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Fish biology

STUDIES ON HAKE, *MERLUCCIUS CAPENSIS* CASTELNAU, 1861, FROM OFF NAMIBIA. II. STUDIES ON FOOD AND FEEDING

BADANIA NAD MORSZCZUKIEM, *MERLUCCIUS CAPENSIS* CASTELNAU, 1861, Z REJONU NAMIBII. II. STUDIA NAD POKARMEM I ODŻYWIANIEM SIĘ

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Feeding intensity and its relation to gonad maturity and fish size are discussed. Food elimination time and diel consumption, food composition and its fish size- and diel feeding rhythm-related changes are presented as well.

INTRODUCTION

Studies on various communities in aquatic ecosystems, pursued recently, allow insights into the ecosystems structure and biological productivity. This is true also with respect to studies on fish feeding under natural conditions. A more and more common approach is to determine absolute amount of food taken up by fish within a defined time interval.

There is a very close relationship between distribution and behaviour of fish at various stages of their life and the occurrence, amount, and behaviour of food organisms. These factors determine also the species composition of fish faunas in different areas as well as their abundances. It is very important to know in detail the feeding behaviour, distribution, and migrations of fish in order to solve numerous problems related to fishing.

Feeding and food of hake in the SE Atlantic are dealt with in a few papers only. Most of them are very general in scope and discuss frequencies of various food items, without giving their biomasses; and yet, only a comparison of those two factors makes it possible to understand trophic relationships. Such data are contained in papers by Davies (1949), Rattray (1947), Assorov and Kalinina (1979), and Chłapowski (1977, 1981).

The aim of the present paper is to further develop those studies. Feeding intensity as related to fish condition and gonad maturity as well as stomach evacuation are treated particularly thoroughly. Food composition in terms of biomas of various items in relation to depth of fish capture is also presented.

MATERIALS AND METHODS

Materials were collected during a cruise to the Namibian waters in March, April, and May 1977 (see Preński, 1984). Individuals to be examined were picked out from catches at random. Total length (l.t.) was measured to 5 cm, rounding up to the nearest full 5-cm class. To calculate condition coefficient, body length (l.c.) was used, the value being obtained from total length by means of Mac Pherson's formula (Mac Pherson, 1976):

$$\text{l.c.} = 0.873\ \text{l.t.}^{1.010}$$

Fish total weight was determined to 1 g. Fish stomachs were collected, their contents being analysed on board; the contents were sorted into various items, each being weighed

Table 1

Analyses and measurements performed

Type of analysis	No. of individuals examined
Total length	1226
Total weight	1226
Gonad weight	709
Liver weight	709
Stomach fullness	1203
Food composition	1163

on a universal joint-hung technical scales to 0.1 g. Table 1 summarises the analyses and measurements performed. Gonad maturity index (= gonadosomatic index, RGS) was calculated as follows:

$$RGS = \frac{\text{gonad weight}}{\text{total body weight}} 100$$

Similarly, hepatosomatic index, RHS, was calculated:

$$RHS = \frac{\text{liver weight}}{\text{total body weight}} 100$$

Fulton's condition coefficient, k, was calculated as follows:

$$k = \frac{\text{total body weight}}{(\text{l.c.})^3} 100$$

Stomach fullness index was calculated as below:

$$\text{Stomach fullness index} = \frac{\text{food weight}}{\text{total body weight}} 10^4$$

When estimating the diel food ration taken up by the fish, it is necessary to establish the so-called "evacuation time". The formula derived by Jones (1974) as transformed and modified by Załachowski (1977) was used for the purpose:

$$t = \frac{M^{0.54}\ 175\ L^{-1.4}}{Q\ 10^{0.035(T_o - T_c)}}$$

where:

- M = initial weight of food consumed (g)
- L = fish length (cm)
- Q = coefficient denoting evacuation rate of 1g of food from stomachs of the fish studied
- t = evacuation time (hours), i.e., the time during which the food weight in stomachs drops from M to zero
- T_o = ambient water temperature
- T_c = standard temperature the value of Q is referred to (6°C).

For M, food weight in the maximally filled stomachs in a given fish length class was used.

For L, mean lengths in age classes, determined in the previous paper (Preński, 1984) were used.

Based on results of Jones (1974), Q = 0.086 for fish and Q = 0.20 for small crustaceans.

For. T_o, 9°C as the mean temperature recorded was used.

Diel food rations were calculated by means of the method given by Załachowski (1977) after Bajkov (1935):

$$D = S \frac{24}{t}$$

where: D = amount of food taken up during 24 h (g)
S = mean amount of food in stomachs of fish in a given length class (g)
t = evacuation time (hours).

RESULTS

1. Studies on food and feeding

1.1. Feeding intensity

Feeding intensity of hake is not constant, similarly to other fish species. It depends on such factors as season, gonad maturity, length, age, sex, and the time of the day. Author's observations covering three months only preclude following changes in feeding intensity over a year. Observations of other authors, particularly Assorov and Kalinina (1979) and Chłapowski (1977 and 1981) show that in the SE Atlantic, both *Merluccius capensis* and *M. paradoxus* feed with the lowest intensity in November. A second, lesser drop in feeding intensity is observed in April, which is related to spawning.

The present author's observations make it possible to follow the relationship between feeding intensity and hake gonad maturity. As seen from comparison of Figs. 1 and 2, feeding intensity increases with gonad maturation and increasing proportion of gonad weight relative to body weight. This is true in both males and females. Generally, the hake feeding intensity is at its lowest when gonads are at the resting stage. On the other hand, Chłapowski's studies (Chłapowski, 1977, 1981) show the gonad maturation to affect the hake feeding intensity to a small extent only. This result was probably caused by a methodological error. That author compared gonad maturity stage and stomach fullness only, while the present paper compares indices of gonad maturity and stomach fullness.

The materials obtained allowed also to follow changes in the hake feeding intensity as affected by changes in fish length. As seen from Fig. 2, those individuals exceeding 70 cm in length feed with the highest intensity. An increased feeding intensity can also be observed in small individuals, 15–39 cm long. The lowest intensity of feeding is observed in those individuals of intermediate length. The above observations concern both males and females of hake.

When studying the feeding intensity, it is important to consider evacuation times as a basis to estimate the diel food ration from. Table 2 presents evacuation times and diel food consumption in various age groups. As can be seen, although evacuation time of fish in different age groups is similar, it is shorter in those fish younger than 3 years and older

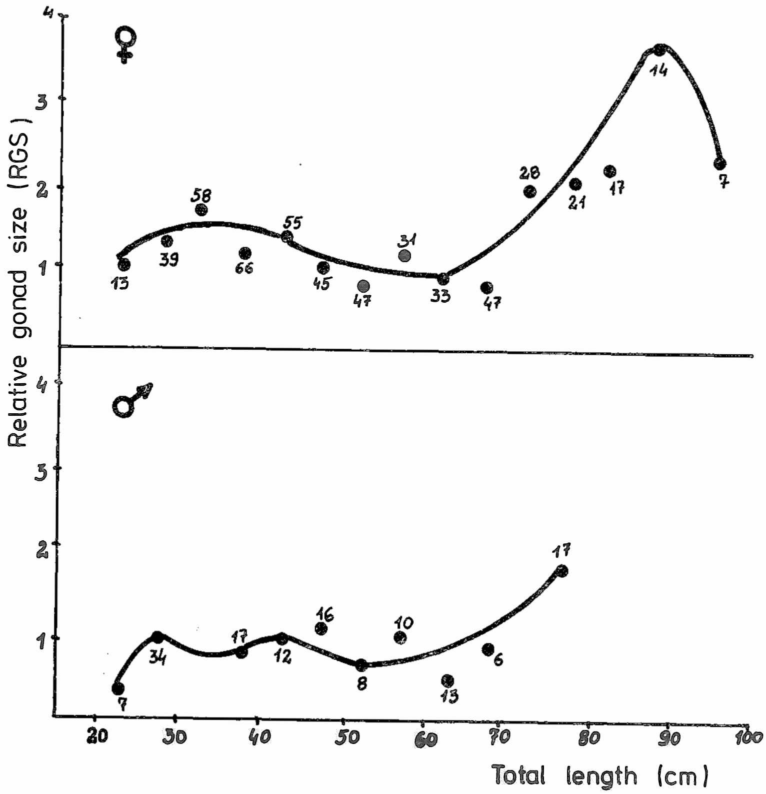

Fig. 1. Gonad maturity index (RGS) – fish length relationship in hake. Numbers with points denote abundances

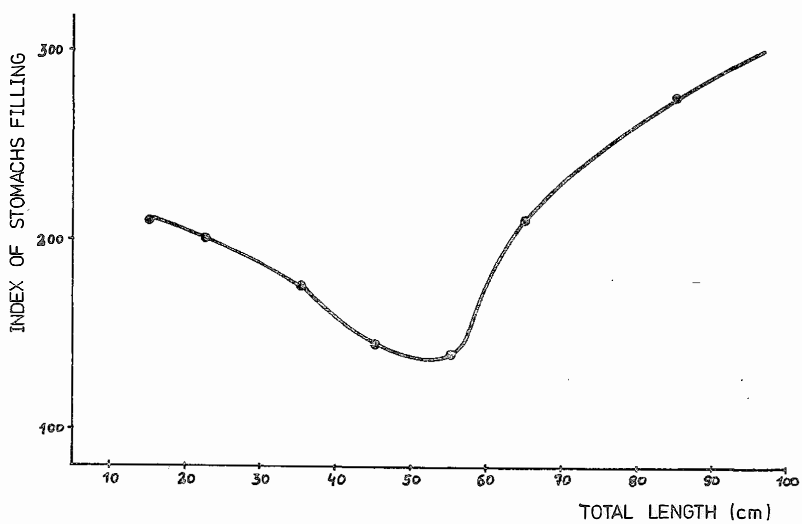

Fig. 2. Stomach fullness index – fish length relationship in hake

Table 2

Cape hake food composition and diel consumption

Age (yr)	No. of ind.	Mean length of fish (cm)	Mean weight of fish (g)	Max. amount of food in stomach (g)	S Mean amount of food in stomach (g)				t Evacuation time (h)		D Diel ration (g)				Diel consumption coefficient = $\frac{D \times 10\,000}{\text{mean fish weight}}$				
					Merluccius	*Gobiidae*	*Myctophidae*	*Euphausiacea*	Fish Q = 0.086	Crustaceans Q = 0.20	*Merluccius*	*Gobiidae*	*Myctophidae*	*Euphausiacea*	*Merluccius*	*Gobiidae*	*Myctophidae*	*Euphausiacea*	Total
I	22	18.9	18.9	6.4	–	–	–	0.0857	71.09	30.57	–	0.296	–	0.067	–	57.05	–	12.93	69.98
II	130	26.6	130.13	14.94	0.07615	2.2638	0.1746	0.09308	69.63	30.25	0.0262	0.78028	0.0608	0.0738	2.01	59.96	4.62	5.67	72.26
III	321	32.6	253.64	26.13	0.7850	2.9498	0.6358	0.13987	70.84	30.77	0.2659	0.9994	0.1090	0.1090	10.48	39.40	8.49	4.30	62.67
IV	265	38.8	478.2	54.8	1.95	4.5698	1.07169	0.16679	82.82	35.98	0.5678	1.3242	0.3105	0.111	11.87	27.69	6.49	2.32	48.37
V	146	48.6	99	4.18	4.18	4.4636	0.7712	0.16506	83.155	36.129	1.206	1.288	0.223	0.1096	14.34	15.3147	2.646	1.303	33.6037
VI	111	56.9	1420.16	145	24.53	2.9099	0.77117	0.1099	81.94	35.60	7.1848	0.852	0.225	0.074	50.59	6.002	1.590	0.5217	58.7027
VII	77	67.2	2134.76	192	56.987	1.3545	0.0545	–	75.54	32.82	18.105	0.589	0.01731	–	84.812	2.76	0.081	–	87.653
VIII	37	73.7	2851.82	208	65.216	1.421	0.38	0.024	69.32	30.12	22.579	0.492	0.13156	0.019	79.174	1.725	0.461	0.067	81.427
IX	22	76.1	3063.30	250	71.90	0.377	0.37	–	73.19	31.8	23.58	0.124	0.124	–	76.965	0.4	0.4	–	77.70
X	16	80.2	3619.68	309	97.87	0.46	0.46	0.0375	76.25	33.13	30.80	0.145	0.145	0.0274	85	0.4	0.4	0.0075	85.875
XI	16	85	4221	341	105.75	5.5	–	–	74.14	32.21	34.23	1.78	–	–	82	4.217	–	–	85.217

than 8 years. These observations concern both fish and crustaceans in food. Diel consumption of various items depends on fish age (and length) in a way similar to the previously discussed relationship between length and stomach fullness index.

Both the present author's observations and those of Davies (1949) show small and medium-size fish to feed mostly on small crustaceans, the Q value and digestion time of which amounting to 0.20 and 30–36 hours, respectively.

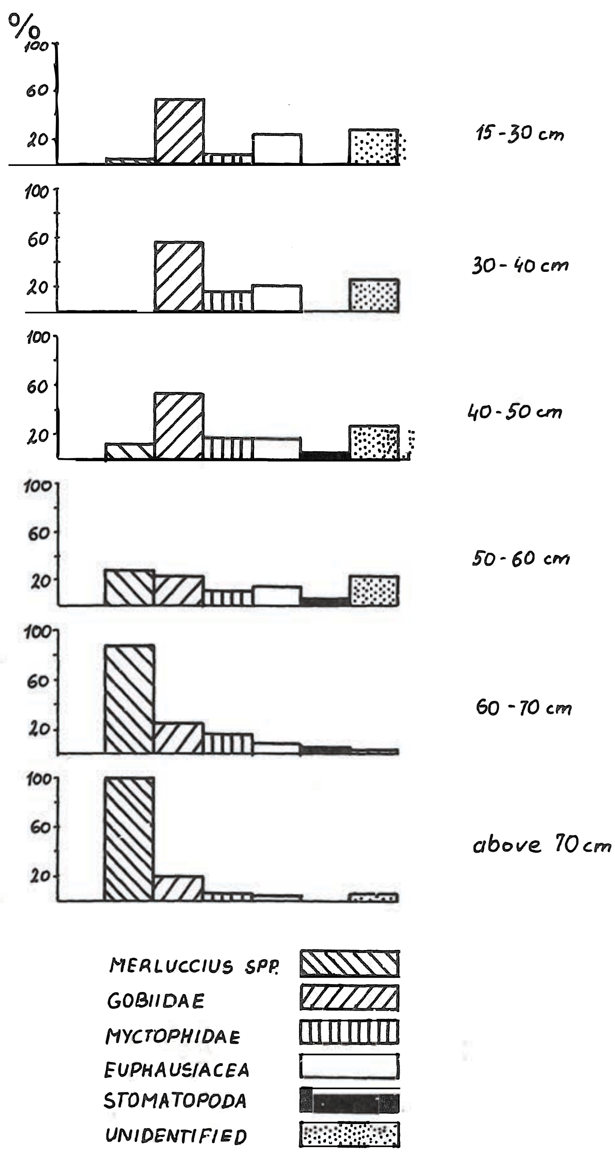

Fig. 3. Frequency of occurrence (%) of various food items in fish of different length classes

2. FOOD COMPOSITION

As mentioned before, the hake food consists of crustaceans and fish (Fig. 3). The main items are: *Merluccius spp.*, the *Gobiidae, Myctophidae, Euphausiacea, Stomatopoda, Macrura, Anomura*, and *Cephalopoda*. The most important items are *Merluccius spp.*, the *Gobiidae, Myctophidae*, and *Euphausiacea*. Frequency of occurrence of each main item depends on the hake length. The frequency of *Merluccius spp.* increases with fish size, the item becoming the most important one in those individuals exceeding 50 cm. The role of the *Gobiidae* in food decreases with increasing length of the hake studied. The *Myctophidae* are most frequent in the medium-size hake. The frequency of the *Euphausiacea decreases with increasing hake length, while the Stomatopoda* occur only in the medium-size hake food.

Similar conclusions can be drawn from observations on food composition as expressed in weight percentages (Fig. 4).

The observations presented above are in agreement with results reported by Davies (1949), particularly with respect to the occurrence of the *Euphausiacea* and *Merluccius spp.*, and with results of Assorov and Kalinina (1979) with respect to the *Gobiidae*. On the other hand, considerable discrepancies are evident when results reported by

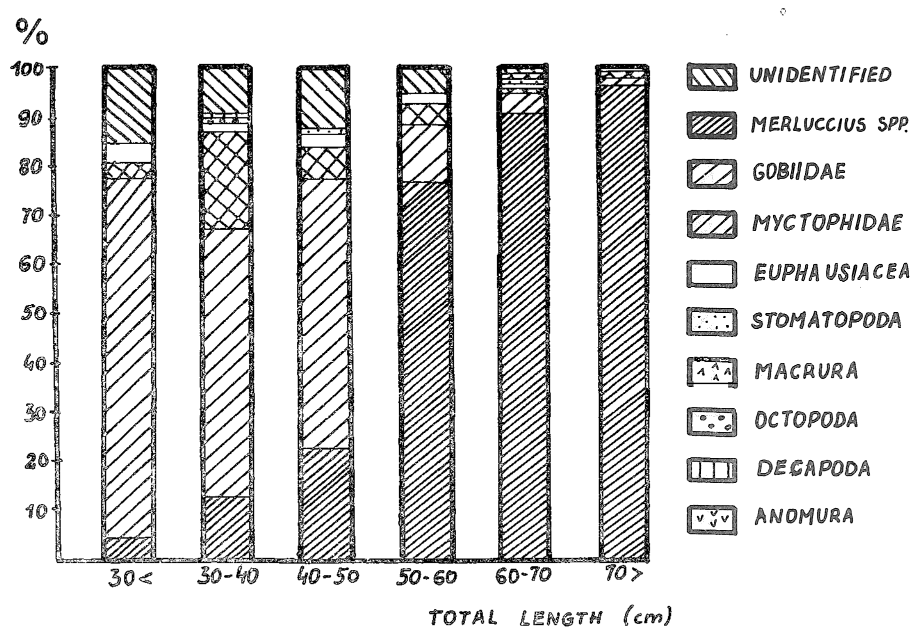

Fig. 4. Food composition as expressed in % stomach content weight in relation to hake length

Table 3

Frequency of occurrence (%) of the most important hake food items in relation to depth and fish length

Main food item	Depth of capture					
	230–290 m			290–380 m		
	Hake length (cm)					
	15–40	40–60	60–96	15–40	40–60	60–96
Merluccius spp.	4.28	17.64	85.00	5.00	34.04	92.45
Gobius spp.	81.82	76.47	39.02	36.67	23.40	–
Myctophidae	10.16	9.41	7.30	26.67	34.04	7.55
Euphausia spp.	12.30	8.24	–	51.67	42.55	7.55

Chłapowski are referred to. He found a high frequency of the *Decapoda* and stated that it did not change much during the year. The present studies, however, revealed the presence of decapods in a few individuals only. The same is true with respect to the occurrence of the *Cephalopoda*. No *Carangidae* and *Coryphaenidae* were found, in contrast to observations of Davies (1949) and Jones and van Eck (1967). The differences seem to be caused by the fact that those authors carried out their work in other SE Atlantic regions and in other seasons. Moreover, food composition is affected by depth of capture. The present author's observations show depth effects in food composition to be considerable, as illustrated by Table 3. The *Gobiidae* occur mainly in more shallow areas, no wonder then that they contribute much to the food of small and medium-size hake occurring at small depths. Gobiids are rare in deeper water where the main food organisms are pelagic *Myctophidae* and *Euphausiacea*, making up most of the food of small and medium-size hake. The contribution of *Merluccius spp.* to the food increases with depth, particularly in large and medium-size individuals.

Based on the present author's observations and results obtained by other authors, particularly Angelescu and Cousseau (1969), Angelescu and Fuster de Plaza (1965), Davies, (1949), and Smith (1965), hake can be regarded as a predator, fish and crustaceans being the principal diet components.

CONDITION

Fig. 5 presents values of condition coefficient, calculated for various length classes. The values decrease with increasing hake length which may be associated with fish shape gradually changing with growth.

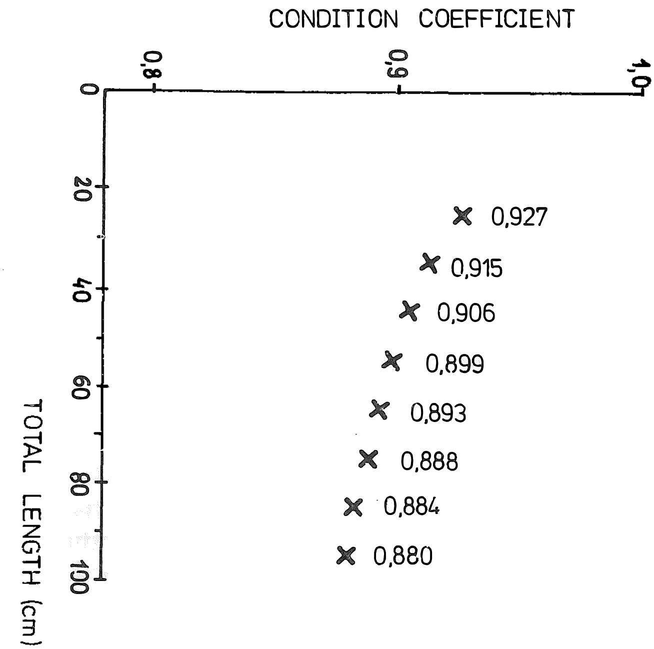

Fig. 5. Condition coefficient – fish length relationship in hake

The hake condition is affected by the liver fat content. For this reason, hepatosomatic index was calculated separately for males and females of different length classes (Fig. 6). The lowest values are found, both in females and males, in those individuals 20 cm and 45–60 cm long. Additionally, low values are observed in females longer than 80 cm. It is interesting to note a certain similarity between distributions of the hepatosomatic index and the gonad maturity index (gonadosomatic index, Fig. 1), and also the stomach fullness index (Fig. 2). The gonadosomatic index distribution is shifted to the right a bit as compared with the hepatosomatic index distribution.

DIEL RHYTHM

Fig. 7 presents changes in proportions of empty stomachs relative to the number of stomachs examined, and also changes in stomach fullness index relative to the time of the day. Small fish (15–40 cm) show a conspicuous nocturnal peak in stomach fullness, another, smaller peak occurring in the morning. Medium-size individuals show a feeding peak during the day. No well-defined feeding rhythm can be discerned in large individuals, although a small nocturnal peak is visible.

The picture of diel feeding rhythm presented is to some extent obliterated by the food digestion rate. As mentioned earlier, it depends on fish length and is at its lowest in medium-size individuals (Table 2).

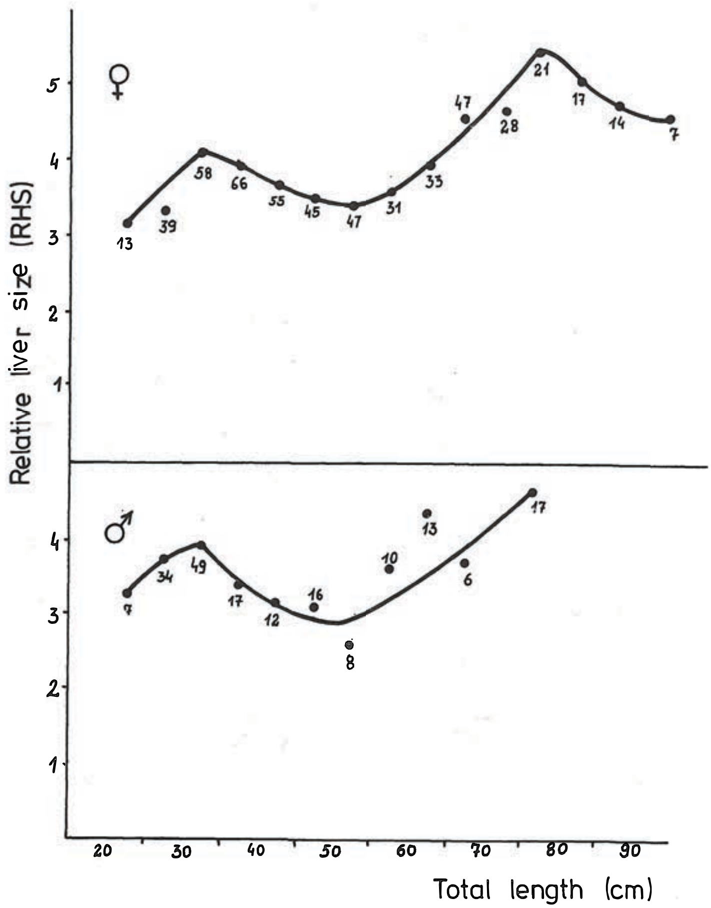

Fig. 6. Hepatosomatic index (RHS) – fish length relationship in hake
Numbers with points denote aboundances

TIME OF DAY- AND VERTICAL MIGRATION-DEPENDENT CHANGES IN FOOD COMPOSITION

As shown in Figs. 8, 9 and 10, small (15–40 cm long) individuals of hake feed mainly on the *Gobiidae*. This kind of food dominates particularly at night, However, the lowest food weight in stomachs is typical of the night hours. The next most frequent food items, the *Euphausiacea* and *Myctophidae* occurred most often within 8.000–12.00 hours. The individuals belonging to length classes between 15 and 40 cm show the weakest cannibalism, recorded mainly within 8.00–20.00 hours.

In the food of medium-size individuals (40–60 cm), the *Gobiidae* are the most frequent food item, too. Two peaks of this kind of food during the day are visible

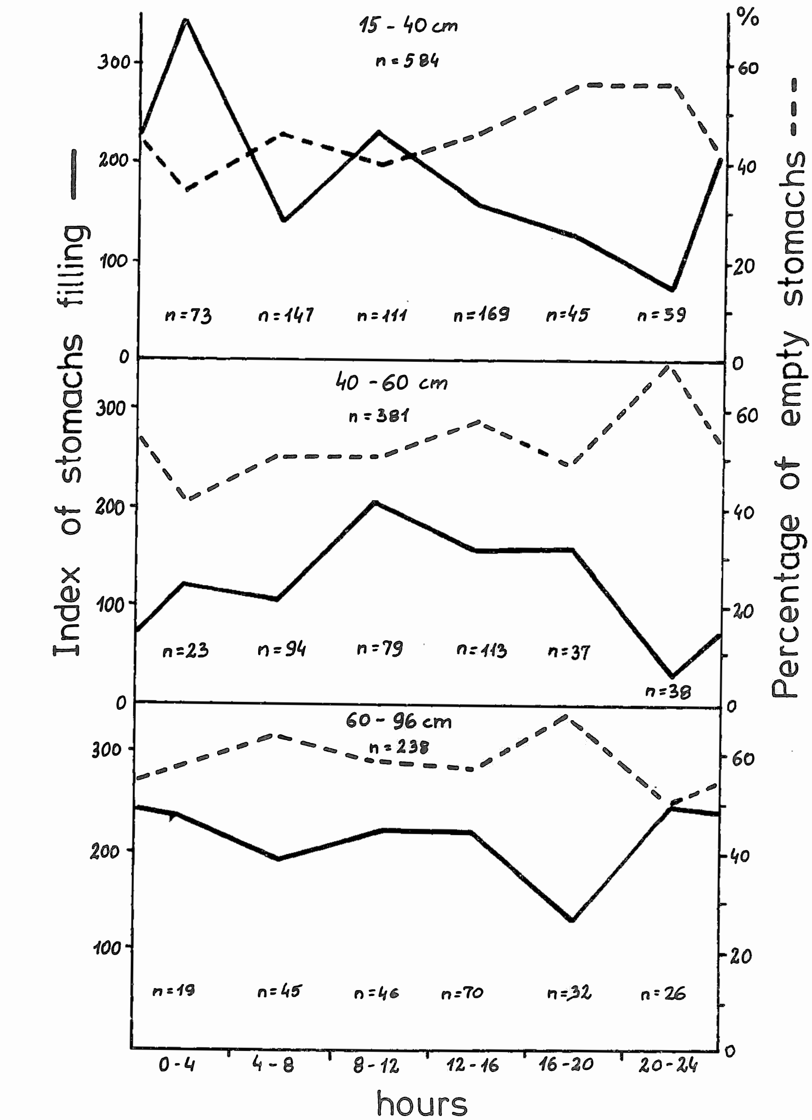

Fig. 7. Diel feeding rhythm of Cape hake

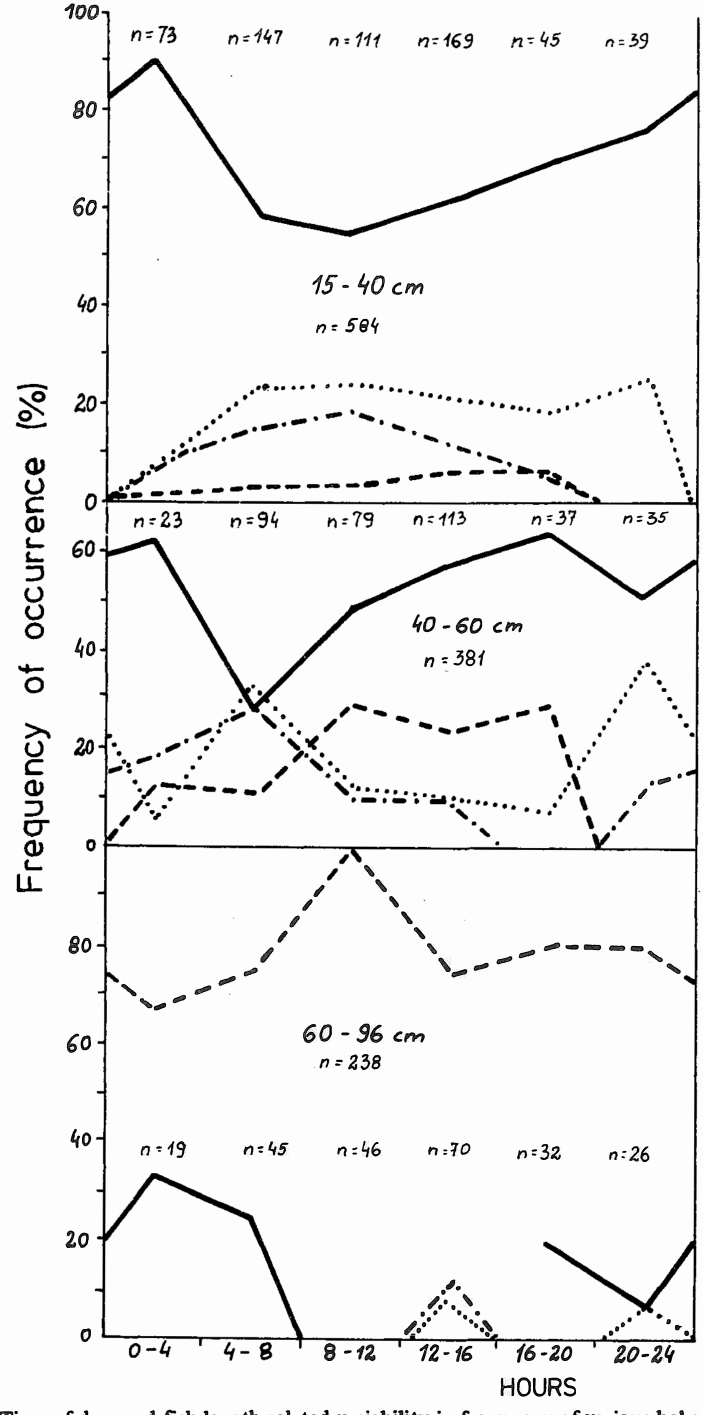

Fig. 8. Time of day- and fish length-related variability in frequency of various hake food items *Merluccius spp.* – – – – – – ; *Gobiidae* ———————; *Myctophidae* —•—•—•—•—•—; *Euphausiacea* . . . .

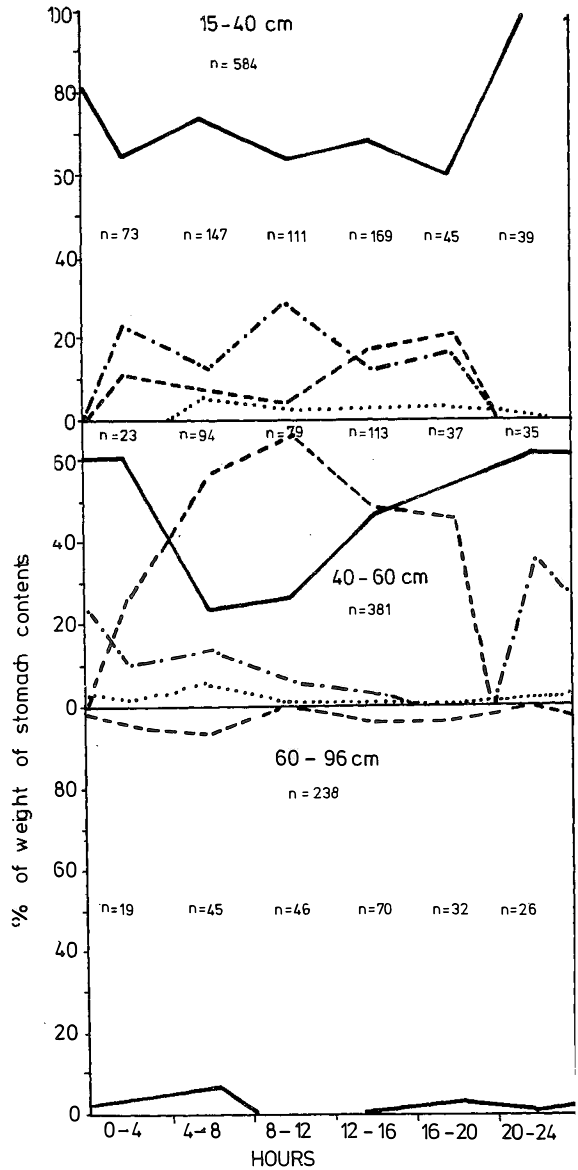

Fig. 9. Time of day- and fish length-related variability in food composition as expressed as % of hake stomach content weight

Merluccius spp. – – – – – – ; *Gobiidae* ––––––– ; *Mytophidae*—·—·—·—·—·—·—·—; *Euphausiacea* . . . .

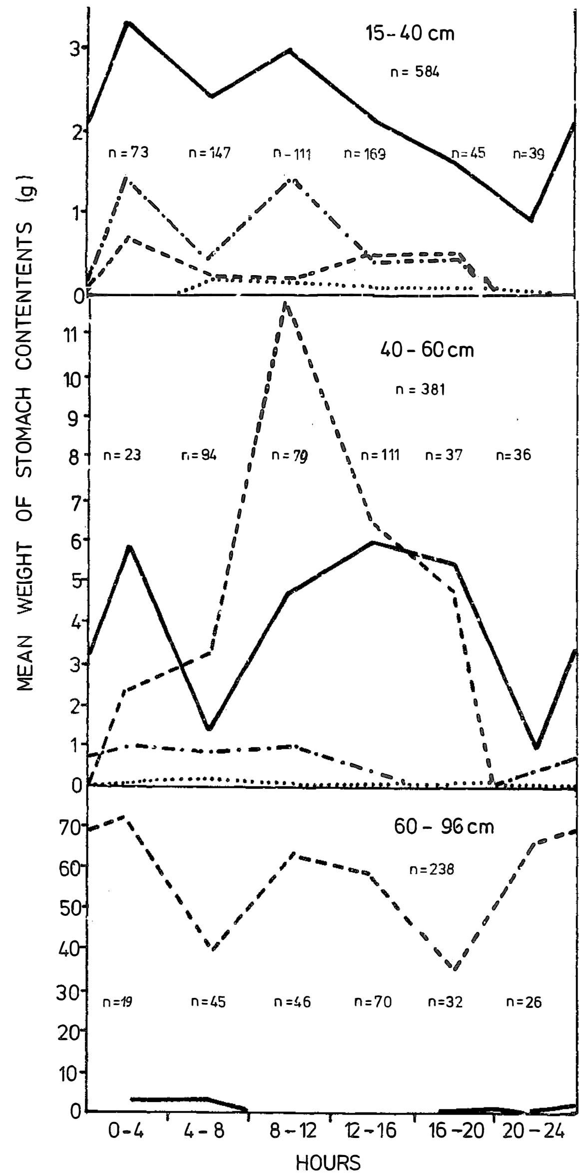

Fig. 10. Time of day- and fish length-related variability in mean hake stomach content weight *Merluccius spp.* – – – – – ; *Gobiidae* ————————; *Myctophidae* —·—·—·—·—·—·—·—;

Euphausicea . . . .

0.00–4.00 hours and 16.00–20.00 hours. The *Euphausiacea* occurred mainly within 4.00–8.00 and 20.00–24.00 hours, similarly to the *Myctophidae. Merluccius spp.* occurred in food mainly within 4.00–20.00 hours. With respect to the weight of food in stomachs, the bulk of it consisted of *Merluccius spp.*, within 8.00–12.00 and of the *Gobiidae* during the night.

The largest hake (longer than 60 cm) whose food consisted in 90% of the conspecific individuals (cannibalism) showed most of this type of food at night.

Angelescu and Fuster de Plaza (1965). Botha (1973), and Davies (1949) show the hake to perform diel vertical migrations in search for food. Chłapowski's studies (Chłapowski, 1977) performed throughout the year show additionally that the vertical migrations can be observed in every month of the year. The migrations take place above the central part of the shelf and above the continental slope. As shown by Botha (1973) and Ślósarczyk (1974), the highest catches in bottom and pelagic trawling were obtained during the day and night, respectively. The present author's observations on board showed the highest catches to be obtained during the day with pelagic trawls operated near the bottom. The hake were fished mostly at the water layer of over 7 m above the bottom, so differences in food composition should be accounted for only by vertical migrations of the hake in search for food.

Based on the results presented here and observations reported by authors mentioned above, the water column inhabited by the hake can be divided into the following four zones:

1. Above the thermocline, with abundant *Euphausiacea* and other pelagic crustaceans; large hake individuals present.
2. The thermocline and the layer just beneath it; the *Myctophidae, Cephalopoda, Trachurus trachurus, Scomber japonicus*, and *Etrumeus micropus* present; large and medium-size hake individuals prevail.
3. Near bottom zone, inhabited by many invertebrates and various fish species constituting potential food resources for hake; all size categories of hake present.
4. Bottom zone; poor food resources compared with the previous three zones; organisms typical of Zone 3 present as well, with the *Gobiidae* dominating.

Both horizontal migrations and vertical distribution of those organisms making up the basic food for hake are not identical in various seasons of the year and change with changes in hydrobiological conditions. As shown by Margalef (1962), the main cause of the hake vertical migrations in search for food is the insufficiency of food resources in a zone inhabited by the species; this is also evidenced by cannibalism.

Generally, the diel rhythm in feeding of hake depends on fish size. Such a temporal and spatial segregation of consumers results in a milder interaspecific competition for food.

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Translated: Dr. T. Radziejewska

Leszek Bruno PREŃSKI

BADANIA NAD MORSZCZUKIEM, *MERLUCCIUS CAPENSIS* CASTELNAU, 1861 Z REJONU NAMIBII

II. STUDIA NAD POKARMEM I ODŻYWIANIEM SIĘ

STRESZCZENIE

Materiały zebrano na szelfie Namibii w marcu, kwietniu i maju 1977 r. (tab. 1).

W miarę dojrzewania gonad i związanego z tym zwiększania się proporcji ich masy w odniesieniu do masy ciała, zwiększeniu ulega intensywność odżywiania się (rys. 1 i 2). Najintensywniej żerują osobniki morszczuka o długościach powyżej 70 cm, zwiększoną intensywność odżywiania się można również zaobserwować u małych osobników (15–30 cm). Najmniej intensywnie żerują osobniki o długościach pośrednich (rys. 2).

Czas ewakuacji (tab. 2) jest zbliżony u ryb w różnym wieku. Dobowe spożycie poszczególnych głównych składników pokarmu zależne jest od wieku (i długości) ryb w sposób podobny do zależności między długością i wskaźnikiem napełnienia żołądka.

Głównymi składnikami pokarmu są: *Merluccius sp., Gobiidae, Myctophidae, Euphausiacea, Stomatopoda, Macrura, Anomura, Cephalopoda* (rys. 3 i 4). Najważniejszym składnikiem jest *Merluccius spp.* Jego znaczenie rośnie z długością badanych morszczuków i u ryb o długości ponad 50 cm jest on głównym składnikiem pokarmu. Rola *Gobiidae* i *Euphausiacea* maleje ze wzrostem długości morszczuków. *Myctophidae* występują najczęściej u ryb o średnich długościach.

W miarę wzrostu długości morszczuków, wartość współczynnika kondycji zmniejsza się (rys. 5). Istnieje pewne podobieństwo między rozkładem współczynnika hepatosomatycznego (rys. 6) oraz rozkładem współczynnika gonadosomatycznego (rys. 1) i wskaźnika napełnienia żołądków (rys. 2).

Odżywianie się morszczuków charakteryzuje się wyraźnym rytmem dobowym u ryb małych (15–40 cm długości) i brakiem wyraźnego rytmu u osobników dużych (rys. 7).

Istnieją wyraźne zmiany składu pokarmu w zależności od pory doby (rys. 8, 9 i 10).

Zarówno dobowy rytm odżywiania się, jak i dobowe zmiany składu pokarmu związane są z pionowymi wędrówkami omawianego gatunku.

Лешек Бруно Преньски

ИССЛЕДОВАНИЯ ХЕКА, MERLUCCIUS CAPENSIS CASTELNAU, 1861 РАЙОНА НАМИБИИ.

II. ИЗУЧЕНИЕ КОРМА И ПИТАНИЯ

Р е з ю м е

Материал собран на шельфе Намибии в марте, апреле и мае 1977 г. (Табл.1). Во время созревания гонад и связанного с этим увеличением пропорции их по сравнению с массой тела, увеличивается ин-

тенсивность питания (Рис.1 и 2). Интенсивней всех питаются особи хека длиной выше 70 см. Увеличенную интенсивность питания можно также наблюдадать у малых особей (15-30 см). С наименьшей интенсивностью питаются особи средней длины (Рис.2)

Время эвакуации (Табл.2) подобно у рыб в различном возрасте. Суточное поглащение отдельных основных составляющих корма зависит от возраста (и длины) рыб также как зависит длина особи и степень наполнения желудка.

Главными составляющими корма являются: Merluccius sp., Gobiidae, Myctophidae, Euphausiacea, Stomatopoda, Macrura, Anomura, Cephalopoda (Рис.3 и 4) Самым основным кормом является Merluccius spp.. Его значение растёт в зависимости от роста длины хека и у особей выше 50 см, он является основной составляющей корма. Значение Gobiidae i Euphausiacea уменьшается с ростом длины хеков. Myctophidae наблюдаются чаще у рыб средней длины.

С ростом длины хеков значение коэффициента кондиции уменьшается (Рис.5). Существует некоторое подобие между гепатосоматическим коэффициентом (Рис.6) гонадосоматическим коэффициентом (Рис.1) и степенью наполнения желудков (рис.2).

Питание хеков характеризуется чётким суточным ритмом у малых рыб (15-40 см длиной) и отсутствием этого ритма у крупных особей (Рис.7).

Существуют чёткие изменения состава корма в зависимости от времени суток (Рис.8, 9, 10).

Суточный ритм питания как и суточные изменения состава корма связаны с вертикальными перемещениями в пелагиали данного вида.

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