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Comparison of Biology and Abundance of Silver Hake (*Merluccius bilinearis*) from Scotian Shelf and Cape Hake (*Merluccius capensis*) from Namibia Area

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Abstract

A comparison was made of some biological characteristics and abundance dynamics of silver hake (*Merluccius bilinearis*) from Scotian Shelf (Northwest Atlantic) and cape hake (*Merluccius capensis*) from Southeast Atlantic area (between 18°–28°S). Differences in size composition, growth rate and length-at-maturity were most significant in late-1960s – first half of 1970s. During the subsequent period these parameters became more similar. Taking into consideration the approximately similar rates of natural mortality, these species may be described as belonging to similar abundance dynamics with high reproduction ability and strong fluctuation of abundance. During the period 1968–90 similarity of recruitment trends and total biomass of southern and northern species was found, along with evidence of a synchronous pattern of general trends under the impact of global climatic variations.

Key words: abundance, biological characteristics, cape hake, Scotian Shelf, silver hake, Southeast Atlantic

Introduction

Representatives of the genus *Merluccius* are widely distributed both in northern and southern hemispheres, and are among the major commercial species in Europe and many other countries due to high abundance and nutritive value of the species. The most researched and well-known species to both fishermen and scientists are the silver hake (*M. bilinearis*) in the Northwest Atlantic and cape hake (*M. capensis*) in the Southeast Atlantic. Although separated by a long distance, these species seem to have a close relationship in the biological parameters and abundance dynamics. In our opinion a comparative analysis of some biological and abundance features, will facilitate a better understanding of processes of the two species. This in turn can provide indicators relevant to stock size dynamics and management of silver hake and cape hake fisheries. In this study some of the biological parameters and the abundance dynamics of the two species are considered to observe any synchronous trends. For convenience of discussion they will be named sometimes as northern and southern species.

Materials and Methods

The two species of *Merluccius* discussed in the paper have been important commercial resources in the USSR/Russian fishery. Therefore, much attention was paid in the Atlantic Research Institute of Marine Fisheries and Oceangraphy (AtlantNIRO) to research of both silver and cape hakes, and significant scientific data were collected. Data on biology and abundance of both species from various published sources were also used. Comparison of biological characteristics and abundance indices for both populations during 1968–93 was the methodical basis of this work. Since neither stock assessment nor the comparison of absolute biomass and recruitment of the species was our purpose, the scales of values used to draw plots were chosen to provide the most clear illustration of the silver hake and cape hake abundance trends.

Results and Discussion

At first it is valuable to discuss the major features of both species distribution and behaviour. Considering first the northern hake, the population of interest is distributed in the Scotian Shelf area between 42° and 45°N at a depth range of 30–450 m (Vyalov and Karasev, 1967). Optimal water temperature for adult silver hake is 8°–10°C (Sigaev, MS 1994). The spawning season extends from June to September, with a peak in July–August. Shallow waters off Sable Island (30–60 m) is the major spawning area. During winter (January–April) along with the cooling of water, fish aggregations mainly occur along the shelf edge at depths of 200–450 m. In May–June as the water temperatures rise, silver hake gradually migrate towards shallower depths (100–200 m).

In reference to population structure of the southern hake, no complete understanding is available at present. While their distribution extends from 16° to 34°S, according to Wysokinski (1986), it seems most likely that a single stock of *M. capensis* is distributed in the Convention Area of the International Commission for the Southeast Atlantic Fisheries (ICSEAF*) in zones 1.3, 1.4 and 1.5 between 18° and 28°S. We have no reason to adopt another point of view. Therefore the indices, presented individually by zones, were pooled and considered as those characterizing the cape hake population in the area between 18° and 28°S (Fig. 1). This species is found in a depth range of 50–500 m (Arteaga, 1976) mainly at water temperature 6.5°–8.5°C. Spawning mainly occurs at depths of 150–250 m. Fishing aggregations are most often found at depths of 250–400 m. Reproduction occurs all year round. The most intensive spawning is observed in winter (July–September in the southern hemisphere). Offshore seasonal migrations are observed in autumn and winter and onshore in spring and summer.

In general there is thus a similarity observed in silver and cape hake distribution pattern and migrating behaviour. However, there are some differences. Spawning of the cape hake occurs at most depths within its distributional range, and so do fishing aggregations during the main part of the year. The differences revealed in the distribution within the respective areas of northern and southern hakes, are likely to be stipulated by peculiarities of temperature conditions which are considerably differerent as dictated by the latitudes.

With respect to the biological characteristics of both populations, Table 1 shows the general picture of the size compositions in the historic commercial catches of both hakes. The data presented show that the southern hake length, unlike that of the northern one, varies significantly through the years. The largest cape hake specimens of maximum length 102 cm were caught in 1973–74. During the subsequent period, the average length dramatically decreased and in some years it was even

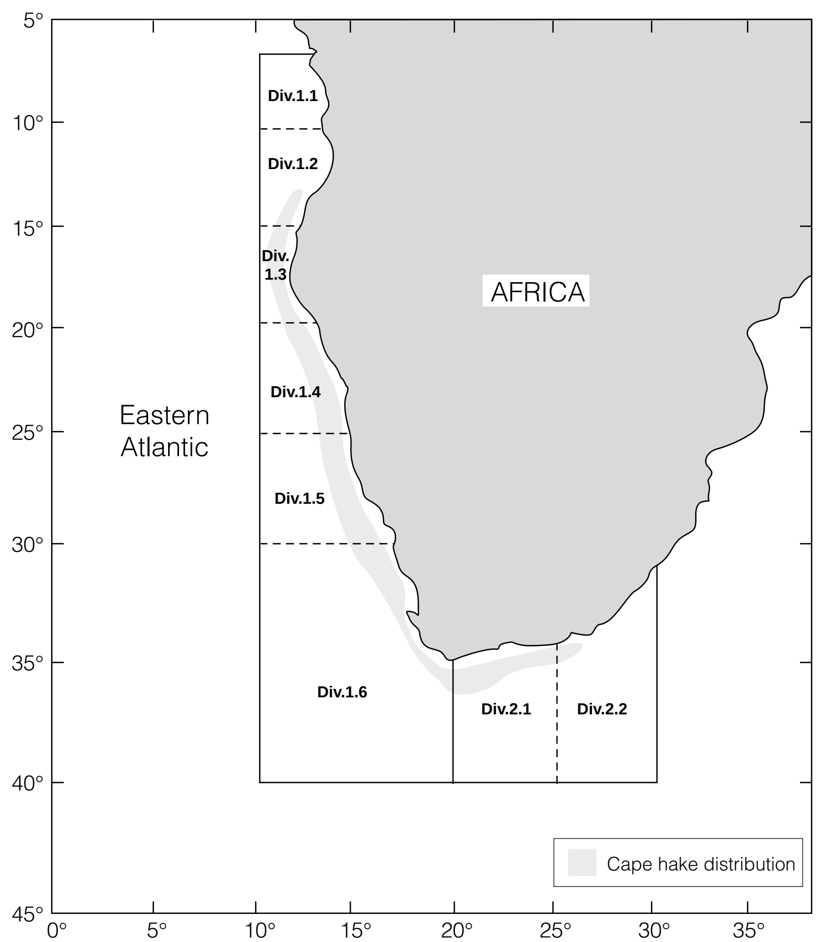

Fig. 1. Map showing ICSEAF area of southeastern Atlantic and the reported distribution of cape hake.

* ICSEAF was discontinued in 1990.

TABLE 1. Indices of length composition (cm) of silver hake and cape hake in commercial catches by year.

	Silver hake			Cape hake		
Years	Range	Modal groups	Average	Range	Modal groups	Average
1968	16–49	24–33	28.4	20–78	32–38	38.4
1969	10–47	23–33	27.8	22–88	32–44	41.8
1970	12–51	24–33	27.8	18–96	28–38	40.4
1971	21–51	24–33	28.4	20–98	36–46	44.6
1972	12–51	20–33	27.2	18–94	24–36	35.4
1973	12–53	24–33	28.1	16–102	34–44	40.8
1974	10–53	24–33	28.8	20–102	24–34	37.7
1975	12–53	24–35	29.6	14–92	26–40	37.2
1976	12–57	25–35	29.9	14–82	26–36	34.0
1977	10–57	26–35	30.6	18–70	34–42	36.6
1978	12–57	26–35	30.6	12–78	24–32	31.4
1979	12–53	25–35	29.6	10–88	24–34	35.7
1980	12–59	26–37	31.1	14–92	24–32	32.9
1981	16–63	28–37	31.5	12–82	18–26	30.4
1982	12–53	26–37	31.4	10–96	24–34	28.5
1983	16–53	28–35	29.4	10–84	18–28	25.1
1984	16–53	28–37	30.8	12–84	24–32	29.6
1985	14–51	26–35	30.1	10–102	32–42	35.3
1986	12–57	26–35	29.8	10–88	24–32	33.8
1987	12–51	22–35	28.4	14–86	24–32	30.9
1988	16–45	26–33	29.7	12–86	26–32	31.3
1989	14–51	26–35	29.6	10–70	22–32	28.6
1990	18–43	26–35	27.7	18–70	24–34	30.3
1991	16–51	26–33	29.1	–	–	–
1992	14–45	24–33	29.0	–	–	–
1993	14–43	26–33	29.1	–	–	–

less than that of silver hake. After 1984, the cape hake size in commercial catches again increased slightly. When considered with the major size groups of silver hake, it actually overlaps similar indices.

Data on age composition are shown in Table 2. Evidently, there are also differences in age composition of species discussed. In 1968–71 the southern hake was represented by older specimens, while during the subsequent period the population became considerably younger and after 1976 the average age appeared to be less than that of the northern hake. During the latest years of the period, a slight increase in age was again observed. In general, the dynamics of cape hake age composition in catches, as may be expected, was similar to that of length composition. Concerning the terminal age, according to published data (Kono, 1978) the southern hake may approach 15 years, while in silver hake it is about 12 years (Noskov, MS 1976). However, as a rule, the bulk of catches of both species consisted of similar age-groups.

Data on hake length and weight relationships shown in Table 3 were obtained from Fuong (MS 1989), Pshenichniy and Assorov (1969), Isarev (1983), Botha (1970), and Draganik and Sacks (1987a, b). From these data it is evident that during the early observation years (first half of 1970s) the growth rate of the southern hake starting from age group 2 exceeded that of the northern hake. This difference in length and weight increased with age, and approached 30 cm and 1 700 g, respectively, by the age of 9 years. However, during the observation years of the 1980s the changes that occurred resulted in a considerable decrease of the cape hake growth rate at the ages 1–4 years. As a result, the average length of the first three age groups by the end of 1980s was almost similar to that of silver hake. Estimates using the Von Bertalanffy growth equation parameters, are shown below (Fuong, MS 1980; Botha, 1970).

		Growth parameters		
Species	Sex	L_∞	K	t_o
Silver hake	Male	43.3	0.251	-1.6
	Female	103.0	0.054	-3.1
Cape hake	Male/Female	115.700	0.130	0.444

TABLE 2. Indices of silver hake and cape hake age composition (years) in commercial catches by year.

	Silver hake			Cape hake		
Years	Range	Modal groups	Average	Range	Modal groups	Average
1968	1–8	2–4	2.9	1–7	3–4	3.3
1969	1–8	1–5	2.9	1–9	3–5	3.7
1970	1–9	1–5	3.0	1–9	2–5	3.5
1971	1–9	2–5	3.3	1–9	3–5	3.9
1972	1–10	2–5	3.3	1–9	2–4	3.0
1973	1–12	2–5	3.6	1–9	3–4	3.5
1974	1–10	2–4	3.2	1–8	2–5	3.2
1975	1–9	2–4	3.2	1–8	2–4	3.1
1976	1–7	2–4	3.3	1–9	2–4	2.8
1977	1–9	3–4	3.4	1–7	2–4	3.1
1978	1–10	2–4	3.4	1–8	2–3	2.4
1979	1–9	2–4	3.1	1–12	2–4	2.7
1980	1–10	2–4	3.4	1–10	2–5	3.0
1981	1–10	2–5	3.5	1–7	1–4	2.5
1982	1–10	2–5	3.6	1–7	1–3	2.2
1983	1–9	2–4	3.0	1–5	1–2	1.8
1984	1–9	2–5	3.4	1–8	2–3	2.3
1985	1–9	2–4	3.0	1–11	2–4	3.5
1986	1–10	2–4	3.1	1–9	2–4	3.3
1987	1–7	2–4	2.6	1–9	2–4	2.8
1988	1–8	2–4	2.8	1–9	2–3	2.5
1989	1–9	2–4	2.9	1–8	2–4	2.9
1990	1–8	2–4	2.6	1–8	2–4	3.0
1991	1–8	2–4	3.1	–	–	–
1992	1–7	2–4	2.9	–	–	–
1993	1–7	2–4	3.0	–	–	–

TABLE 3. Average length (cm) and weight (kg) of silver hake and cape hake by age.

	Silver hake		Cape hake			
	First half of 1970s		First half of 1970s		First half of 1980s	
Age	Average length	Average weight	Average length	Average weight	Average length	Average weight
1	20.3	0.048	19.3	–	20.1	0.050
2	26.9	0.118	31.0	0.149	26.8	0.145
3	30.2	0.185	39.0	0.300	33.6	0.290
4	32.6	0.252	48.0	0.597	42.6	0.573
5	36.1	0.360	54.0	0.965	52.5	0.928
6	38.9	0.446	61.0	1.343	60.3	1.470
7	42.4	0.591	68.0	1.807	67.4	2.900
8	45.9	0.803	74.0	2.275	77.0	2.920
9	50.3	1.186	80.0	2.883	85.0	3.846
10	–	–	85.0	3.275	92.0	4.975

Wysokinski (1986) noted that the fluctuations of age and growth rate values of cape hake over a wide range are caused by different interpretation of otolith annual rings by researchers and sometimes by errors in species identification. However, data on length composition and length-at-maturity (see below) provide evidence of the actual existence of fluctuations observed, although different approaches to age determination may certainly affect the value of growth rate indices.

In the case of cape hake it is rather difficult to compare rates of maturation due to the sharp variations observed during the period discussed. Thus, according to Isarev (1983) in 1967 the length at first maturity was 34 cm while the majority of population was observed to mature at a length of 60 cm. In 1970 the length of first maturity decreased to 23 cm. In 1980–81 first maturity of males was observed at the length of 15 cm while the majority reaching maturity occurred at 21–26 cm in males and 23–28 cm in females. Unfortunately no data on the southern hake maturity rate by ages are available. We may only assume, at a high probability level, that the age-at-maturity has changed towards decreased ages, i.e. the process of maturation was accelerated considerably. Evidently under such conditions it is reasonable to compare only the data for approximately the same period of observations (Table 4) (Arteaga, 1976; Doubleday and Halliday, 1975).

It is evident that in the first half of 1970s the northern hake reached maturity at significantly smaller lengths and likely at earlier ages than the southern one. However, later on after a sharp decrease of abundance caused by overfishing (Isarev, 1983), the length-at-maturity of cape hake significantly decreased. The same seems to be true for the age as well. Accelerated maturation seems to facilitate the decrease in growth rate. Thus, in the case of cape hake it is suggested that the population abundance decrease and growth rate inhibition of the population occurred simultaneously. Nikolskiy (1974) considered such events to be associated with climatic conditions, and the transformation of unfavourable ones to the biological parameters of the population. Nevertheless, the decrease in the growth rate coupled with direct removal of large fishes caused by the fishery, and fleet effort transition to fishing of the young age groups may have resulted in such considerable decrease of cape hake length in catches during the second half of 1970s to early-1980s (Table 1).

TABLE 4. Silver hake and cape hake length-at-maturity in the early-1970s.

	% of mature fish	
Length (cm)	Silver hake	Cape hake
20	2.2	2
24	31.6	5
28	84.8	12
32	96.6	40
34	99.2	50
36	98.8	64
40	100.0	80
44	100.0	90
48	100.0	95
52	100.0	99
56	100.0	100

The coefficient of instantaneous natural mortality (M) is an important parameter to describe the abundance dynamics of a speices. According to Assorov and Scherbich (1979) and Terré and Mari (1978) the average coefficient M of cape and silver hakes amounted to 0.42 and 0.40, respectively, i.e. both values were approximately similar. However, there are other estimates as well. According to Rikhter (MS 1988), M for silver hake amounted to 0.50 while Wysokinski (1986) estimated M for the southern hake at 0.20. Wysokinski explains this low value of natural mortality as a consequence of the intensive fishery resulting in a significant decrease of stock of the cape hake. However, we think that addressing the actual data provides the best assumption of natural mortality rate variability by age. Appropriate data are presented below (Table 5) (Lleonart *et al.*, MS 1983; Rikhter, MS 1991; Wysokinski, 1986).

Taking into account a slightly longer life cycle of the cape hake, the estimates of M for the modal age groups of ages 3–4 years seem too high, and the mortality rate is doubtful as a result of the decrease of older fish. However, on average, the rate of mortality of both species seems similar in spite of some discrepancies.

Estimates of abundance (recruitment) of one year old fish and total biomass (one year and older) of the northern and southern hakes, obtained from VPA method, were used as indices of stock dynamics. Since no regular stock size data were available for the whole observation period (1968–93), estimates obtained by different researchers and in different times were used (Clay and Beanlands, MS 1980; Draganik and Sacks, MS 1987a, b; Showell and Bourbonnais, MS 1994), including unpublished data of AtlantNIRO. Observation series for the cape hake is divided into 1968–86 and 1987–90, and that for the silver hake into 1968–76 and 1977–93.

TABLE 5. Estimates of insantantaneous mortality (M) by age.

	Age (years)								
Species	1	2	3	4	5	6	7	8	9
Cape hake	0.575	0.574	0.566	0.525	0.343	0.209	0.170	0.157	0.157
Silver hake	0.733	0.642	0.236	0.332	0.521	0.544	–	–	–

Taking into account differences in tuning methods and some input parameters it is not correct to compare the absolute values of biomass and abundance, therefore, the trends of the latter will be discussed (Fig. 2 and 3). It is evident that curves of both figures are similar. Thus in 1968–76 biomass of silver and cape hakes in general was at a high level due to appearance of several strong year-classes. The second half of 1970s was characterized by both populations experiencing a depression in abunance. Several weak year-classes resulted in sharp decreases of southern and northern species populations. Recovery started in 1982 when the stocks in both areas were recruited by a strong year-class of 1981. Subsequently, abundance was retained at relatively high levels until 1987. After that another decrease occurred in the northern stock until 1993. Reliable information for the southern species after 1990 is unavailable.

Thus, similarity of trends in recruitment abundance and total biomass of silver and cape hakes is rather high. It is unreasonable to expect total similarity (with several exceptions) of year-class abundance variations by years, which is confirmed by low correlation coefficient (r = 0.28), estimated for the period of 1977–90 with the most reliable data on the silver hake. As for the total biomass, the correlation for the same years is rather high (r = 0.70) and reliable at 99% probability. Qualitative comparison of silver hake population abundance in the Scotian Shelf area with near-bottom and surface water temperature anomalies in the area (Drinkwater *et al.*, 1996) show evidence that there is a likely effect upon stock size variations.

During the entire period discussed (1968–93), the positive temperature anomalies were associated with strong year-class occurrences with subsequent increases of total and fishable biomass. Relatively high positive correlation (r = 0.72) was found between water surface temperature (SST) and silver hake abundance (Sigaev and Rikhter, MS 1994). Before 200-mile zone enforcement in 1977, the active fishery may have had effect on the abundance level, however, the general abundance trends seem to be determined by the temperature factor. Such trends are also relevant to the cape hake, where evidence of year-class abundance was dependent on the water temperature conditions in the southern hemisphere (Isarev, 1988; Kuderskiy and Galaktionov, 1991). Besides, similar to the northern hake, warming seems to facilitate strong year-class formation, especially during the major spawning period.

Conclusions

1. Results of the comparison performed showed that during the observed period (1968–93) the cape hake biological characteristics varied considerably unlike those of the silver hake. While in the late-1960s to the first half of the 1970s southern hake size composition, growth and maturity rate significantly differed from those of the northern hake. During the subsequent years, however, trend for those parameters showed some similarity. No convincing reasons of variations relevant to the cape hake during the period considered are revealed. In general both species seemed to show the same type of abundance dynamics,

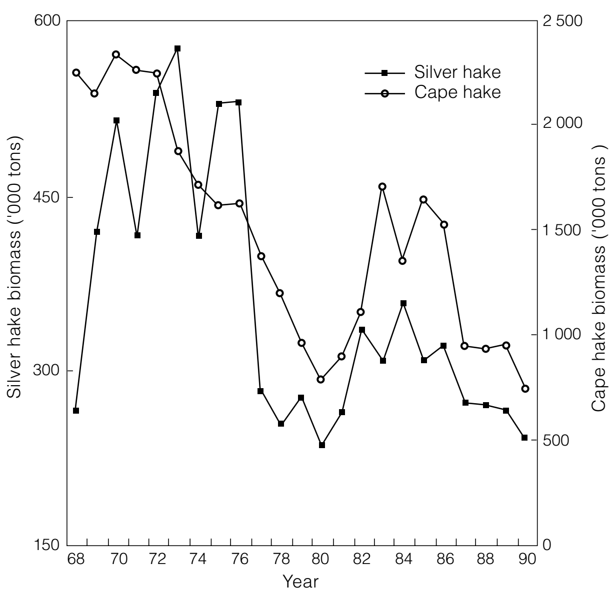

Fig. 2. Dynamics of silver and cape hakes total biomass.

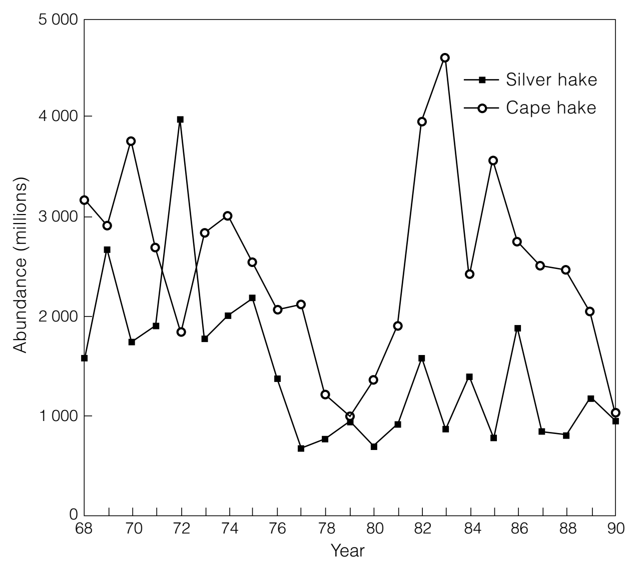

Fig. 3. Dynamics of one year old silver and cape hakes abundance.

characterized by a high reproductive ability and significant abundance fluctuations.

2. Similarity of trends of year-class abundance and total biomass of the silver hake and cape hake allows to assume a synchronous pattern for the two populations of *Merluccius* in the southern and northern hemispheres under the impact of the global climatic variations. Certainly, it does not mean the total coincidence of strong and weak year-classes in the two areas.

3. If this general similarity of trends can be confirmed by further research, the possibility may exist to obtain qualitative estimates and to update trends of one hake population on the basis of appropriate data on the other population. As regards to fishery management, similar pattern of abundance dynamics may imply that common principles could be applied to both silver hake and cape hake management.

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