

FOOD HABITS, SCHOOLING AND PREDATORY BEHAVIOUR OF THE YELLOWMOUTH BARRACUDA, *SPHYRAENA VIRIDENSIS* (PERCIFORMES: SPHYRAENIDAE) IN THE AZORES

by

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ABSTRACT. - The yellowmouth barracuda is one of the most common coastal pelagic predator in the Azores archipelago which probably constitutes their northernmost range in the Eastern North Atlantic. The biology, behaviour and feeding ecology of this species is virtually unknown. Between 1997 and 1998, 100 individuals of *S. viridensis* were collected in the Azores islands. Their size ranged from 545 to 1190 mm (TL). Stomach contents were analysed and 66% of them contained food. Fish were the only prey observed. Juveniles of *Trachurus picturatus* were the dominant item identified, occurring in 82.2% of the stomachs containing food. Mean size of prey was correlated to the mean size of barracudas. Some 550 hours of behavioural observations were carried out. Different types of aggregations were observed with small groups and isolated individuals in winter conditions and big schools in summer, displaying several types of predatory behaviour.

RÉSUMÉ. - Habitudes alimentaires, comportement d'aggrégation et de prédation de la bécune à bouche-jaune *Sphyraena viridensis* (Perciformes: Sphyraenidae) aux Açores.

La bécune à bouche-jaune (*Sphyraena viridensis*) est l'un des prédateurs pélagiques les plus fréquents des côtes des Açores, qui représentent probablement la limite la plus septentrionale de son aire de distribution. La biologie, le comportement et l'écologie alimentaire de cette espèce sont peu connus. Entre 1997 et 1998, 100 exemplaires de *S. viridensis* ont été capturés aux Açores. La taille des individus variait entre 545 et 1190 mm (LT). L'analyse des contenus stomacaux a révélé que 66% des estomacs contenaient de la nourriture, composée uniquement de poissons. La bécune se nourrit surtout de juvéniles du chinchard *Trachurus picturatus*, observés dans 82,2% des estomacs pleins. La taille moyenne des bécunes a été comparée à celle des proies. Des observations du comportement ont été faites pendant 550 h. environ. Différents types d'aggrégations ont été observés, avec des petits groupes et des individus isolés en hiver et de grands bancs en été, correspondant à différents types de comportement de prédation.

Key words. - *Sphyraena viridensis* - Yellowmouth barracuda - Azores - Behaviour - Schooling - Predation.

The yellowmouth barracuda *Sphyraena viridensis* Cuvier, 1829 is a coastal pelagic predator common in the Azores, which is, probably, the northernmost limit for this species in the northeastern Atlantic. The species occurs in Madeira, Cape Verde, Canaries and in the Mediterranean (Ben-Tuvia, 1986; Bizsel and Cihangir, 1996; Wirtz, 1998; Vacchi *et al.*, 1999) and is the only species of barracuda so far known in the Azores Archipelago (Santos *et al.*, 1997). Santos *et al.* (1997) also described the characteristic ichthyofauna of the Azores, while Porteiro *et al.* (1996) treated the similarities of Azorean Labrids, an important group of littoral fishes, with other regions, temperate and subtropical, of the eastern Atlantic.

Relini and Relini Orsi (1997) identified *Sphyraena viridensis* from the Italian shores as well as from the Balearic and Sardinian waters. Its geographical range is probably wider because this species is often confused with *S. sphyraena*. Like all barracudas, *S. viridensis* has a slender fusiform

body with a conical, hydrodynamical snout. Its mouth, which is long, with low protractile capacity and with a prognathic lower jaw, has two rows of long canine-like teeth. This barracuda has no scale on the preoperculum, which is one characteristic that allows differentiation from *S. sphyraena*. Its body is darkish grey to bluish dorsally and silvery ventrally. The upper half of the body has numerous vertical dark bands that extend below the lateral line in the anterior part of the flanks. Juveniles are more greenish to dark yellow.

Data on the biology of this species are virtually non-existent except for distribution (*e.g.*, Relini and Relini Orsi, 1997). In fact, the biology, especially behaviour, of the whole genus *Sphyraena* has been treated in few scientific publications. In a recent work, Paterson (1998) studied the occurrence and formation of *S. barracuda* schools in the islands Turks and Caicos. In the present paper, along with the feeding habits, we described the predatory and schooling behaviour of the yellowmouth barracuda.

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MATERIAL AND METHODS

Collection of specimens

All specimens sampled were collected near the Azorean islands of Santa Maria, Terceira, Faial, Pico, Flores and Corvo by spearfishing (Fig. 1). The two main reasons considered for using this method were because spearfishing prevents regurgitation (e.g., Bowen, 1983) and selection of specimens is easier (Derbal and Kara, 1996).

Collections were made during the whole year around in the islands of Terceira, Faial and Pico, and from June to September around the other islands. Due to unfavourable weather conditions no collections were made in December 1997 and February 1998. A total effort of 400 h. of observation was done in Terceira, Faial and Pico and 150 h. in Santa Maria, Flores and Corvo. Specimens were collected with a standard 16 to 20 mm diameter rubber powered speargun with stainless steel 6.5 to 7.0 mm diameter x 130 to 160 cm long spears. The bulk of these collections was made by snorkeling.

Food habits

After collection the fish were immediately weighed (with a dynamometer to the nearest g), their total length (TL) was measured (to the nearest mm) and the fish were sexed.

The length-weight relationship of the Azorean yellowmouth barracuda, including most of the specimens collected for this work, appeared in a recent paper (Morato *et al.*, 2001). Freshly ingested prey were investigated for the presence of wounds and their relative position (cephalic or caudal) in the oesophagus of barracudas. In the laboratory a degree of digestion was attributed to the stomach contents. Each food item was identified to the lowest taxonomic level possible and, after superficial drying, weighed with an electronic balance (± 0.01 g). The length of recently ingested items was measured to the nearest mm.

Importance of prey items in the fish diet was based on

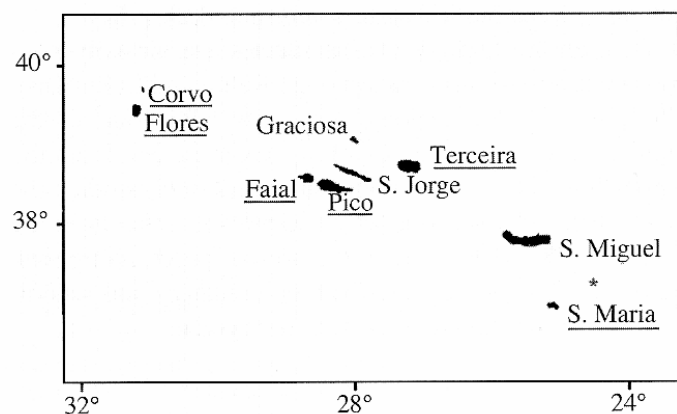


Figure 1. - The Azores Archipelago. Islands where collections were made are underlined. * Formigas islets.

the feeding coefficient (Q) of Hureau (1970), in which:

$$Q = (\%C_{na} \times \%C_{pa})$$

where

$$\%C_{na} = \frac{\text{number of a prey}}{\text{total number of prey}} \times 100$$

and

$$\%C_{pa} = \frac{\text{weight of a prey}}{\text{weight of all prey}} \times 100$$

Geistdoerfer (1975) proposed the index "F" for determining the frequency of a prey:

$$F\% = \frac{\text{number of stomachs with the item a}}{\text{total number of full stomachs}} \times 100$$

The index Q gave an idea of the quantitative importance of a determined prey item in the fish diet, while F expressed the frequency with which a prey is captured.

Behavioural observations

Schooling and predatory behaviour of the yellowmouth barracuda were observed in Terceira island, especially in Baixas da Serreta (area A1) and Ilhéus dos Fradinhos (area A2). Area A1 is a complex of shallow sea-pinnacles located approximately 5 miles west of the island and area A2 is a small rocky outcrop situated 1.5 miles south of the island.

Between June 1996 and December 1998, 550 h. of observation have been performed on schools (more than 10 individuals), small groups (fewer than 10 individuals), pairs or isolated individuals. The bulk of these observations was made by snorkeling (95%) and the remainder by SCUBA diving. Once the fish were detected we stayed near them for as long as possible, taking notes on a waterproof writing board. Besides initial, but brief, reaction, the fish seemed indifferent to our presence.

We defined "group" as an aggregation of two or more animals that kept a fixed distance between them, according to Keenleyside (1979) as individuals tend to perform the same activity together. These individuals could be moving or still. In these aggregations the number of fish was recorded and the maximum and minimum size of individuals was estimated, as well as the average fish size in a given aggregation. Three estimated size classes (in cm) were observed: i) TL < 50, ii) 50 < TL < 100 and iii) TL > 100 cm. Their relative position in the water column was tested with the χ^2 test (Ludwig and Reynolds, 1988).

Surface water temperature was measured and varied from a minimum of 16.3°C in mid February 1997 to a maximum of 25.4°C in early September 1998. Surface sea temperature averaged 17.2°C ($\pm 1.3^\circ\text{C}$) in winter and 23.7°C ($\pm 2.1^\circ\text{C}$) in summer. Current speed was evaluated by noting the drifting speed of a piece of cardboard paper and horizontal visibility was noted by placing a buoy at known distances. Current speed/presence of schools was tested with the Spearman Rank Correlation (Ludwig and Reynolds,

Species	Numeric percentage (Cn%)	Weight percentage (Cp%)	Hureau's Q Index of importance in diet	Geistdoerfer's F Index of frequency (%) in diet
<i>Trachurus picturatus</i>	82.2	62.6	5145.9	74.2
<i>Boops boops</i>	0.9	2.4	2.2	1.5
<i>Pagellus acarne</i>	2.8	1.1	3.2	1.5
<i>Thalassoma pavo</i>	0.9	2.3	2.1	1.5
Unid. Exocoetidae	0.9	2.5	2.3	1.5
Unid. Teleostei	12.1	29.2	354.4	19.7

Table I. - Diet of *Sphyraena viridensis*.

1988). Nocturnal observations were limited to 6 h and 4 dives in "Ilhéus das Formigas" (2 dives, 2 hours) (Fig. 1) and in area A1 (2 dives, 4 hours) and used artificial lights.

RESULTS

Food habits

A total of 100 individuals of *Sphyraena viridensis* were captured of total length ranging between 545 and 1,190 mm and total weight between 560 and 5 800 g. Among them, 66% contained food.

The diet of *S. viridensis* was only composed of fish (Tab. I). The species *Trachurus picturatus* (Carangidae) was the most important prey with 74.2% of frequency. Its numerical percentage is very high (82.2%) as well as its weight percentage (62.6%). Unidentified Teleostei had a frequency percentage of 19.7%.

In single occasions remains of *Boops boops* and *Pagellus acarne* (Sparidae), *Thalassoma pavo* (Labridae) and one unidentified Exocoetidae were found, corresponding to a frequency of 1.5%.

The use of teeth for capturing prey was only evident in 8 prey (all *T. picturatus*) recently ingested from a total of 27. The position of recently ingested prey in the oesophagus was, in 21 occasions observed, cephalic (12 times) or caudal (9 times).

Schooling behaviour

During summer months great schools have been observed near shallow sea-mounts and deep cliffs wherever the depth was greater than 20 m. The largest school observed contained more than 180 individuals and the average size of schools was between 30 and 50 fish ($n = 76$; geometric mean = 39.1; SD = 23.3). All these large schools were observed in areas subjected to noticeable, sometimes strong, currents although no significant correlation ($r_s = 0.483$, $p > 0.05$) were found between the pair school/current speed. Schools apparently do not depend on current speed to aggregate.

Fish present in these aggregations were sub-adults of

both sexes, females being generally larger than males. Besides this fact, there is no way of determining sex other than examining the gonads. The smallest fish observed were about 30 cm TL and the largest were longer than 130 cm. The average TL was approximately 70 cm.

Schools occurred over a vast area, occupying the water column from the surface down to 30 m deep. Sub-adults tended to group near to the surface, medium size fish occupied an intermediate position and large females stayed at the bottom of the school ($\chi^2 = 4954.03$, $df = 3$, $p < 0.001$).

During 75% of the time, fish stayed almost immobile, drifting with currents in the water column. The rest of the time was spent chasing prey or, in brief occasions, apparently, interacting sexually.

When something forced the group to disperse (e.g., the descent of a diver) the "closing" of the group is immediate, followed by the typical "mill", in which, for a short moment in our cases, the school swims in circles.

Whereas most barracudas were observed schooling in summer ($n = 116$, 65.6%) they were also found isolated (12 occasions - 10.3%), in pairs (10 occasions - 8.6%) or in small groups (18 occasions - 15.5%). Small groups, pairs or isolated fishes ($n = 40$) 98% occurred in shallow water bays and only one isolated fish was observed in deep water.

The formation of large schools of barracudas was observed between May and October, with 88% of the large schools being observed in July, August and September ($n = 67$). Their occurrence is always associated with sites that are subjected to strong currents.

In winter time (November to April) no large schools were detected. Only 12 small groups of juveniles were observed in shallow water bays. Large individuals (always longer than 90 cm TL) were found isolated or in small groups from 2 to 6 animals with a maximum of 12 ($n = 23$; geometric mean = 3.2; SD = 3.95). They were found near shore over rocky bottom, close to sandy bottoms.

Differences between size of schools between summer and winter was highly significant (paired t-test $p < 0.001$) since no large schools was detected in winter.

Territoriality was not observed in *S. viridensis* and this fish was never found in association with any other species.

Predatory behaviour

Predation episodes were observed in summer (78 dives) and winter (42 dives) (Fig. 2). These are classified as follows: a) one predator chasing one prey; b) several predators chasing one prey; c) one predator chasing several preys; d) several predators chasing several preys.

Type a) actions involved an attack towards an isolated prey. The predator, after locating itself as near as possible moved suddenly and very fast towards it. The success rate of this type of attack was 32% in 38 observations. These attacks were observed all year long.

Type b) several individuals of a school (2 to 8) simultaneously pursue an isolated prey that, in all 26 observations, was captured. The predators involved were of equivalent sizes and did not react agonistically between them. Pursuits were very fast lasting from 6 to 48 seconds until the prey was eventually captured. All these observations occurred between July and September.

Type c) was observed all year long (43 times). A single predator invested several times against a school of prey. The success rate observed was of 75%. This was the only type of attack in which a prey other than *Trachurus picturatus* was involved. The others were, respectively, in one and four occasions, small schools of *Macrorhamphosus scolopax* and *Capros aper*. All these observations were made at night near "Ilhéus das Formigas" (Fig. 1). The predator, while repeatedly attacking a school of prey, gradually disperses the school into smaller units. Artificial lights did not affect predator/prey behaviour.

Type d) was the type of action most commonly seen in summer. We observed it 72 times between June and September. Three different cases happened:

1) Prey were near the surface. Predators located in the

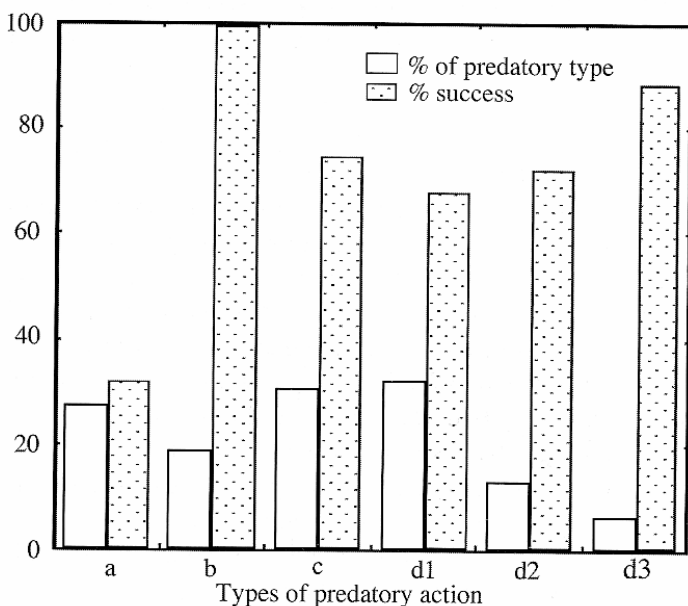


Figure 2. - Relative importance of predatory actions and success rate.

upper part of the school attacked first, while animals located lower dispersed laterally and attacked from the sides. This situation was observed 45 times with a success rate of 68%;

2) Prey were in midwater position. Midwater and bottom placed predators made a straight attack. Animals on top almost never interfered. This situation was observed 18 times with a success rate of 72%;

3) Prey located in deeper water were attacked only by the large individuals from this area. This situation was observed 9 times with a success rate of 89%.

DISCUSSION

Yellowmouth barracudas from the Azores have an obvious main prey in small juveniles of *Trachurus picturatus*, although small juveniles of many other species are also common in these waters (mainly: *Pagellus acarne*, *P. bogaraveo*, *Sardina pilchardus*, *Trachinotus ovatus* and *Scomber japonicus*) often in large schools. The dependence of barracudas on juvenile *T. picturatus* has several implications, as *T. picturatus* is an important commercial species both for human consumption and for live bait in tuna fishing (see Isidro, 1990). Other potential prey for *S. viridensis* are also common in the Azores (although not as much as those mentioned above) such as *Macrorhamphosus scolopax*, *Capros aper* and *Sardina pilchardus*.

Yellowmouth barracudas in the Azores seem to be mainly piscivorous thus agreeing with the very few other works on barracuda food habits (e.g., de Sylva, 1963; Schmidt, 1989). However, the diet of *Sphyræna viridensis* in the Azores is clearly dominated by juveniles of only one species, while Schmidt (1989) referred, for young *S. barracuda*, to four important fish species in 50 stomachs analysed and 15 species that strongly contrast to the six species in our 66 stomach samples.

Yellowmouth barracudas in the Azores seem to aggregate in large schools only in summer, becoming scarce and dispersing when the water gets cold. Comparing with the observations of *S. barracuda* by Paterson (1998) from Turks and Caicos, *S. viridensis* have a strong seasonality in their group formation. That happens mainly because of the higher latitude of the Azores and may also explain why large schools (larger than those observed by Paterson (1998)) occur, apparently, only in summer in the sense that they may have to concentrate in a shorter period of time for reproduction purposes. The observed significant difference in the school size between summer and winter could also be due to the fact that there are less individuals in shallow water in winter because many migrate to deeper water or to southern latitudes. Those found in shallow water are thus scarcer and less aggregated. A few *ad libitum* observations in São Tomé

island (Gulf of Guinea) and in oil platforms in Gabon, respectively with *S. barracuda* and with *S. sphyraena*, are more similar to those of Paterson (1998).

Although aggregations of barracuda were always associated to areas subjected to strong currents, its speed is unlikely to cause aggregating behaviour. According to Paterson (1998), although typically associated with particular sites and current flow, group formation may also be influenced by factors such as social facilitation, prey availability, and behavioural tradition.

Contrary to Paterson (1998), no territorial behaviour was observed in *S. viridensis*. Nevertheless, the large summer schools appear to be strongly size/sex segregated because the large females tend to aggregate at the bottom of the school. This is maybe due to the fact that females, being larger, have access to a more favourable hunting position and/or are in a more protected position against potential predators. In a recent work, Magurran and Garcia (2000), showed that schooling in fish may be determined by sex differences in size and morphology. It is possible that females form the core of the school and males aggregate to them for obvious mating advantages (Griffiths and Magurran, 1998).

Large schools are associated with offshore seamounts, deep canyons and small islets and dominated by big individuals when a feeding opportunity appears. The reasons for such aggregations are probably the same that Paterson (1998) referred for *S. barracuda*: i) resting aggregations; ii) pre-spawning aggregations; iii) anti-predatory advantage and iv) foraging advantage. In fact, group foraging has an obvious advantage since predators acting together can more easily restrict the movements of a school of prey fish than when they are alone (Keenleyside, 1979). Our results seem to point towards this since percentage of success was higher when in group actions. It is known that group-foraging piscivores increase food intake through passive information sharing about quality or location of food patches and coordinated attack on schooling fishes (Ryer and Olla, 1992; Pitcher and Parrish, 1993). Barracudas, then, may sometimes form polarized and non-polarized schools (Shaw, 1970), depending on their activity, although Keenleyside (1979) indicates that pelagic species show the most highly polarized forms and that some authors use the term aggregation for non-polarized schools and school only for polarized units. In this sense, barracudas may aggregate as shoals or as schools. They form shoals when in resting moments and stationary situations (Paterson, 1998) and transform to schools when swimming actively and reducing individual distances. The "mill" formation, as described by Parr (1927), would be the highest polarized formation detected in *S. viridensis*.

However, in winter, the few large individuals observed were associated with shallow waters over rocky bottom close to sandy banks, which may consist in a hunting pos-

ture with obvious camouflage advantage. This same pattern was described for *S. barracuda* (de Sylva, 1963; Paterson, 1998). Juveniles form small groups in winter and tend to remain in sheltered bays, which are slightly warmer and with fewer potential predators than further offshore. Small groups of *S. borealis* juveniles were reported in sheltered, shallow water environments (Rountree and Able, 1992; Able and Fahay, 1998; Rountree, in press).

Yellowmouth barracudas in the Azores were never seen in heterospecific groups as happened with the *S. barracuda* by Paterson (1998). However, several fishermen, operating on tuna fishing vessels, report that barracudas are seen constantly in the vicinity of whale sharks. There is also a published photograph, taken in Graciosa island (Saldanha, 1995), that shows a large solitary yellowmouth barracuda closely swimming to a large specimen of the manta ray *Mobula tarapacana*. Predatory behaviour of *S. viridensis* in the Azores also seems to be more efficient when schools are formed. Group attack always ended in the capture of an isolated prey and the rate of predatory success was always higher. Scientific studies on yellowmouth barracudas in particular and on other species of barracudas in general are very rare which implies that a wider comprehension of this very important predator is, at least locally, of extreme importance.

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