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TEMPERATURE AND MOONLIGHT AS STIMULATORS FOR FEEDING ACTIVITY BY SWORDFISH

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SUMMARY

The vertical distribution of 306 swordfish caught by longlining in the area between 2°-16°N latitude and 19°-31°W longitude in 1983 was analyzed in relation to water temperature and the intensity of moonlight. The catch rate (catch in kg per 100 hooks) was used to make inferences about feeding intensity. The highest catch rates were recorded for 10-m layers with the largest temperature gradients, i.e., optimal feeding conditions occurred in the layers where the thermocline was located. The catch rate also increased during the period of the full moon in comparison with other lunar periods when the intensity of moonlight was lower.

RESUME

La distribution verticale de 306 espadons capturés à la palangre dans la zone comprise entre 2-16º N de latitude et 19-31º W de longitude de 1983 a été analysée en relation avec la température de l'eau et l'intensité de la lumière lunaire. Le taux de la prise (prise en kg pour 100 hameçons) a été utilisé pour tirer des conclusions sur l'intensité alimentaire. Les taux de capture les plus élevés ont été enregistrés dans des couches de 10-m avec les taux de température les plus élevés, à savoir que des conditions optimales trophiques se produisent dans les couches où la thermocline est située. Le taux des prises a également augmenté durant la période de pleine lune par rapport à d'autres périodes lunaires lorsque l'intensité de la lumière lunaire est plus faible.

RESUMEN

La distribución vertical de 306 ejemplares de pez espada capturados por palangre en la zona entre 2-16°N de latitud y 19-31°W de longitud en 1983 se analizó en relación con la temperatura del agua y la intensidad de la luz lunar. Se utilizó la tasa de captura (captura en kilos por 100 anzuelos) para hacer deducciones acerca de la intensidad de la alimentación. Se registraron las tasas de captura más altas en los estratos de 10-m, con las mayores tasas de aumento de la temperatura, es decir, las condiciones óptimas de alimentación tuvieron lugar en los estratos donde se hallaba la termoclina. La tasa de captura aumentó también durante el período de luna llena, en comparación con otras fases de la luna, cuando la intensidad de la luz era menos intensa.

INTRODUCTION

Swordfish (Xiphias gladius L.), whose savoury flesh has been prized by men since the remotest of times, particularly by the inhabitants of the Mediterranean region and Japan, annually contributes only some 40 000 - 55 000 tonnes to the world's total catch of fish (in 1950 the total reported world catch of swordfish was 8 000 t).

It is a cosmopolitan species common in oceans throughout the world, with the exception of the polar zones. The largest catches by area are taken in the Mediterranean Sea and the Northwest Pacific. In the Atlantic, swordfish catches rose to 24 000 t in 1985 from 13 600 t in 1975 (ICCAT 1986), mostly by long-lining. It is curious to note that a harpoon fishery for this species also exists.

This species' high metabolic rate and large body size requires a large intake of food to sustain life activities and a high growth rate (8-year-old fish reach 80 - 130 kg in weight, Berkeley and Houde, 1981). Consequently, the highest population densities for the species are found in waters with high indices of primary production, and the fish feeding concentrations in turn determine the most productive areas for the swordfish fishery. Such areas are located off the eastern coasts of Central America, Brazil, the United States, and in tropical waters off western Africa (Figure 1).

At the end of the 1950s, swordfish made up a substantial part of the by-catches taken in the Norwegian shark fishery off Nova Scotia. This spurred local fishermen to develop a swordfish long-line fishery in the Northwest Atlantic, where in the four years up to 1964 catches tripled, reaching 8 800 t (Beardsley 1978; Berkeley and Houde 1981). In that same period catch rates ranged between 104 and 230 kg per 100 hooks. Small boats with a capacity for setting 100 - 200 hooks were once employed in the swordfish fishery in the neighboring area off the eastern United States (Wilson and Barlet 1967). A long-line fishery was rapidly developed off the coast of Florida starting around 1975, with 200 fishing units in operation by the end of the 1980s, contributing 2 400 t of swordfish annually. In this latter area 2- to 4-year-old fish weighing 9-36 kg prevail in the catches.

In the North Atlantic, steadily increasing fishing effort as measured by number of baited hooks set inevitably led to falling catch rates and decreases in the mean weight of fish caught, from 120 kg in the 1960s to 80 kg at the end of the 1970s.

Evidence confirming the common occurrence of swordfish in waters with temperatures higher than 13 ºC increased with expansion of the Japanese tuna fishery in the Atlantic (Beckett 1974). Catch rates for swordfish in the Japanese long-line fishery during the past two decades have fluctuated over a rather broad range, with no explicit trend (Figure 2).

Two countries, Italy and Spain, take over 50 % of the total swordfish catch in the Atlantic. Until 1983 Spain ranked first among 16 countries fishing for swordfish in Atlantic waters, but in the last three years it has been outdistanced by Italy. Spanish catch rates in 1973-1982 ranged from 281 to 365 kg per 1 000 hooks (Garcés and Rey 1983).

There is a big international demand for swordfish, whose flesh has a very agreeable flavour that does not deteriorate to any great extent, even when frozen. In Japan the fish enjoys an excellent reputation as a sea food and is consumed fresh as sashimi (sliced with condiments added, the most important ingredient being soya bean sauce). Swordfish contributes 3.6 % of the total catch of "tuna-like fishes" as compared with 12 % of the total market value of fishes of this group (Wise 1983).

During the research cruise of the R/V "Wieczno" to Central Atlantic waters in 1983, swordfish made up 11.8 % of the total long-line catch by weight (Długosz 1983). The observations recorded in the course of fishing activities during that five-month cruise provided valuable information on swordfish behaviour that could be of interest to both fishermen and scientists studying biological aspects of this species.

MATERIALS AND METHODS

This paper is based on catch records made during the research cruise of the R/V "Wieczno" to the Central Atlantic between 16th July and 26th November 1983. The records on the volume and geographical distribution of catches, depth, and atmospheric conditions were made by the vessel master, one of the authors. Hydrological conditions were recorded by a scientific team from the Sea Fisheries Institute in Gdynia under the leadership of R. Długosz.

The northern and southern boundaries of the area in which the experimental catches were made were 2º and 16º N latitude; the eastern and western boundaries were 19º and 31º W longitude. In all, an area of 360 000 km² was scouted and 306 swordfish were caught (13 tonnes live weight). Figure 3 provides detailed information on the catch distribution in the area. A total of 63 sets were made, 75 261 hooks in all, using saira and squid as bait. Depth, water temperature, distance from the thermocline, intensity of moonlight, and fish body weight were recorded separately for each fish caught. The analysis of the entire fished swordfish population in relation to the above factors assumed that the smallest area unit with a homogeneous fish distribution was 1º by 1º, irrespective of latitude. Temperature gradients were determined for 10-m layers starting at the surface, dividing differences in temperature measurements at the upper and lower limits by ten.

The hydrological conditions in the research area were the result of interactions between such known mass water movements in the Central Atlantic as the Canary, North Equatorial, Guinea, Equatorial, and South Equatorial Currents and the Equatorial Countercurrent.

The influence of the Canary and North Equatorial Currents and the Equatorial Countercurrent north of 7º N prompted Długosz (1983) to distinguish between a northern and a southern region within the area. The authors, however, have not considered catches in relation to mass water movements but have confined their interpretation of data to the conditions recorded at the spot where fish were actually caught.

Assuming that the catch records can in fact be interpreted as evidence of feeding activity, they may then be examined in relation to temperature and luminescence, which conditions affect the distribution of the fish and invertebrates preyed upon by swordfish. The role of temperature and luminosity with depth in determining fish behaviour have been underlined by Gorbunova (1969), Casey and Hoening (1977), and Casey and Hoening (1981).

Catch distribution in the study area

The Atlantic regions where different water masses mix, a primary indicator of high productivity and fish abundance, are well known and are depicted on hydrological maps. However, documentation on regional productivity of swordfish is much more limited, because it is available from specialized fleets only, whose activity is often restricted to coastal waters. Information retrieved from tuna fisheries is less detailed, as swordfish taken in the mid-Atlantic long-line tuna fishery are considered by-catch, and the data available are not compatible with the data generated by the specialized fisheries.

The density of swordfish distribution was not uniform in the study area. Most of the fish, in number as well as in weight, were taken in the southern portion, where the highest catch per 100 hooks was recorded (58 - 66 kg), between 5º and 6º N latitude. The share of swordfish in the catch per 1-degree area unit ranged between 2 and 31 % (Figure 3). The mosaic nature of the swordfish distribution suggests that the observed differences were the result of a complex of environmental factors changing with time.

Vertical catch distribution

Baited hooks were set at depths ranging from 50 to 150 m. Swordfish were taken from 60 to 150 m, and the highest frequency was recorded for the layer between 80 and 90 m. 38 % of the total catch was taken there, and the catch rate was also higher. 78 % of the total swordfish catch was taken between 60 and 90 m. This is consistent with the results given by Guitart (1864), who stated that 75 % of long-line swordfish catches were taken in waters above 100 m. The average catch rate during the cruise was highest for the layer between 80 and 90 m

(30.9 kg/100 hooks) and ranged between 10 and 18.7 kg.

The data collected show no clear relationship between depth of capture and fish body weight down to 120 m, after which the largest specimens were taken.

Catch rates and water temperature

The most productive waters had a temperature between 18 and 20 ºC, where the average catch rate was 35.7 kg/100 hooks. Fluctuations above or below this temperature range were accompanied by decreased catch rates, except for the temperature range of 26-28 ºC, the highest water temperature at which catches were made, where a second catch rate peak was observed (Figure 4).

The highest effort (no. of hooks) was expended in waters where the temperature was below 18 ºC, providing 58 % of the total catch in weight. The catch rates in such waters were half those recorded for the warmer waters.

The correlation between feeding activity (abundance) and temperature was more pronounced when relating catch rates to temperature gradients. Fishing efficiency was found to improve as the gradient increased (Figure 5). From this it may be inferred that optimal feeding conditions for swordfish are found in the layer around the thermocline. 77 % of the total catch originated in this layer, which also featured the highest catch rates, regardless of the depth at which the thermocline occurred and the thickness of the thermocline layer.

Feeding activity and moonlight

The influence of moonlight on successful long-lining for swordfish is commonly acknowledged by fishermen, though more on the basis of tradition than of documented evidence.

Guitart (1964) was unable to find any confirmation for the above-mentioned relationship, though he pointed out that Cuban fishermen are strongly convinced that the full moon is the most propitious time to achieve good swordfish catches.

For many years the species has been believed to effect extensive diel vertical migrations (Beckett 1974). Tracing the radio signals emitted by transmitters attached to fish, Carey and Robinson (1981) demonstrated that a fish weighing 70 - 80 kg undertook vertical migrations of up to 600 m over a 24-hour period (Figure 6). At night swordfish frequent the upper layers above 100 m, where they feed intensely. At daybreak they descend to deeper, usually cooler waters. Carey and Robinson (1981) concluded that illumination is a determining factor for the vertical migrations of this species. Since fish visualize when seeking prey, a minimum of light is required. The amount of light is a function of the intensity of the light reaching the surface, depth, and water transparency. It is fair to assume that, when the thermocline is located in deeper layers. more light will be provided by a full moon than by a new moon, and that this stimulates feeding activity, because a fish may encounter more prey near it.

The data from the research cruise analyzed here supported the hypothesis linking feeding intensity (biting a baited hook) with the intensity of the moonlight reaching the ocean's surface. The catch rates recorded during the different phases of the moon were 9.4 kg/100 hooks during the new moon, 8.3kg/100 hooks during the first quarter, 33.8 kg/100 hooks during the full moon, and 14.9 kg/100 hooks during the the second quarter. The distribution of the catch rate in relation to the phase of the moon is illustrated in Figure 7. The data thus confirmed the traditional opinion of fishermen that swordfish feeding activity increases during the full moon and that, as a result, there can be a higher expectancy of successful catches at that time.

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Table 1 Average swordfish weight (kg) in the catches by 10 m depth interval

Depth interval	60.1-70.0	70.1-80.0	80.1-90.0	90.1-100	100.1-110	110.1-120	120.1-130	130.1-140	140.1-150
Average weight	42.3	32.2	48.8	39.4	44.6	44.8	—	60.7	57.0

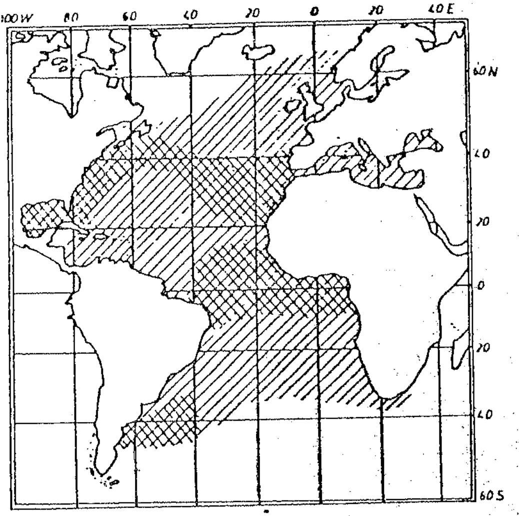


Fig.1 Distribution of swordfish in the Atlantic Ocean.
//// range main fishing grounds.
/Pelczarski 1983/

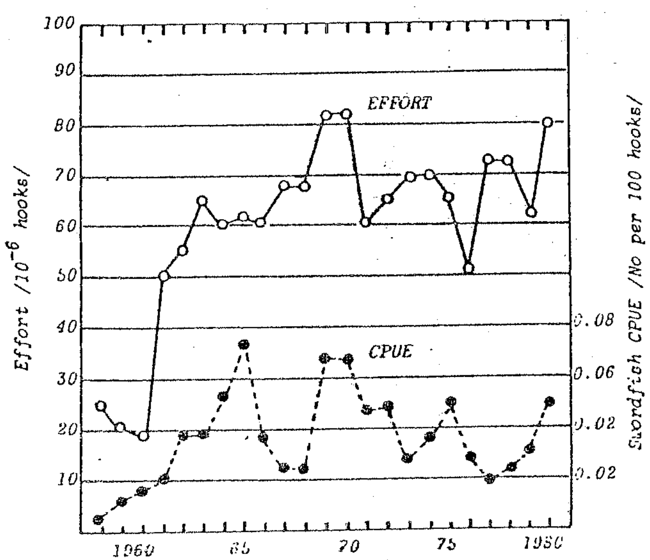


Fig.2 Fishing effort and CPUE in the Japanese long-line fishery in the Atlantic.

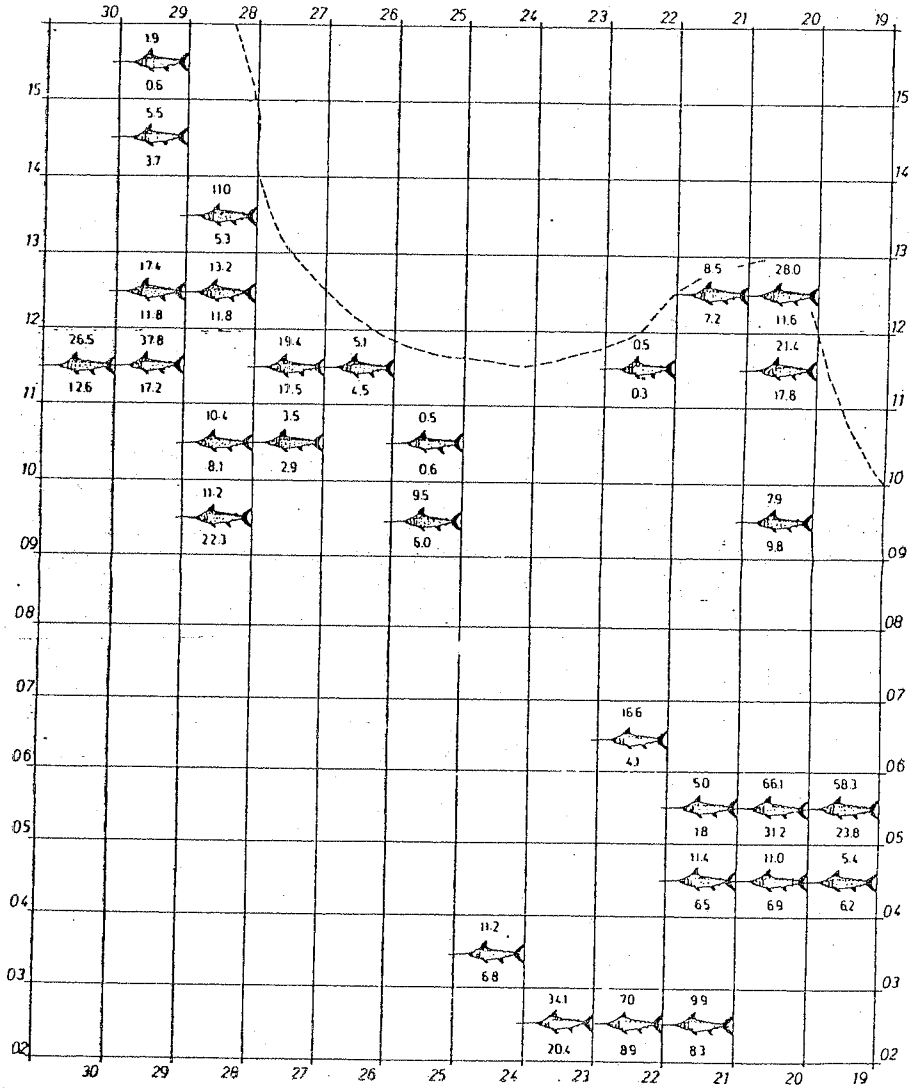
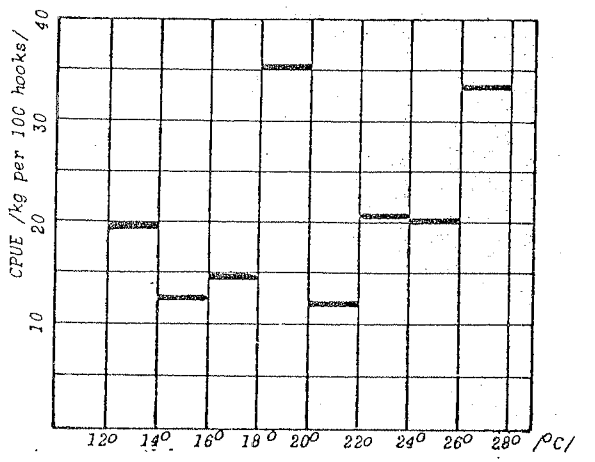


Fig.3 Distribution of swordfish catches during the cruise of R/V "Wieczno"; upper figure — kg per 100 hooks; lower figure — share of swordfish in the total catch from square (in %).



Fid.4 Swordfish CPUE in relation to water temperature.

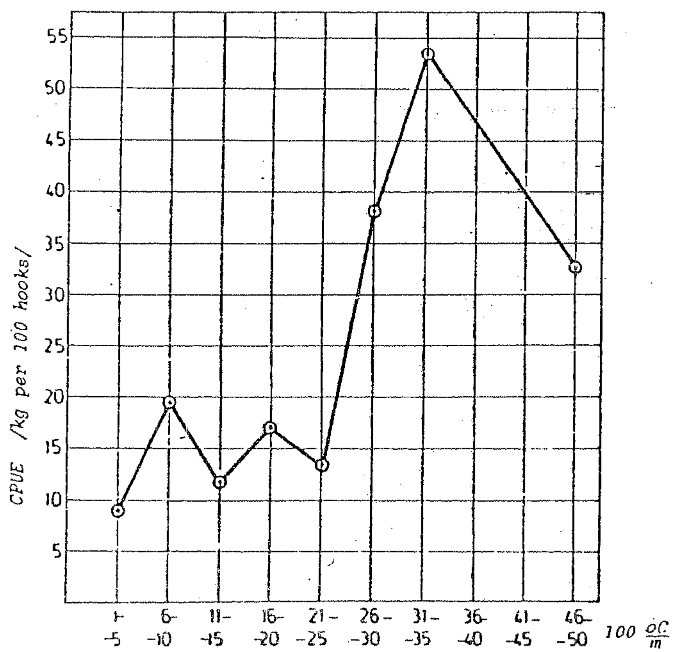


Fig.5 Swordfish CPUE in relation to temperature gradient

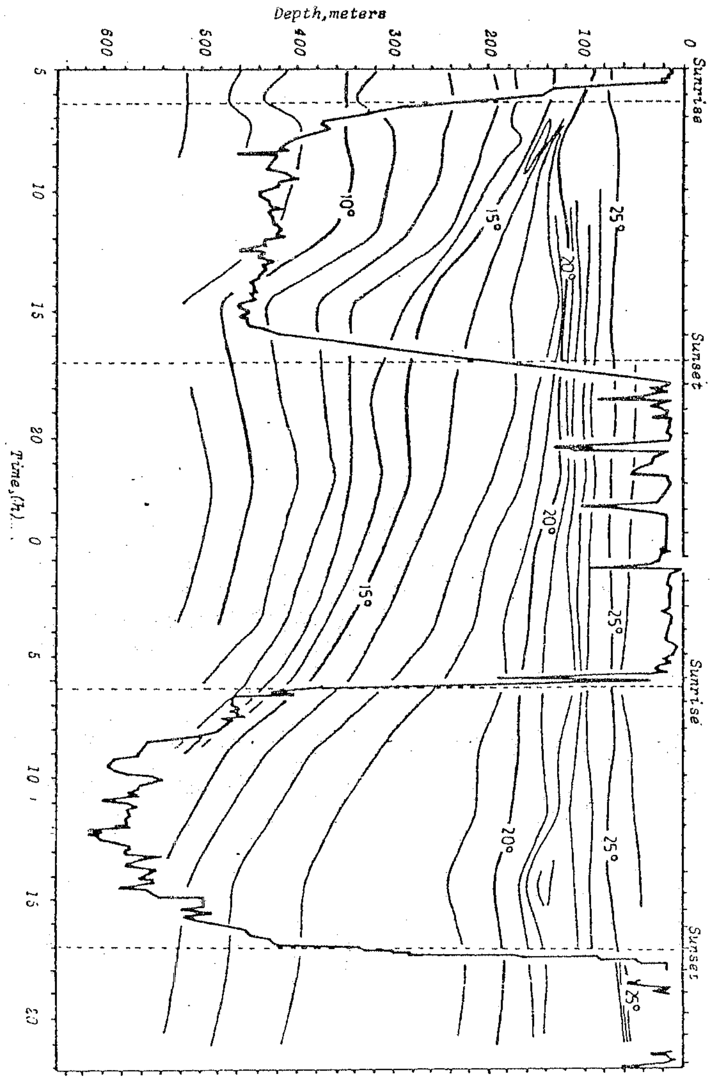


Fig.6 Depth record for swordfish with isotherms drawn - from XBT casts /Report on acoustic telemetry experiments 1976-1978, Carey and Robinson 1981).

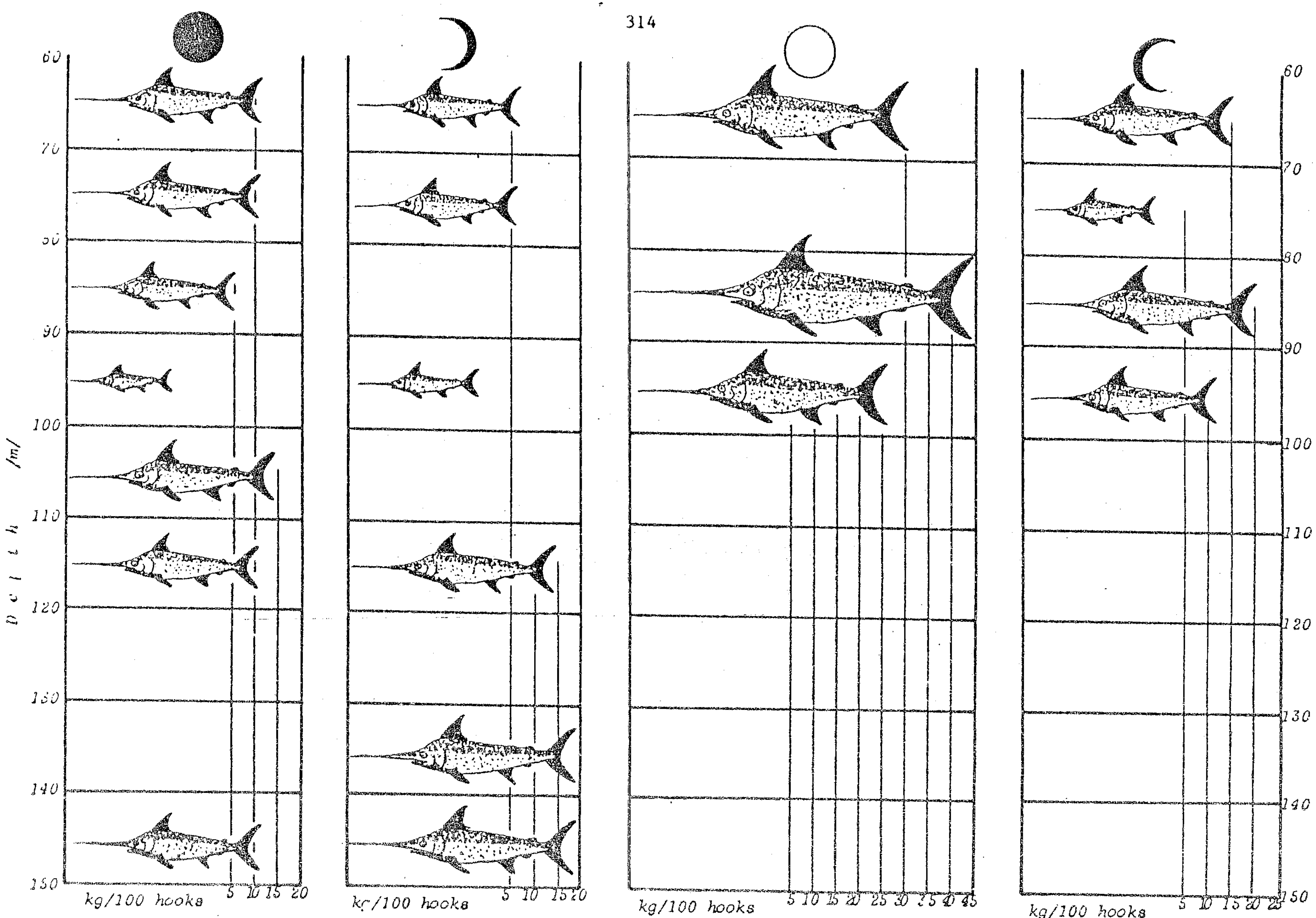


Fig.7 Influence of moonlight on swordfish catches.

● new moon ○ full moon.