. albidus* at 73% of all trawl stations in depths of 182 to 1,100 m.

Relative apparent abundance of *M. albidus* in the Gulf of Mexico was established by computing catch rates based on historical fishing records. Highest concentrations occurred in the northern Gulf between Tampa, Fla., and the Mississippi Delta. Prior to the *M. albidus* assessment cruise in June 1971, catch rates of 14 kg/h (31 pounds/h) or greater occurred at only 37 Gulf of Mexico stations (Figure 1) of which 78% had catch rates less than 50 kg/h. These stations are primarily in the northeast quadrant of the Gulf of Mexico in depths of 370 to 930 m (Figure 1). Maximum catch rates recorded for this period in the Gulf of Mexico are as follows: north Gulf, De Soto Canyon, 640 m, 161 kg/h; east Gulf, off Tampa, 490 m, 284 kg/h; west Gulf, east of Brownsville, Tex., 430 m, 31 kg/h; south Gulf, east of Veracruz, Mexico, 540 m, 22 kg/h; and north of Campeche Bank, 550 m, 20 kg/h.

Nineteen 5-h trawling stations were completed on the De Soto Canyon slope in June 1971 to obtain biological data and estimate the size of the *M. albidus* population. Catch rates varied from 5.7 to 144.0 kg/h in depths of 370 to 730 m and averaged 38.7 kg/h (Figure 1).

Highest catch rates of *M. albidus* after June 1971 were 12.5 kg/h in 440 m on the western slope of De Soto Canyon, 15.5 kg/h in 550 m south of Dry Tortugas, and 58.5 kg/h in 420 m on the De Soto Canyon east slope. These catch rates may be artificially low, as the trawls used were not rigged specifically for catching *M. albidus*. Abundance in the western and southern Gulf of Mexico is unknown due to the considerable area of untrawlable bottom off Texas, western Louisiana, and in the Gulf of Campeche.

Merluccius albidus were caught at depths of 200 to 795 m in the Caribbean Sea including the insular slopes of the Antilles. During a 1970 trawl survey on the Caribbean slope between Belize and Aruba, it was taken most frequently at depths of 450 to 630 m north of Aruba. Caribbean trawling records give no indication of any significant concentrations of *M. albidus*. However, Cervigon (1964) reported that *M. albidus* may be of economic importance off Venezuela in depths greater than 370 m.

RELATION OF DEPTH TO SIZE AND SEX

Studies have shown that size increases with bottom depth in various species of hake (Grinols and Tillman 1970). Rohr (1972) showed that *M. albidus* segregates by size and sex on the continental slope in the Gulf of Mexico (Figures 2, 3). Juveniles of both sexes, young adult females, and adult males inhabit the upper slope (depths <550 m) while larger, mature females are concentrated on the lower slope (depths >550 m). This pattern is clearly demonstrated when plotting the male-female ratio vs. depth (Figure 3).

A similar distributional pattern of *M. albidus* was reported on the Honduran-Panamanian slope by Bullis and Struhsaker (1970) and observed by the senior author on both the western and southern Caribbean slopes from Belize to Aruba.

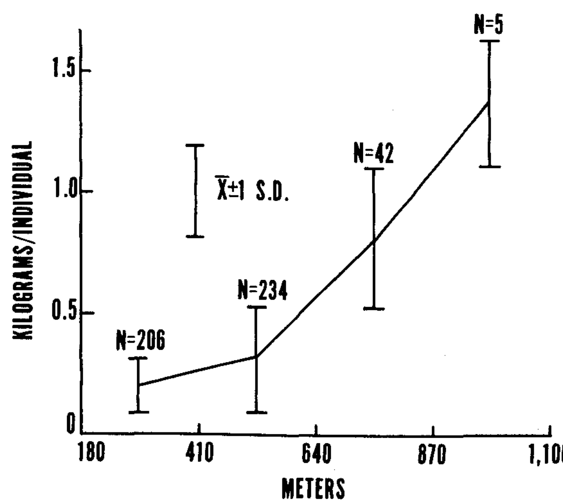

FIGURE 2.—Average weight of individual *Merluccius albidus* vs. depth for 487 trawl stations in the Gulf of Mexico.

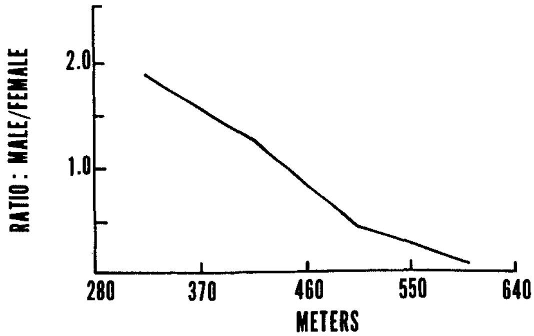

FIGURE 3.—Ratio of male to female *Merluccius albidus* decreases with increasing depth.

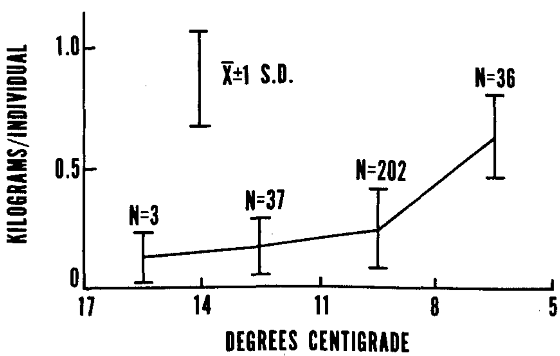

FIGURE 4.—Average weight of individual *Merluccius albidus* vs. bottom temperature for 278 trawl stations in the Gulf of Mexico.

An increase in size of *M. albidus* with increasing depths and decreasing temperature was observed in the present study (Figures 2, 4; Table 3).

REPRODUCTION

Fecundity data of *M. albidus* were not collected; however, a partially spent 680-mm SL female taken on the De Soto Canyon slope in August 1970 yielded an estimated 340,000 greenish-white eggs weighing 340 g. Advanced eggs in the ovaries of *M. productus* ranged from 80,000 in small, 350 mm SL, to 496,000 in large, 690 mm SL, specimens (MacGregor 1966). Since the estimated number of eggs in the specimen of *M. albidus* is somewhat similar to that of *M. productus*, the fecundity of the two species may be similar.

A spawning period extending from late spring to early autumn is hypothesized for *M. albidus* in the Gulf of Mexico and Caribbean Sea. Ripe fish were observed as early as May and as late as October. Running ripe males and females were taken together in September 1973 on the Mississippi Delta and De Soto Canyon slope (Table 4). Females caught in February were in an advanced resting stage, i.e., gonad maturation stage 4. Spawning occurs in New England from April to July (Colton and Marak[3]). Some species of *Merluccius* spawn throughout much of the year, although most have a short spawning period varying in time for individual species (Grinols and Tillman 1970).

Gonad maturation data suggest that spawning occurs near the bottom in depths of 330 to 550 m. Limited numbers of ripe fish were taken during cruises which surveyed both the upper and lower

[3]Colton, J. B., Jr., and R. R. Marak. 1969. Guide for identifying the common planktonic fish eggs and larvae of continental shelf waters, Cape Sable to Block Island. Biol. Lab., Woods Hole, Mass. Lab. Ref. 69-9, 15 Sept. 1969.

TABLE 4.—Date, area, and depth at which ripe *Merluccius albidus* have been collected in the Gulf of Mexico.

Date	Area	Depth (m)
	Females	
June 1970	Gulf of Campeche	360-730
Aug. 1974	Central north Campeche Bank slope	570-550
Aug., Sept. 1970	De Soto Canyon	380-770
June 1971	East De Soto Canyon and west Florida slope	370-730
Oct. 1971	East Mississippi Delta slope and west De Soto Canyon slope	550-730
May 1973	Mississippi Delta-west De Soto Canyon slope	460
May 1973	Dry Tortugas slope	372
Sept. 1973	Mississippi Delta-west De Soto Canyon slope	330-460
	Males	
Aug. 1970	Dry Tortugas slope	550
Aug. 1970	West Florida slope off Tampa, Fla.	275
Aug. 1970	East De Soto Canyon slope	390
May 1973	Mississippi Delta-west De Soto Canyon slope	357
May 1973	Dry Tortugas slope	350-550
Sept. 1973	Mississippi Delta-west De Soto Canyon slope	330-460

TABLE 3.—Range and mean fishing depths, bottom temperatures, lengths, and weights of *Merluccius albidus* sampled on the De Soto Canyon slope north of Tampa, Fla., in June 1971.

Stratum	Depth (m) Range	Depth (m) $\bar{X}$	Temperature (°C) Range	Temperature (°C) $\bar{X}$	Number fish sampled	Standard length (mm) Range	Standard length (mm) $\bar{X}$	Weight (g) Range	Weight (g) $\bar{X}$
1	370-459	409	9.3-11.0	10.1	497	47-455	234	1- 985	158
2	460-549	500	7.8- 9.6	8.3	494	215-520	299	42-1,550	360
3	550-639	577	5.6- 8.5	6.9	488	268-562	389	265-1,960	624
4	640-730	686	5.6- 6.7	6.3	392	313-575	424	315-2,070	818

slopes. Ripe males were not found at depths greater than 550 m (Figures 5, 6, 7). Since few ripe fish were caught by bottom trawls, it is possible that spawning occurs at some distance above the bottom. First time spawners appear to move down slope to spawn whereas the older maturing females (spawning for their second or more times) were found lower on the slope and moved up the slope into the spawning area.

Few spent males or females were taken during this study. Spent females may move down the slope from the spawning area to recover and then gradually move back up the slope to enter a resting stage. Alternatively, after spawning they might immediately move onto the upper slope in depths of 180 to 360 m to feed and recover, and finally move back into depths greater than 360 m to enter the resting stage.

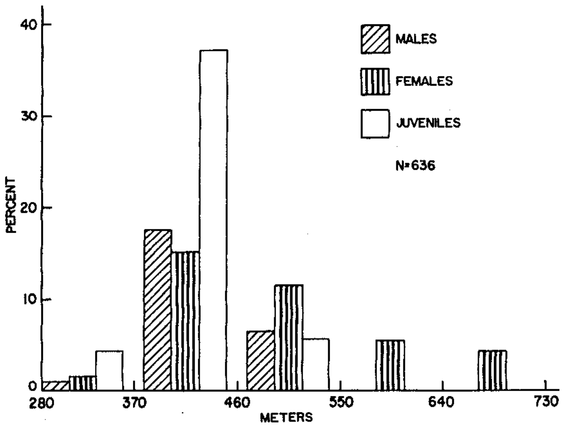

FIGURE 5.—Distribution of male, female, and juvenile *Merluccius albidus* by depth on the east Mississippi Delta and west De Soto Canyon slope in October 1971.

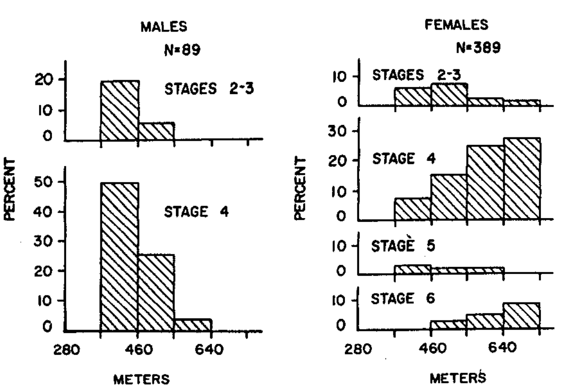

FIGURE 6.—Gonad maturation stages of *Merluccius albidus* by depth on the west Florida-De Soto Canyon slope in June 1971.

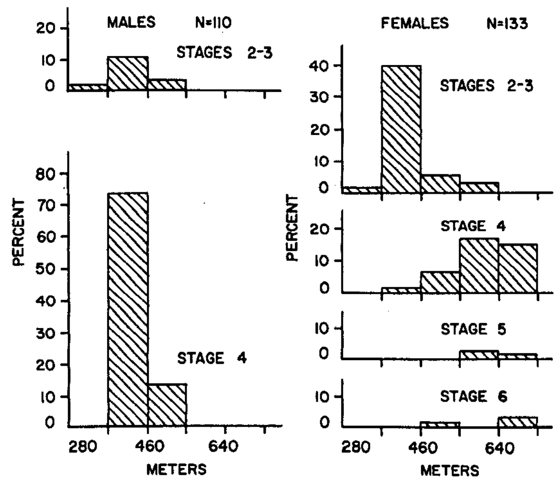

FIGURE 7.—Gonad maturation stages of *Merluccius albidus* by depth on the east Mississippi Delta and west De Soto Canyon slopes in October 1971.

European, Argentinean, and Pacific hake are reported to feed ravenously after spawning. If *M. albidus* follows this pattern, it would probably move up to the shelf edge following spawning, as a richer supply of food is available in this area. Additional deepwater samples are needed before this hypothesis can be tested.

Spawning males and females were found together at depths of 330 to 460 m but only one spent male and female were caught in the same tow.

Merluccius albidus may spawn later in the Caribbean than in the Gulf of Mexico. In November 1970, 11 of 21 females collected off Aruba in 604 m were in spawning condition. Spent females were also found in November 1970 in depths of 550 to 730 m off Colombia. The depth distribution of females in the Caribbean appears to be similar to that in the Gulf of Mexico; but data are very limited. Only one male was collected from the Caribbean.

Merluccius albidus are also distributed on the slope in relation to gonad maturation stages. Eighty-eight percent of the juveniles occurred in 370 to 460 m. They were observed at other times and at other geographic sites in the Gulf of Mexico and Caribbean Sea, but always on the upper slope between 180 and 460 m. It is possible that the distribution of juveniles seen in October is similar to their overall distributional pattern.

The distribution of gonad stages of male and female *M. albidus* on the Mississippi Delta and De Soto Canyon slopes in 1971 are shown in Figures 6 and 7. Males were found primarily on the upper slope (280 to 550 m) during both June and October. Only 1.3% of all males taken were caught in depths exceeding 550 m, with 613 m being the maximum depth at which males were taken. Females were found throughout the depth ranges surveyed (Figures 5, 6, 7).

Location of *M. albidus* on the slope appeared to be dependent on gonad maturation stage and size of individuals. In 1971, stage 4 males dominated at all depths where males were collected except in 280 to 370 m; neither ripe (stage 5) nor spent (stage 6) males were taken (Figures 6, 7). In 1973, the data showed a predominance of stage 4 males though a few ripe and spent males were found (Table 5). Males, regardless of maturation stage, were always taken in depths less than 550 m. The predominance of stage 4 male *M. albidus* in the autumn of 1971 and 1973 (Figure 7, Table 5) suggests that stage 4 is an advanced resting stage, with these fish not spawning until the following spring. The stage 4 males were probably in the spawning cycle in the spring of 1971 and 1973 (Figure 6, Table 5) and would have spawned some time during the summer based on a spring-summer spawning period for *M. albidus*.

Female *M. albidus* of all sizes and maturation stages were found throughout the depth range surveyed. Young females mixed with males and juveniles on the upper slope, but larger females predominated on the lower slope. Lower slope females, larger than 250 mm SL, caught in the autumn were in the gonad resting stage and would not spawn until spring or summer. Females in stages 2-4 were most frequently caught as they were in the prespawning and/or resting stages. The paucity of ripe or spent females caught in trawls is evident from Figures 6 and 7 and Table 5. The few ripe and spent females (stages 5, 6) caught in 1973 (Table 5) were partially a result of the depths at which fishing operations were conducted, as few stations exceeded 600 m. Ripe and spent female *M. albidus* were found lower on the slope than were stages 2-4.

Eggs and early larval stages (first 84 h) of *M. albidus* off Martha's Vineyard (New England) were described by Marak (1967), but larvae larger than 4 mm SL are unreported. Egg and early larval development of *M. albidus* in the Gulf of Mexico and the tropical Atlantic may be similar to that off New England, although hatching may be more rapid in warmer latitudes than the 6 to 8 days reported by Marak (1967). Larvae reared by Marak (1967) ranged in length at hatching from 3.05 to 3.75 mm, averaging 3.5 mm and were relatively undeveloped. The yolk was small and was rapidly assimilated after hatching, thereby necessitating early initiation of feeding.

FOOD HABITS

All hake species are opportunistic feeders (Grinols and Tillman 1970). In the Gulf of Mexico, *M. albidus* feed on a large variety of items found on and off the bottom (Table 6).

A feeding pattern based on adaptive zones of prey species (i.e., epipelagic, mesopelagic, and benthic) suggests that hake feed primarily on benthic and mesopelagic organisms (Table 7). The lack of a day-night differential in bottom trawl catch rates (Table 8) suggests that *M. albidus* feed on or near the bottom since a differential would be expected if *M. albidus* moved well off the bottom to feed.

Merluccius albidus apparently feed at about the same rate throughout the day except near dawn (0500-0700, Table 9). The higher incidence of food in the stomach during daylight hours corresponds to the time when the mesopelagic fauna are closer to the bottom. This hypothesis is reinforced as 81% of the myctophids were found in stomachs from fish caught during daylight hours (0700-1800), and in only 1% of the stomachs from fish caught at dusk (1800-2000). The mesopelagic fauna leaves the bottom at dusk and moves higher in the water column, thus becoming unavailable as prey to the hake. Stomachs from specimens caught at night

TABLE 5.—Maturation stages in Gulf of Mexico *Merluccius albidus* for May and September 1973 listed as percentage of occurrence.

Gonad state	May				September	
	Mississippi Delta-west De Soto Canyon slope 344-730 m		Dry Tortugas slope 353-595 m		Mississippi Delta-west De Soto Canyon slope 330-503 m	
	Females N = 1,069	Males N = 59	Females N = 323	Males N = 525	Females N = 2,083	Males N = 1,430
2-3	43.3	6.8	96.6	6.5	65.3	7.2
4	55.7	88.1	2.2	66.1	32.5	79.0
5	0.4	5.1	1.2	20.4	1.6	12.1
6	0.6	0.0	0.0	7.0	0.6	1.7
Total	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 6.—General systematic list of prey species identified from the stomachs of 649 *Merluccius albidus*. List is arranged alphabetically.

- FISHES
  - Apogonidae
    - *Epigonus pandionus*
    - *Synagrops* sp.
    - *Synagrops bella*
    - *Synagrops spinosa*
  - Argentinidae
    - *Argentina striata*
  - Ariommidae
    - *Ariomma* sp.
    - *Ariomma bondi*
  - Bathyclupeidae
    - *Bathyclupea* sp.
  - Brotulidae
    - *Dicrolene intronigra*
    - *Monomitopus agassizi*
  - Carangidae
    - *Trachurus lathami*
  - Chauliodontidae
    - *Chauliodus sloani*
  - Chlorophthalmidae
    - *Chlorophthalmus agassizi*
  - Clupeidae
    - *Etrumeus teres*
  - Evermanellidae
    - *Evermanella* sp.
  - Gempylidae
    - *Nesiarchus nasustus*
    - *Scombrolabrax heterolepis*
  - Gonostomatidae
    - *Gonostoma* sp.
    - *Gonostoma elongatum*
    - *Maurolucius mulleri*
    - *Polymetme corythaeola*
    - *Triplophos hemingi*
    - *Yarella blackfordi*
  - Macrouridae
    - *Bathygadus macrops*
    - *Coelorhynchus carminatus*
    - *Coryphaenoides colon*
    - *Gadomus arcuatus*
    - *Gadomus longifilis*
    - *Hymenocephalus italicus*
    - *Malacocephalus* sp.
    - *Nezumia* sp.
    - *Nezumia aequalis*
  - Malacosteidae
  - Melanostomatidae
  - Merlucciidae
    - *Merluccius albidus*
    - *Steindachneria argentea*
  - Myctophidae
    - *Lampadena luminosa*
    - *Neoscopelus macrolepidotus*
  - Nomeidae
    - *Cubiceps* sp.
    - *Psenes* sp.
  - Percophididae
    - *Bembrops* sp.
    - *Bembrops gobioides*
  - Polymixidae
    - *Polymixia lowei*
  - Squalidae
    - *Etmopterus schultzi*
  - Sternoptychidae
  - Stomiatidae
  - Trichiuridae
  - Unidentified fishes
- MOLLUSKS
  - Limpets
    - Fissularidae
  - Squids
    - *Illex* sp.
    - *Illex illecebrosus*
    - *Oregoniateuthis springeri*
    - *Pholidotheuthis adami*
  - Unidentified squids
- CRUSTACEANS
  - Caridea
  - Euphausiacea
  - Euryonidae
    - *Steromastis sculpta*
  - Glyphocrangonidae
    - *Glyphocrangon* sp.
    - *Glyphocrangon alispina*
  - Nematocarcinidae
    - *Nematocarcinus* sp.
  - Oplophridae
    - *Notostomus* sp.
  - Pandalidae
    - *Plesionika acanthonotus*
  - Pasiphaeidae
    - *Pasiphaea* sp.
  - Penaeidae
    - *Aristeus antillensis*
    - *Benthysicymus* sp.
    - *Hymenopenaeus* sp.
    - *Hymenopenaeus debilis*
    - *Hymenopenaeus robustus*
    - *Parapenaeus* sp.
    - *Penaeopsis megalops*
  - Unidentified crustaceans
  - Unidentified shrimps
- UROCHORDATA
  - Pyrosomidae
    - *Pyrosoma* sp.

contained primarily members of the resident benthic community.

This feeding behavior is in contrast to that described for other species of *Merluccius*. Initiation of feeding after sunset has been suggested for *M. productus* (Alton and Nelson 1970) and for all hake (Hickling 1927).

Most offshore hake caught during the survey regurgitated due to changes in hydrostatic pressure with only 8.2% (651 of 7,944) of those stomachs examined containing food. Fishes composed the major portion of the diet of *M. albidus*, followed by squid and crustaceans (Table 7). Fishes were exclusively present in about 75% of the stomachs

TABLE 7.—Types of identified prey, according to the adaptive life zone they inhabit, from the stomachs of 649 *Merluccius albidus*.

Adaptive zone	Taxa	Frequency	Percent total frequency
Epipelagic	Carangidae and Clupeidae	7	1.4
Subtotal		7	1.4
Mesopelagic	Myctophidae	84	16.5
	Miscellaneous fishes	20	3.9
	Squids	95	18.7
	Euphausiacea	10	2.0
	Miscellaneous crustacea	4	0.8
	Pyrosomidae	1	0.2
Subtotal		214	42.1
Benthic	*Steindachneria argentea*	142	28.0
	Apogonidae	21	4.1
	Ariommidae	17	3.3
	Macrouridae	17	3.3
	Merluccius albidus	12	2.4
	Trichiuridae	11	2.2
	Miscellaneous fishes	30	5.9
	Penaeopsis megalops	21	4.1
	Penaeidae	7	1.4
	Miscellaneous crustaceans	7	1.4
	Mollusks	2	0.4
Subtotal		287	56.5
Grand total		508	100.0

TABLE 8.—Catch rates of *Merluccius albidus* and trawl effort by time of day on the slope in the Gulf of Mexico during May 1973.

Item	Day 0700-1759	Twilight 0500-0659 1800-1959	Night 2000-0459
Average no. of fish/hour	15.2	13.6	14.5
Hours fished	60.75	34.00	54.00

TABLE 9.—Frequency of *Merluccius albidus* stomachs containing food, from the Gulf of Mexico in 330 to 730 m during May and September 1973, in 4-h intervals.

Time of day	No. fish sampled	Number stomachs containing food	Percent frequency stomachs with food
0000-0300	566	56	9.9
0400-0700	1,121	61	5.4
0800-1100	679	84	12.4
1200-1500	724	64	8.8
1600-1900	963	117	12.1
2000-2300	1,315	131	10.0
Total	5,368	513	9.6

examined and either singularly or together with crustaceans and squid in about 80% of these stomachs. Twenty-nine percent of the fishes eaten were mesopelagic and 69% were benthic.

Thirty-two identifiable prey species from *M. albidus* stomachs are listed in Table 6 by familial groups. *Steindachneria argentea* (Merlucciidae) was found most frequently, followed by species of Myctophidae (Table 7). About 2% of the specimens examined had been feeding on juvenile *M. albidus* indicating some degree of cannibalism.

Benthic penaeid and caridean shrimp were the dominant crustaceans found in stomachs of *M. albidus*. *Penaeopsis megalops* was the dominant penaeid shrimp and suggests selective feeding by *M. albidus*. Stomachs of *M. albidus* contained a higher frequency of *P. megalops* than *Hymenopenaeus robustus* even at those stations where *H. robustus* was more abundant. Abundance of these two species was based on the catch rates when they were taken together. This preference may indicate a feeding migration to depths of greater abundance of *P. megalops*.

Merluccius albidus are active predators with type and size of prey varying as follows: juveniles (90 to 149 mm SL) contained primarily shrimp 29 to 45 mm TL with a few fragments of fishes and squid; maturing adults (150 to 299 mm SL) contained a variety of fishes 100 to 240 mm TL, with one 320-mm TL trichiurid, crustaceans 40 to 130 mm TL, and squid 38 to 160 mm ML (mantle length); adults (larger than 300 mm SL) contained primarily Stomiatoidei fishes 100 to 240 mm TL, macrourids 150 to 255 mm TL, trichiurids up to 500 mm TL, caridean shrimp 49 to 80 mm TL, and squid 70 to 170 mm ML.

AGE AND GROWTH

Otoliths have been used successfully to estimate ages of several species of *Merluccius*. Annual growth patterns for *M. productus* were defined and used to establish age composition (Nelson and Larkins 1970). Botha (1969) used otoliths to establish the growth rates of both *M. capensis* and *M. paradoxus* and concluded that zonation and composition of the otoliths from various species of *Merluccius* were similar.

Otoliths of *M. albidus* have well-defined opaque and hyaline zones which increase in number with size and age of the fish. However, an analysis of the complex banding pattern in 206 pairs of otoliths from juveniles (7 to 14 cm TL) was impossible, because all bands were not defined and slow growth rings (hyaline bands) did not agree with age estimates based on length frequencies. Similar difficulties were encountered in the analysis of otoliths from 56 males (15 to 34 cm TL) and 171 females (15 to 54 cm TL).

The tentative age structure presented for Gulf of Mexico *M. albidus* was based on length frequency data (Figure 8, Table 10). Harding-Cassie age-class lines were computed (Harding 1949; Cassie 1954) based on the lengths of 1,839 males and 2,852 females taken in October 1971 and September 1973. Calculated mean lengths were very similar to those shown on Table 10 for both male

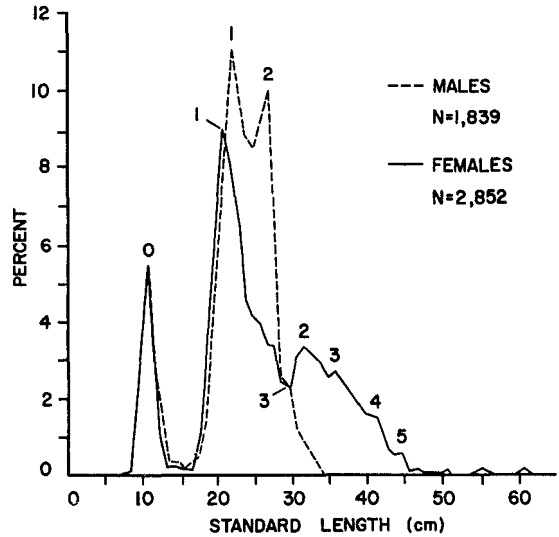

FIGURE 8.—Length frequency and modal size for ages 0 to 5 for *Merluccius albidus* from the east Mississippi Delta and west De Soto Canyon slope October 1971 and September 1973.

TABLE 10.—Tentative ages with midpoint of modal size groups of northern Gulf of Mexico *Merluccius albidus*.

	Males		Females	
Age (yr)	SL	TL	SL	TL
0	10.5	11.8	10.5	11.8
1	21.5	24.0	20.5	22.9
2	26.5	29.6	31.5	34.1
3	29.5	32.9	36.5	40.6
4			40.5	45.1
5			44.5	49.5

and female *M. albidus*. Longevity of *M. albidus* is unknown, but Botha (1971) reported that Cape hake live at least 11 yr. Juvenile male and female *M. albidus* are about the same size, but males are slightly larger than females at age 1. However, females are significantly larger by age 2 with difference becoming more evident as the fish becomes older (Figures 8, 9; Table 10). The largest male caught during this study was 404 mm SL and 0.6 kg while the largest female was 680 mm SL and 4.1 kg. The growth rate until age 1 was similar in both sexes. Thereafter, males which mature earlier use a proportion of their available energy to produce sexual products which may result in their reduced growth and smaller size. Because females mature later, they direct more of their energy toward growth for a longer period of time resulting in their larger size.

Female *M. albidus* between ages 4 and 5 grow at a rate about equal to that reported for female *M. productus* (Nelson and Larkins 1970; Table 11).

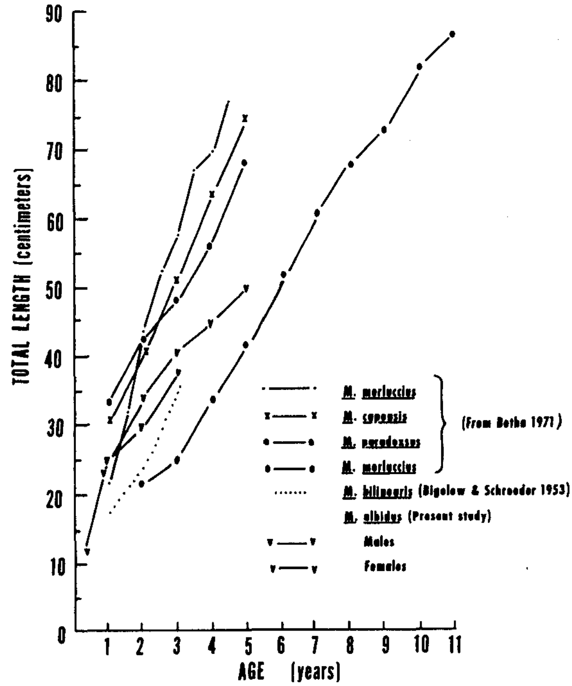

FIGURE 9.—Comparative growth rates for five species of Atlantic *Merluccius: M. merluccius, M. capensis,* and *M. paradoxus* from various authors after Botha (1971, fig. 17), *M. bilinearis* from Bigelow and Schroeder (1953), and *M. albidus* (present study).

TABLE 11.—Comparative length in centimeters by age for *Merluccius albidus, M. capensis, M. paradoxus,* and *M. productus.*

Age	TL *M. albidus*[1]		TL *M. capensis*[2]		TL *M. paradoxus*[2]		FL *M. productus*[3]	
(yr)	Male	Female	Male	Female	Male	Female	Male	Female
2	29.6	34.1						
3	32.9	40.6	27.6	31.0	31.3	32.6		
4		45.1	38.1	40.0	39.4	41.7	46.5	45.7
5		49.5	47.3	48.5	45.4	49.8	49.5	50.8
6			55.3	56.5	49.7	57.3	52.8	53.9
7			62.1	63.9	52.9	63.3	54.4	56.4
8			68.0	70.9		68.9	55.4	58.7
9			73.1	77.5		73.9	56.1	59.7
10			77.5	83.6		78.3	56.6	60.7
11			81.4	89.3		82.2		61.2
12								61.5

[1]Data from Table 10 of present study.
[2]Calculated lengths from Botha (1971).
[3]Calculated lengths (Nelson and Larkins 1970); Dark (1975) gives similar calculated lengths for *M. productus* including estimates for 1, 2, and 3 yr fish as 16.6, 26.2, and 41.1 FL.

Growth rates of male and female *M. productus* (Dark 1975) indicate that growth is rapid during the first 3 yr but then slows perceptibly. Gulf of Mexico *M. albidus* are larger than *M. productus* at age 2. However, the growth rates of 3- to 5-yr-old female *M. albidus* and *M. productus* appear similar. Growth rates of males of these species do not appear to be similar. *Merluccius albidus* from the Gulf of Mexico appear to grow faster than *M. bilinearis* (Figure 9).

A small number of female *M. albidus* were collected in February 1970 below the head of De Soto Canyon in depths of 550 to 730 m. These fish ranged from 21 to 59 cm SL and showed modal peaks at 36, 40, and 44 cm SL which were similar to the peaks shown in Figure 8. Females collected on the De Soto Canyon slope in June 1971 at depths of 550 to 730 m showed modal peaks at 38, 42, and 45 cm SL.

Length frequency data imply that males rarely live longer than 3 yr whereas a large number of females live at least 5 yr (Figures 8, 9; Tables 10, 11). However, longevity in other species of *Merluccius* is reported as upwards of 13 yr for females and 11 yr for males. Additional sampling lower on the slope throughout the year may generate a broader data base from which additional age-classes could be defined bringing longevity of *M. albidus* in closer agreement to other species of *Merluccius*. Figure 8 suggests a high mortality rate for 2- to 3-yr-old males residing higher on the slope which probably increases their accessibility to predators. Botha (1971) showed that male *M. paradoxus* do not live as long as females and stated that males over 7 yr of age are extremely rare.

A length-weight curve for males and females was computed from 1,920 specimens from the Gulf of Mexico (Figure 10). Rate of weight increase was similar in both sexes up to about 18 cm SL, after which the rate of increase for males became greater possibly because males develop mature gonads earlier.

STANDING STOCK OF *M. ALBIDUS* IN THE GULF OF MEXICO

The standing stock estimate and confidence interval for each stratum and for all strata are listed in Table 12. Maximum density per drag in June 1971 was 11 kg/hectare, mean density 3 kg/hectare, and minimum density 0.45 kg/hectare.

Since trawl efficiency or catchability coefficient (q) is unknown for offshore hake, a q of 1 was used in the calculations thereby minimizing the standing stock estimate. Catchability of any trawl is somewhat dependent on several biological, physiological, and adaptive characteristics of the species sought which must be considered in assigning a value to q. Other species of hake come off the bottom to feed and *M. productus* forms large schools about 9 m off the bottom (Nelson and

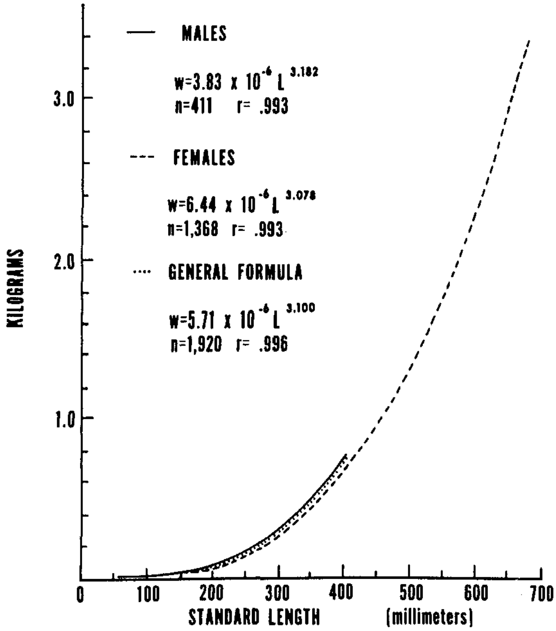

FIGURE 10.—Length-weight relationship of *Merluccius albidus* from the Gulf of Mexico.

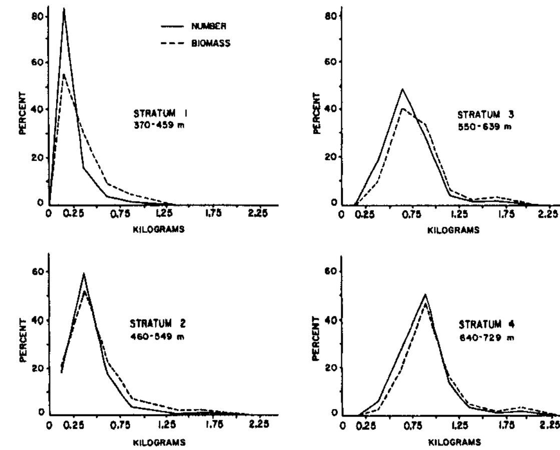

FIGURE 11.—Number and biomass of *Merluccius albidus* by 90-m depth strata on De Soto Canyon slope north of Tampa, Fla., June 1971.

Larkins 1970). If such behavior is characteristic of *M. albidus,* then it may be necessary to use both mid-water trawls and higher-opening fish trawls, coupled with more tows of a shorter duration. More short tows will allow greater coverage of the grounds and dampen inherent variability in the catch rates. This will enable us to develop more realistic population estimates.

Distribution and abundance of *M. albidus* on the De Soto Canyon grounds north of Tampa show that the largest segment of the stock was located in stratum 2 (Figure 11, Table 12). Numbers of fish were highest in stratum 1 (49%) but they only represented 22% of the population biomass. Most commercial-sized (greater than 0.45 kg) *M. albidus* were caught in strata 3 and 4 (Figure 11).

Commercial potential for this species is considered to be low, particularly when compared to landings of presently exploited hake species. Landings of various species of *Merluccius* in 1965 were in excess of 9.1×10^9 kg (Grinols and Tillman 1970) yet our standing stock estimate is only slightly more than 3.4×10^6 kg and our highest recorded catch was only 284 kg/h.

Additional effort must be expended in order to classify the life history and to test the hypothesis discussed in this paper. Population estimates must be more realistic and delineation of the grounds occupied by this species more precise. *Merluccius albidus* are known to occur from Georges Bank to off the northeastern coast of South America; however, presently little is known concerning its population, life history, or commercial potential.

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TABLE 12.—Standing stock estimates of both weights and numbers for *Merluccius albidus* on the De Soto Canyon slope north of Tampa, Fla.; estimates are based on 19 5-h tows made in June 1971 using a 40-m fish trawl with 3-m bracket doors.

Stratum number	Depth (m)	Area (hectares)	Number of samples	Area sampled (hectares)	Total catch (kg)	Mean density[1]	Biomass (kg × 10^6)	Percent biomass	Biomass estimate[2] (kg × 10^6)	Number of individuals × 10^6	Percent individuals
1	370-459	327,410	5	326.2	716	2.19	0.72	22	0.26-1.20	5.27	49
2	460-549	310,400	5	318.2	1,424	4.48	1.39	42	0-2.87	3.70	34
3	550-639	247,618	5	294.0	883	3.00	0.75	23	0.51-0.99	1.21	11
4	640-730	195,788	4	253.6	576	2.27	0.44	13	0.27-0.63	0.61	6
Total		1,081,216	19	1,192.0	3,599	3.02	3.30	100	2.15-4.47	10.79	100

[1]Values in kilograms per hectare.
[2]Confidence interval = 90%.

samples of eastern Atlantic *M. merluccius* otoliths, examined the Gulf of Mexico *M. albidus* otoliths, and provided copies of his plates of otoliths of both Atlantic and Pacific species of *Merluccius* (unpublished monograph on Gadidae otoliths). David M. Cupka, South Carolina Wildlife and Marine Resource Department, Charleston, S.C., kindly identified the squids commonly found in *M. albidus* stomachs. D. M. Cohen kindly reviewed the manuscript.

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