Aquatic Mammals 1987, **13.2,** 65–80

Preliminary observations of the bottlenose dolphin (*Tursiops truncatus*) in the Sado estuary (Portugal)

Manuel E. dos Santos[1] & Miguel Lacerda[2]

[1]*Instituto Superior de Psicologia Aplicada, Rua Jardim do Tabaco, 44 1100 Lisboa, Portugal*
[2]*Museu do Mar, Câmara Municipal de Cascais, 2750 Cascais, Portugal*

Abstract

Bottlenose dolphins may be sighted in the Sado estuary throughout the year. Between April 1981 and May 1986, we have observed these animals during small-boat surveys and also from the coast. These observation sessions were non-systematic and total 87.6 hours of direct observation in 71 sightings. Photographs were taken during the boat surveys.

The photographs allowed us to recognize by the dorsal fins a total of 26 individuals, some of which were scored several times throughout these 5 years. Mean group size was 13.7. We estimate that this resident demographic unit is formed by at least 40 animals. In this wide estuary, dolphins were most frequently observed near the mouth of the river, on its southern side. We have also followed them for 15 km upstream as well as about 20 km along the coast southwards. Our fragmentary data do not indicate any significant relation between the movements of the groups and the tides. Inside the estuary, feeding-related behaviours are markedly predominant. Important prey-species are the mullets (*Mugilidae*), the cuttlefish (*Sepia officinalis*) and the twaite shad (*Alosa fallax*). We present some behaviours that seem to be undescribed for free-ranging groups of Tursiops. Information on the 8 bottlenose dolphins found dead in this region since 1982 is also presented.

Bottlenose dolphins were traditionally considered as a nuisance by local fishermen, and they made efforts to kill the dolphins and eat them, but this persecution is now practically over. At the present time, industrial pollution seems to be the most significant threat to these animals.

Introduction

According to local fishermen, the presence of the bottlenose dolphins in the Sado estuary and adjacent coastal waters is ancient and it has been permanent. In spite of this and of the great interest that this species has aroused all over the world, they are scarcely known by the public and by the scientific community.

These delphinids, locally known as 'roazes' or 'golfinhos', were first reported in the area by the naturalist Bocage in 1863. More recently, other workers reported on the existence of a resident population in this estuary (Reiner, 1981; Teixeira, 1981). The dolphins were observed again in September 1980 (Teixeira & Duguy, 1981) and in October 1981 (Hussenot, 1982), and the possibility of recognizing some of the animals by natural marks on the dorsal fins was confirmed. Some possible habits of the animals were also discussed by those authors, such as a tidal pattern of movements, but the data gathered to support these discussions have been insufficient for definite conclusions. The size of the group was stated as between 20 and 30 individuals and some feeding and resting areas were indicated. Some more important prey-species, such as the cuttlefish (*Sepia officinalis*) and mullet (*Mugilidae*), have been referred by Teixeira (1981).

The present authors have been observing these dolphins for several years, although with irregular periodicity and in schedules of variable intensity. In this preliminary report we try to synthesize the information collected for further discussion of the characteristics of this group of dolphins.

One of us (M. d. S.) used part of this material on a graduation thesis for the university of Lisbon (dos Santos, 1985).

The study area

The Sado estuary has a maximum width of 5 km, although its mouth is about 2 km wide, due to the long and sandy Peninsula of Tróia that has been formed in front of the Setúbal bay (see Fig. 1). The approximate position of the Sado river mouth is 38°29'N, 08°55'W. Between Setúbal and the Peninsula the estuary is divided into two channels by sand and mud banks. The south channel is larger, deeper and shows a more intense water flow. Maximum depths are 40 m at the mouth, 25 m in the south channel and 15 m in the north channel. The inner part of the estuary is very shallow, with extensive mud flats.

The influence of the sea is dominant in the estuary, especially in the summer months. This is reflected by

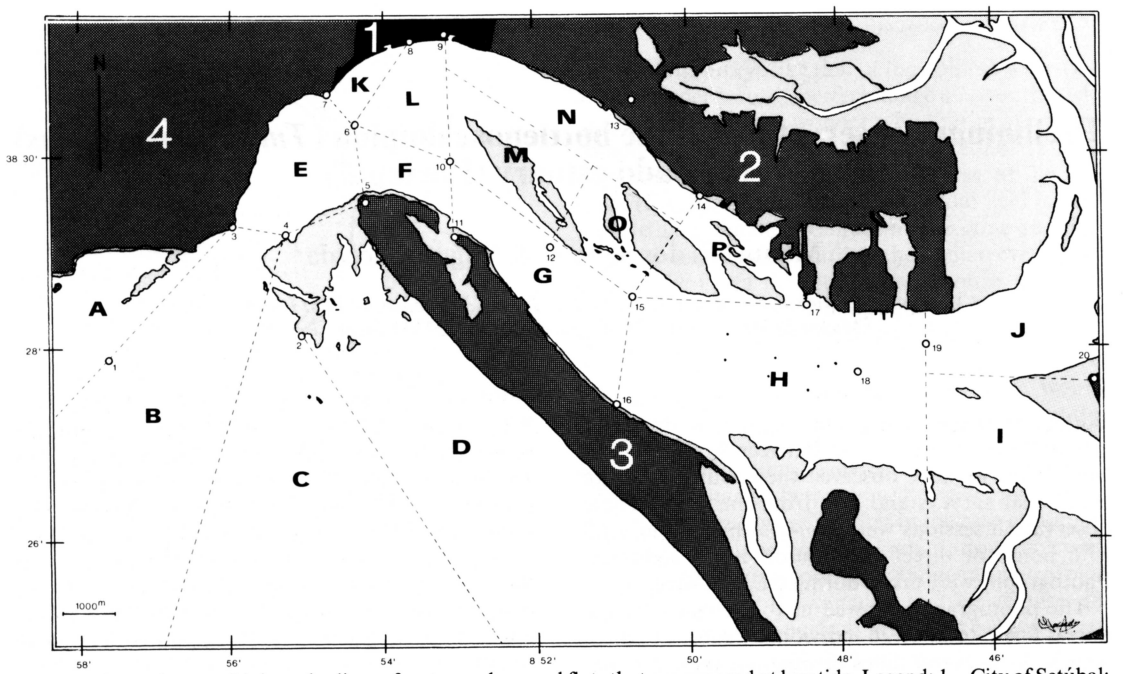


Figure 1. The study area. Lighter shading refers to sand or mud flats that are exposed at low tide. Legend: 1—City of Setúbal; 2—Industrial zone; 3—Peninsula of Tróia; 4—Arrábida Hills.

its fauna, which is predominantly marine. Some of the apparently more important fish speceis reported in the estuary are: the mullets (*Mugil cephalus, Liza ramada, L. saliens, L. aurata* and *Chelon labrosus*), the common eel (*Anguilla anguilla*), the twaite shad (*Alosa fallax*), the anchovy (*Engraulis encrasicolus*), the toadfish (*Halobatrachus dydactilus*), the sea bass (*Dicentrarchus labrax*), the red mullet (*Mullus surmuletus*) and the conger eel (*Conger conger*). As to the cephalopods, the great abundance of the cuttlefish between March and October must be stressed. The octopus (*Octopus vulgaris*) and the squid (*Loligo vulgaris*) are also present.

Fishing, agriculture and salt extraction are typical human activities in the region, but industry has grown in the northern edge of the estuary. The waste discharges to the north channel and to some areas more upstream have been damaging to the traditional faunal wealth of this estuary. Overfishing is another very aggressive activity in the region, and illegal gear is commonly used.

To the south of the Sado river mouth, the coast is formed by long and open sandy beaches. To the west, the coast is basically rocky and high. Just outside of the river mouth there is a large sand bank that nearly unites with the Peninsula at low tide.

Methods

Thirty-five boat surveys have been conducted in the study area, with the participation of at least one of the authors. These surveys were irregularly spread between the months of July 1981 and May 1986, and took place usually between 10.00 and 18.00 hours. The observation effort during these surveys was not equally spread throughout the study area. Before a sighting was made, we spent most of the time surveying the lower part of the estuary (especially subareas E, F and L), and many of our incursions upstream or to the sea happened while we followed a group of dolphins. Several rubber boats have been used, measuring usually about 4 m and equipped with outboard engines around 25 HP. We used a 35 mm camera (without a motordrive) and lenses of 50 and 200 mm to take photographs of the dolphins' dorsal fins, for individual identification (see Würsig and Würsig, 1977), and also of their aerial behaviours. As we were not able to rely on photography to count the animals present in each group, we made direct counts. It is often difficult to count dolphins, particularly when groups are large and present tight formations. Therefore some of our group size data are estimates rather than absolute counts, i.e. we used the mean between the minimum and maximum number of animals counted.

Sightings were also made from shore or from other types of boats (like fishing boats or yachts), either by the authors or by volunteers with experience. The total amount of time spent looking for the dolphins was not quantified and some of the sightings were casual. Anyway, the periodicity of shore-

based observation sessions was also very irregular throughout the time-span of this study.

During these shore-based observations periods we used fixed points near the tip of the Peninsula, either at sea-level or on top of the buildings that exist there. The records that we have collected indicate the time of the sighting, movements of the groups and their duration, and the number of animals counted or estimated by the same procedure as above.

Shore-based observations and boat surveys were aided by binoculars (10 × 50) and a tape recorder was used. We divided the study area in subareas, as shown in Fig. 1, and these subareas were used to indicate the general movements and distribution of the groups. To define the subareas we needed topographic references that could be easily identifiable visually from our shore points and from a boat, and so we have come to work with subareas of unequal sizes.

We have also been collecting information about all strandings of cetaceans in the region since 1982, reported to us by the Customs Guard, the Navy, other institutions and individuals. A number of dead bottlenose dolphins have been inspected, photographed, and measured according to a method adapted from that of Norris (1961). In some cases the remains were then taken to the Museu do Mar for casting, dissection and skull recovery. We looked for parasites and stomach contents. After preparation, the skulls were measured according to the method of Ross (1984), and the teeth were collected. Some were sent to institutions experienced in age estimation and are now being examined.

We conducted informal interviews with fishermen and other people who use the estuary in their daily activities, thus collecting information about fish catches in different parts of the study area, and other relevant qualitative informations.

Results

Direct observation of groups

By group we mean all the animals that could be seen during a sighting, even when they were spread over a wide area. When there was an obvious separation between smaller units, we refer to these loosely as subgroups. When a group was lost and then dolphins were sighted again after more than 15 minutes, we refer to this as a new sighting and a new group.

Bottlenose dolphins were sighted in 31 of the 35 boat surveys (or 89%). We sighted 40 groups and accumulated in this way 69.8 hours of direct observation. From shore, or from other types of boats, we recorded 31 sightings which represent 17.8 hours of observation of the animals. We thus obtained a total of 87.6 hours of direct observation.

In our total of 71 sightings, 975 animals were counted ($\bar{x}=13.7$; $s=9.2$). The frequency distribution of group size classes is shown in Fig. 2.

The exact time the dolphins spent in each habitat subareas was not quantified. However, the number of times that groups or subgroups were seen in the various subareas, regardless of the time that they stayed there, is represented in Fig. 3.

In our effort to study the possible relations between the semidiurnal tides and the movements of the groups, we divided the tidal periods in which we had sightings in 12 one-hour units, plus a rest of about 20 minutes between each tide. As to the movements of the groups, we tried to identify always a general direction of travelling. Even when the various animals in a group are surfacing in different, sometimes opposite, directions, there is often a directional displacement of the group. In a habitat like this estuary, whose main dimension is its length, the more obvious and perhaps relevant distinction in the displacement of a group is whether it moves 'upstream' or 'downstream'. When we were unable to identify this general direction we called it 'indeterminate'. Throughout the tidal periods, the number of times groups were seen moving in the 3 different 'direction categories' was computed for all our tidal units. A summary of these results is presented in Table 1.

Photographic records

In 17 of the boat surveys we photographed the dolphins, obtaining a total of 1009 photographs. The dorsal fins in favourable positions were enlarged and then drawings were made of the fins that were clearly recognizable. We can now recognize a total of 26 different dorsal fins, which are represented in Fig. 4. These animals were given names, whose first 3 letters are also presented.

We have photos of the same animals that were taken with intervals of several years, and it is obvious that the fins change, showing more natural marks as time passes. The rate of change is not common to all animals, though. Some fins are relatively stable, but some may show many new marks in less than a year. See, for comparison, the fins of two animals that are shown in Fig. 5.

Anway, the drawings present the shape of each fin as we have it in its last clear photograph.

As to the presence of these recognizable individuals throughout the study period, our data are summarized in Table 2.

Observation of behaviour

We also recorded the dolphins' behaviour, and made some photographs of aerial behaviour occurrences. This is a qualitative account of these preliminary observations, and we present some behaviour patterns that seem to be undescribed for free-ranging groups of Tursiops.

From shore the dolphins may be observed without any effect on their natural behaviour, but this is

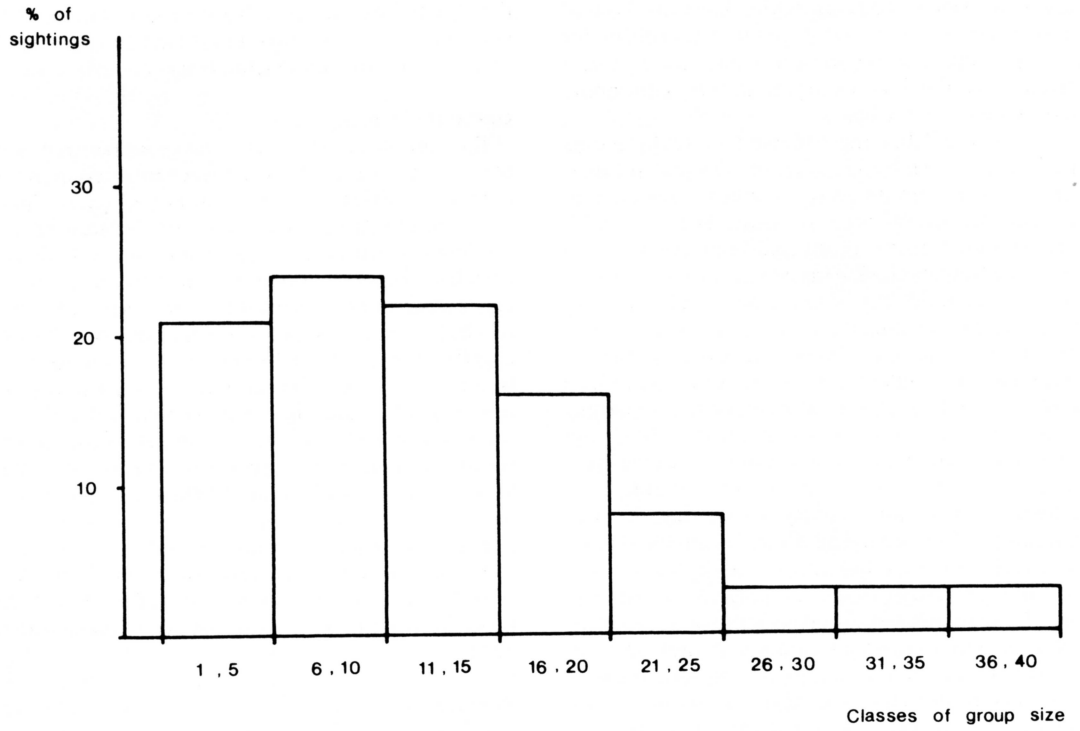


Figure 2. Frequency distribution of group size in our 71 sightings.

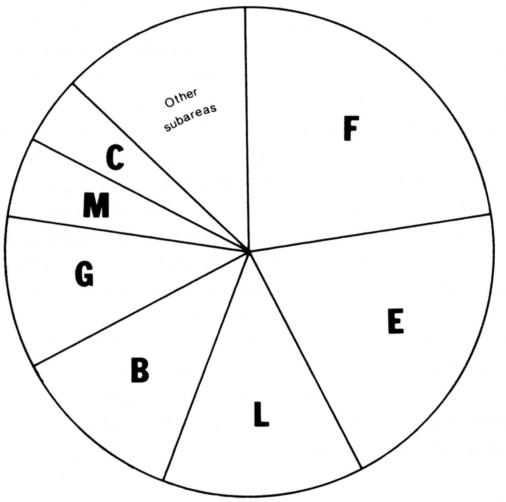


Figure 3. Number of times the dolphins were seen in the subareas defined in Fig. 1. F-52 (22.9%); E-45 (19.8%); L-30 (13.2%); B-26 (11.4%); G-23 (10.1%); M-12 (5.2%); C-10 (4.4%); Total for other subareas-29 (13.0%).

very unlikely when they are followed by a boat. Apparently the animals perceive our approaching manoeuvres at a considerable distance (see also

Table 1. Summary of data on the relation between the direction in which the groups were moving and the tides

Tides →	Flood tide		Ebb tide	
Direction of ↓ swimming	Abs.	%	Abs.	%
Upstream	45	45	27	40
Downstream	34	34	27	40
Indeterminate	21	21	13	20

Würsig and Würsig, 1979). We adopted the alternative strategy of imposing our presence at a close distance for long periods, in an effort to become familiar to the animals. We usually approached the groups slowly, until they dove away ('flushing'). They were then followed at a distance just above that particular flushing distance. The dolphins did allow us to move closer after some time of following them in their routines. Usually, after about one hour some animals would start surfacing and leaping very close to our boat, particularly when the boat was running very fast. There were instances when 2 or 3 dolphins

placed themselves belly-up underneath the bow of our fast-moving boat, and stayed in that position for periods of up to 30 seconds, in what seems to be a variation of the bow-riding behaviour commonly observed with larger boats.

We observed that the behaviours usually recognized as components of feeding activity (e.g. submersions of up to 3 minutes, dispersions over a wide area, surfacing in several directions and surfacing with prey in mouth) are present in diverse contexts and are extremely frequent inside the estuary. In this area we found it very difficult to use the traditional categories of 'travelling', 'feeding', 'resting' and 'social interactions' (see Shane *et al.*, 1986), because most behavioural sequences that we were able to describe include feeding-related behaviours that make the sequences at least partially overlapping in content.

The most common activity pattern that we have observed in the estuary is apparently a compromise between two major activity categories, namely travelling and feeding. The animals show surfacing sequences with the following pattern: 2 or 3 submersions that are usually less than 15 seconds long followed by a submersion that lasts for about 3 minutes. The directions in which the animals are moving when they surface may change or remain constant and they often surface in tight lateral formations of up to 6 individuals. The speed of their movements at the surface while engaged in this activity pattern remains fairly stable in time, but can change abruptly when the group finds abundance of prey (such as a school of mullet). This suggested that even when the dolphins are moving in a definite direction with such a pattern, inside the estuary, they are looking for food on or near the bottom, and that the presence of prey is always an important event affecting their movements.

We also observed many instances of individual and collective feeding at the surface. Dolphins surface and leap frequently in limited areas, where mullets are also seen leaping or being thrown up in the air by the dolphins, who often capture them in mid-air. Another very common behaviour on these occasions is a rapid form of 'pinwheeling', in which the dolphin comes to the surface belly-up, sometimes waving the flippers, and presumably in pursuit of fish directly ahead (see description by Leatherwood, 1975).

Dolphins may also trap groups of fish against the shoreline. The area where mullet predation was observed more frequently was near the tip of the Peninsula, close to shore and in shallow waters. We also observed the dolphins throwing mullets onto the beach. The fish usually fell about half a metre away from the water, and would stay on the sand twisting the body repeatedly. The dolphins, isolated or in small groups, would then swim directly towards the beach, stranding part of the body and thus capturing the fish before crawling back to safe waters. This resembles the behaviours described by Hoese (1971) and by Hamilton and Nishimoto (1977).

Cuttlefish breaking

We observed several instances of aerial behaviour of dolphins with cuttlefish between their teeth. In this type of individual feeding behaviour, a dolphin comes to the surface, exposing just the head or also the flippers, with a cuttlefish held by the head, and then hits the water forcefully, either with frontal or lateral movements, as illustrated in Fig. 6. The body of the cuttlefish is broken approximately by the mantle collar, and the dorsal part of the cephalopod is projected away. The dolphin then swallows the head part of its prey, ignoring the remainder. Bottlenose dolphins in the Sado also break cuttlefish frequently in high frontal or lateral leaps, when they strongly hit the surface snout-first.

The octopus' defence reaction

The event we are now reporting was observed at close distance and photographed on 29 March 1985. One dolphin was seen surfacing with a cephalopod between its teeth, easily identifiable as a large octopus. It seemed the beginning of something like 'cuttlefish breaking'. However, the octopus reacted in a defensively effective way. Some of its arms were seen migrating to the top of the dolphins' head and their tips penetrated into the blowhole (see Fig. 7). The dolphin seems to have released the pressure of its jaws, and the octopus pulled itself to the top of the dolphin's head. After this, the dolphin performed a rapid sequence of leaps in different positions and directions, appearing severely distressed by the blowhole obstruction, until the octopus was finally released by a strong hit on the surface. During this troubled period, the dolphin was apparently unconcerned by the close proximity of our boat.

Before this event was observed, several fishermen had already remarked to us that dolphins, in spite of their 'catholic appetite', did not prey on octopuses, because these cephalopods would 'drown them to death with their arms'. This story seemed to us very unlikely, but we think that the event just reported provides an explanation for this popular belief. Probably other episodes occur and are witnessed with some frequency, and it appears that octopuses, at least the adult ones, are in fact dangerous prey for dolphins.

Bird staring

On the occasions when several dolphins are feeding on mullet at the surface, flocks of seagulls (*Larus sp.*) are often seen flying in circles above the dolphins, and diving occasionally among them, apparently to pick up pieces of broken fish. In the behaviour we call 'bird staring', one dolphin exposes the head for a

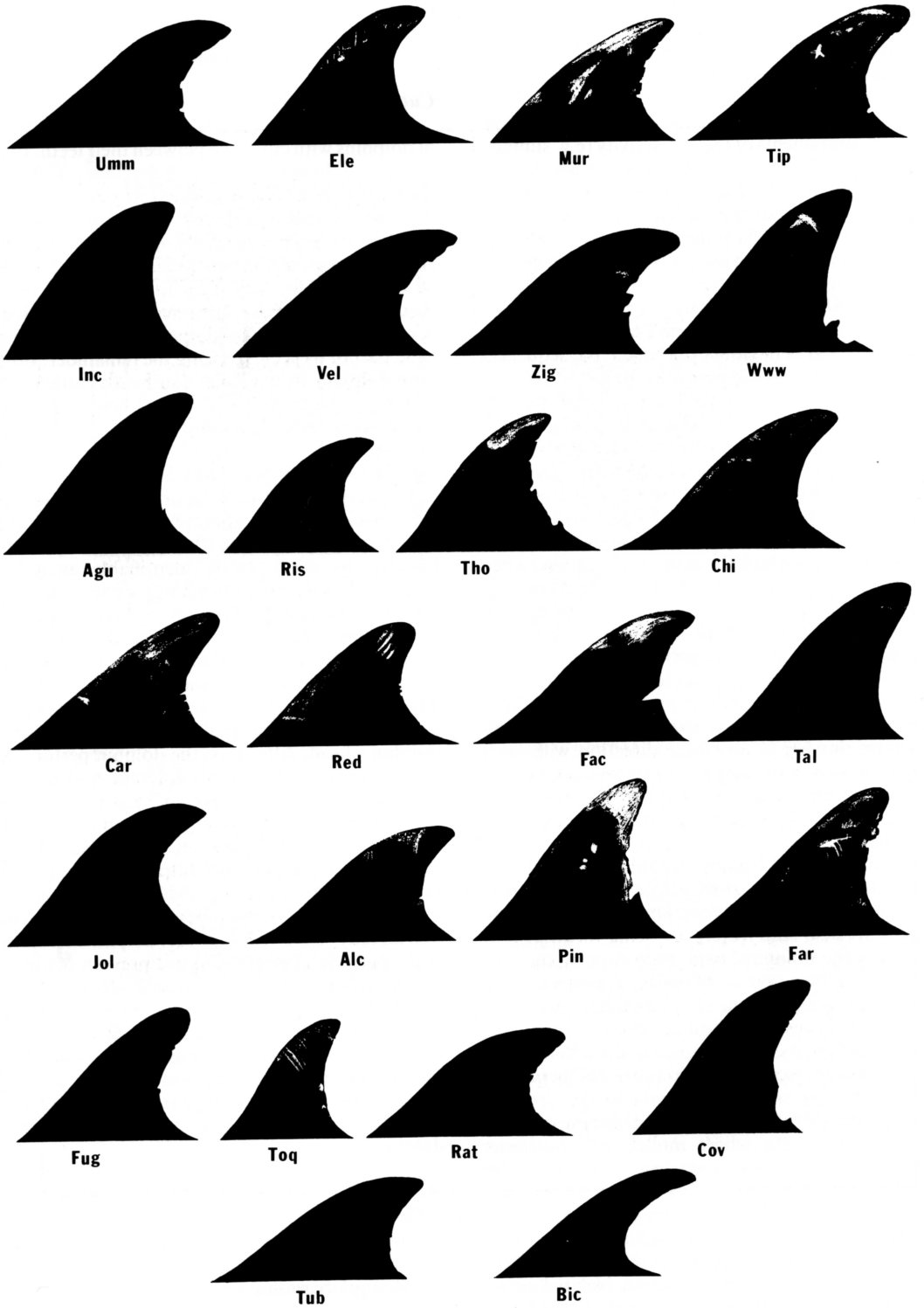


Figure 4. Drawings of the 26 different dorsal fins that we are able to recognize in our photos. The drawings are not based on an accurate size scale.

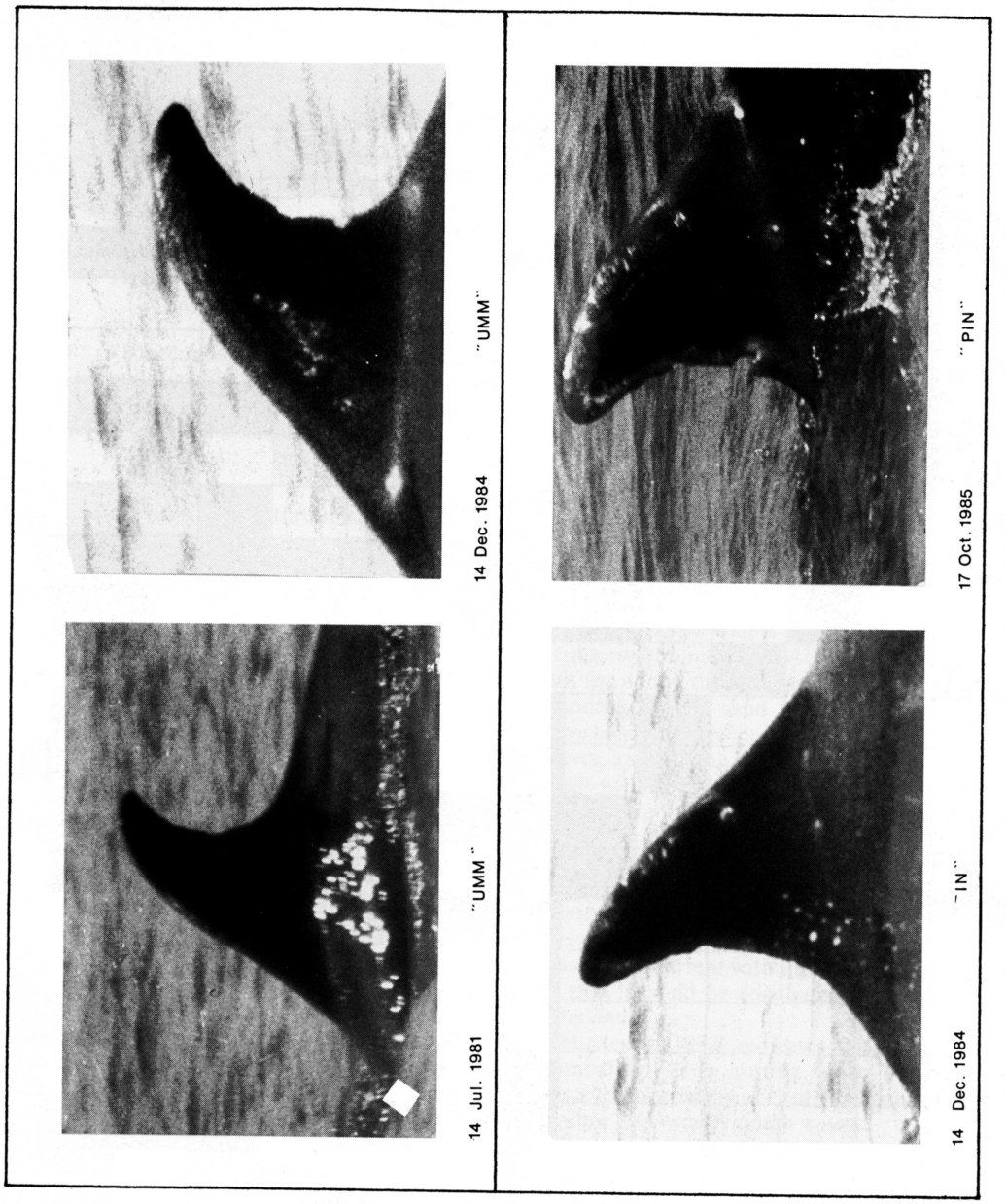


Figure 5. The dorsal fins change with the years, although at different rates, but the animals are still recognizable.

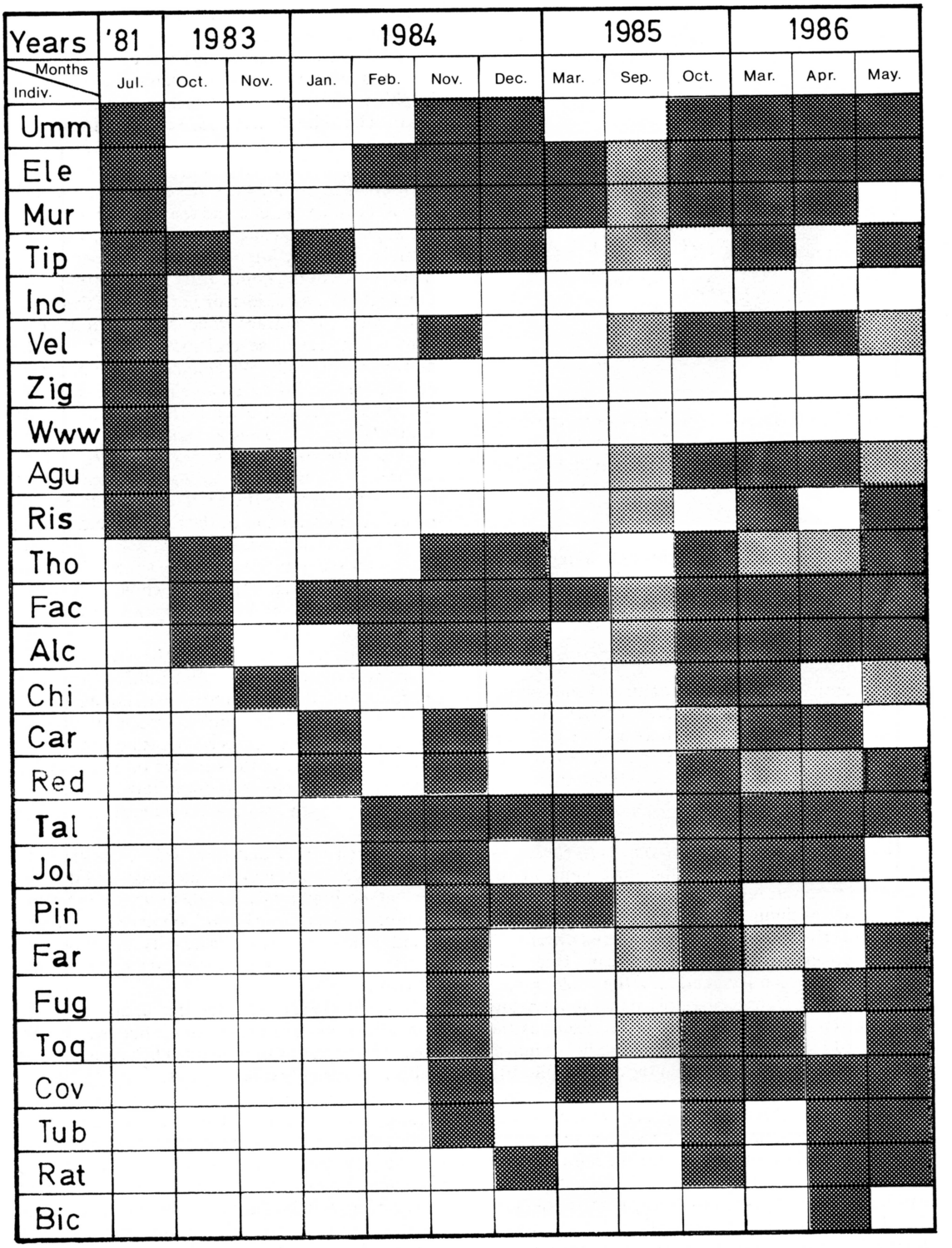


Table 2. Presence of the 26 recognizable individuals throughout the study period. The lighter shading indicates visual recognition without photography

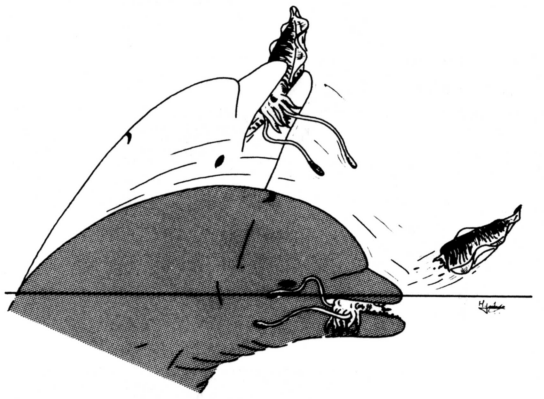


Figure 6. 'Cuttlefish breaking'.

period of 5 to 10 seconds, slowly following the movements of the gulls (see Fig. 8). This behaviour may be repeated several times by the same animal, with its head either in a vertical or inclined position.

Medusa tossing

Dolphins pass frequently through waters where literally hundreds of medusae may be seen near the surface. These medusae, *Catostylus tagi,* are particularly common from June to October. In this behaviour, a vigorous movement of the fluke projects a medusa up in the air (see Fig. 9), after which the dolphin dives or continues to swim, and the cnidarian splashes against the surface. Smaller dolphins do not usually throw medusae as high as the more robust animals. This behaviour can be repeated by the same dolphin or others, for several minutes.

Calf throwing

This behaviour was observed on 17 October 1985, in the shallow waters near the sand bank at the mouth of the river. A group of animals of mixed sizes had been travelling downstream with long dives, went to the river mouth and stayed in that area for 12 minutes before swimming back upstream. One adult and a calf were seen surfacing, and the adult animal, coming quickly from behind, placed its snout below the posterior area of the calf's body. Then, as the adult lifted its head with a sudden and brusk movement, the calf was thrown up in the air (see Fig. 10), violently splashing with its side against the surface. We suppose that this was an unpleasant experience to the calf, perhaps comparable to the form of 'punishment' described by Tavolga (1966) in a captive group (in that case the mother swam belly-up holding the calf between the flippers and lifting it above the surface for some time). The possibility that this was a form of play seemed to us more remote because the animals were moving with minimum aerial activity, quite the opposite of those occasions when there is clearly a playful context.

On 30 April 1986 an occurrence of sexual behaviour was observed in the estuary, involving two dolphins who were temporarily isolated from the group. The animals displayed several bouts of rapid swimming side by side while in physical contact and interchanging their relative positions very often. Both animals initiated the passage to the opposite side of the other animal, and the motion has a screw-like appearance. Such a sequence may last up to 30 seconds, involving intense splashing caused by partial exposure of the bodies (see our interpretation of it on Fig. 11a). After this, one of the dolphins turned on its side at the surface while the other approached from a distance of several metres away and they interlocked ventrally. We assumed this to be a copulation event, and the animals swam in this position for up to 5 seconds, often diving or rolling at the surface (Fig. 11b, c, d and e). After the dolphins were separated, they swam slowly side by side for about one minute. This sequence was repeated 9 or 10 times. After some of the copulation bouts, the dolphin which appeared to be the female (because of its still posture in the phase illustrated in Fig. 11b and c) was seen waving its fluke at the surface with a slow lateral motion (Fig. 11f). This whole sequence of behaviours lasted for 35 minutes, and took place in the middle area of the estuary.

In the shallow waters around the wide sand bank at the river mouth (called 'Cambalhão') waves can run for a long distance before breaking against the smoothly sloped sand bank. Groups of dolphins have been observed on several occasions riding these waves, and leaping in the surf. On one occasion, an adult with a calf was seen doing this several times, and leaving the waves only a few metres away from shore.

Fishermen report that some fish, particularly the sea bass, are common in this surf zone, and it's possible that the dolphins feed on them while they swim in this area. However, we haven't observed any feeding episode concurrent with this activity, and it seems to us that it could be adequately categorized as play behaviour.

Hussenot (1982) indicates this area around the Cambalhão as a resting area, but we haven't observed any resting or even quiet behaviour in these shallow and usually rough waters.

We have observed activities that were scored as 'resting' only inside the estuary and during the afternoon. Dolphins, in groups of 2 or 3 animals, were seen in very quiet waters no more than 5 m deep, remaining nearly still at the surface, and close together for periods of about 10 minutes, and breathing about every 30 seconds. On one occasion, however, a different pattern was observed. Two animals were in such a shallow area, in a time when the water

Figure 7. 'The octopus defense reaction'.

happened to be very clear, and we were able to see the dolphins coming to the surface for breathing and then slowly descending to the bottom, where they remained still and close together for almost 3 minutes before returning to the surface. This sequence lasted for nearly one hour.

Strandings

The approximate locations where 8 dead bottlenose dolphins were found are shown in Fig. 12. Summarized data on these animals are presented on Table 3. We examined 4 of these animals, which were all in a state of advanced decay, and we were unable to determine the causes of death. No parasites were identified and all animals had empty stomachs.

A note on other cetaceans in the region

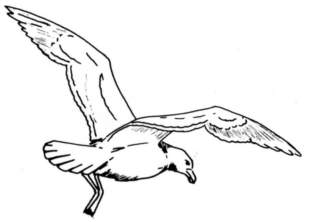
Other cetaceans have been found stranded in the area or were captured with commercial purposes by local fishermen before the protection law of 1981. Included are the common dolphin, *Delphinus delphis,* the striped dolphin, *Stenella coeruleoalba,* the harbour porpoise, *Phocoena phocoena,* and Risso's dolphin, *Grampus griseus* (see Reiner, 1985).

As to the Sado estuary itself, we can report the sighting of 3 species other than the bottlenose dolphins. These are the pilot whale, *Globicephala sp.* (6 individuals were sighted by Reiner on 12 August 1973, pers. comm.), the harbour porpoise, *Phocoena phocoena,* (1 individual was sighted on 13 April 1981) and the orca, *Orcinus orca* (2 individuals were seen entering the estuary on 26 July 1977).

Discussion

Historically, the Sado region has been richer in bottlenose dolphin sightings than any other part of the Portuguese coast. Until the 1960's, however, dolphins were also very common in the Tejo (Tagus) estuary, and some descriptions point to the possibility that these were *T. truncatus* as well. It has also been suggested that these dolphins were driven away by the great increase in pollution and ship traffic that the Tejo estuary went through during this period (Teixeira, 1979).

Anyway, we are obviously not in a position to define a demographic unit with a clear home range. So, when we talk of the Sado dolphins we mean the groups that have been observed in the area, of which several individuals are recognizable repeatedly, but



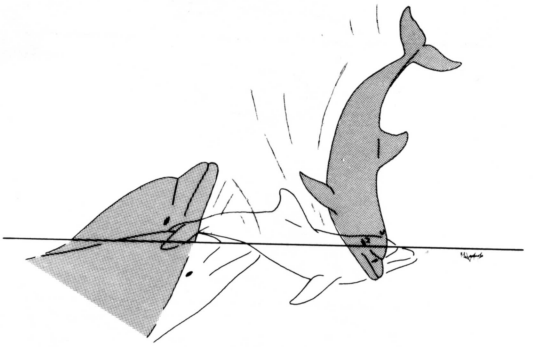


Figure 10. 'Calf throwing'.

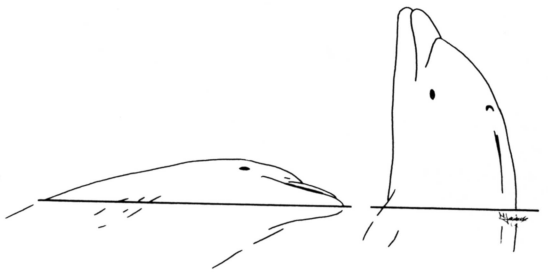


Figure 8. 'Bird staring'.

Figure 9. 'Medusa tossing'.

we cannot define accurately the limits of their range nor the contacts that they possibly have with other such demographic units.

Considering our incomplete photographic records and our counts and estimates of group sizes, we assume that this more stable unit is composed of at least 40 animals.

We have followed groups into the inner parts of the estuary, sometimes about 15 km upstream from the river mouth, and fishermen and local residents report the presence of dolphins in places that are at least 40 km upstream. It should be noted that the presence of dolphins in such distant locations is reportedly predominant in the summer months and much rarer nowadays than in preceding decades.

The dolphins were followed for more than 20 km along the coast to the south and this is probably far from the limit of their dispersion. We have also followed the dolphins to the west, although for shorter distances. They were sometimes sighted at least 5 km away from the nearest coast, in areas where depths are between 50 and 100 m.

Although the strandings map (Fig. 12) cannot serve as a home range indicator, it surely indicates that these dolphins are spread to the north and south of the Sado, and that this estuary can perhaps be considered as a 'core area' of their range.

There is not enough information to discuss the seasonal pattern of habitat utilization. It's quite sure that these dolphins enter the estuary throughout the year, if one considers the unanimous reports of local people and the percentage of success in our scattered surveys. In fact, our high percentage of sightings in the boat surveys, associated with the recognition of the same animals on several occasions in different years, clearly suggests that this group of dolphins is resident in the Sado estuary and adjacent coastal waters.

The time spent by the dolphins in the various activities was not quantified for this study, as

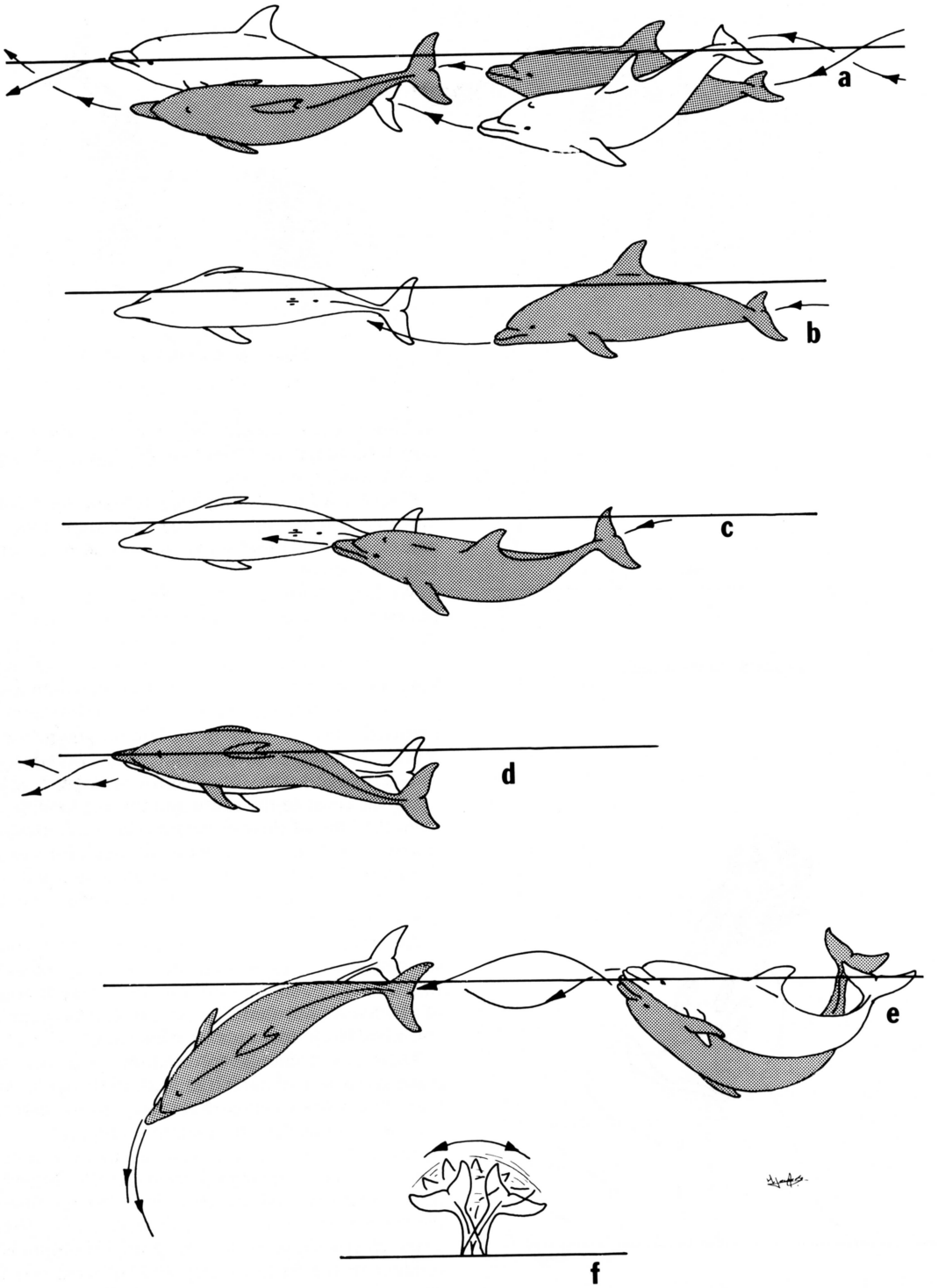


Figure 11. An occurrence of sexual behaviour.

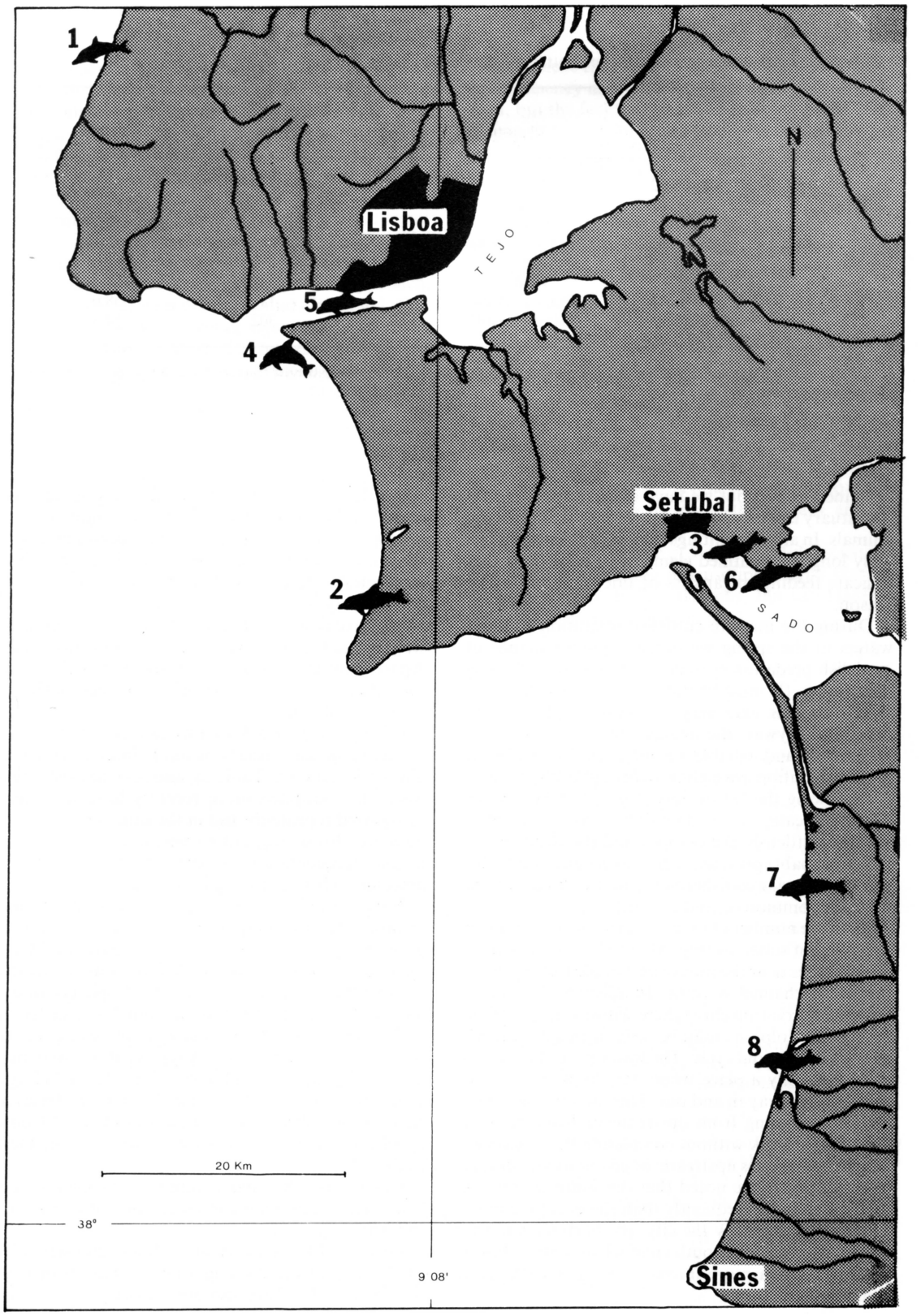


Figure 12. Approximate locations of stranded bottlenose dolphins in Portugal from 1982 to 1986.

Table 3. Summarized data on stranded bottlenose dolphins

No.	Date	Place	Sex	Total length (cm)	Total length of skull
1	23.04.82	Magoito	♂	330	51.7
2	22.06.83	Praia das Bicas	?	?	?
3	15.11.84	Setúbal	♀	305	50.9
4	07.03.85	Costa da Caparica	?	?	?
5	08.04.85	Belém	♀	278	?
6	05.08.85	Setúbal	♀	343	52.3
7	22.01.86	Praia do Pêgo	♀	(a)	58.0
8	29.01.86	Santo André	♀	302	54.3

(a) The total length of the remains, with the fluke missing, was 352 cm. We estimate that the total length of the animal was about 380 cm.

explained above, but we have realized the fact that the estuary is a very important feeding area for these animals. In all our sightings that were at least moderately long we identified elements of behaviour that indicate feeding, regardless of tide, time of day or season.

During the massive cuttlefish migration to inner waters in the spring we noted a predominance of cuttlefish predation episodes and individual feeding behaviours. (It must be noted that the anadromous twaite shad is also very abundant in the spring months). Anyway, the mullets seem to be the most permanent and reliable resource, and episodes of mullet predation are common throughout the year.

Reviewing the list of important prey species, we would indicate, by our direct observation, the mullets, the cuttlefish, the octopus and the twaite shad. Other probable prey, according to general consensus among interviewed fishermen, are the squid, the sea bass, the common eel and the anchovy.

As to the number of times dolphins were sighted in the different subareas (Fig. 3), the predominances of the subareas near the mouth and in the lower part of the south channel is certainly affected by a more intense observation effort there. However, it must be noted that dolphins may be seen in this area in all periods of the tidal cycle. The lower part of the estuary is not only a place where the dolphins have to pass on their way in and out. They actually go there and feed, coming from upstream or from the sea, and may go back without completing their passage. When they do pass upstream, or go out to sea coming from upstream, we noted that the south channel is used much more frequently than the north channel, which is bordered by the city, the harbour and the industrial zone. The south channel, as stated above, is deeper, has a more intense flow, less traffic and certainly more food.

On the other hand, the summarized figures presented on Table 2, which relate the direction of swimming to the tides, indicate that these dolphins do not show a tidal pattern of movements. There may be a more subtle tendency, but our data are too scarce for a finer analysis.

We have reports that the dolphins feed at night as well, inside the estuary, often with associated leaps. Apart from their common presence at night inside the estuary, detailed descriptions of their activities are not available.

Of the 26 individuals that we can recognize, 7 were observed in the estuary several times throughout almost 5 years (see Table 2), and several others that were photographed more recently have also been recognized repeatedly and in the same group. These data are also scarce, but suggest long-term stability in the frequentation of the estuary and in the association between some of the individuals.

Four animals which are presented seem to have disappeared. 'Inc', 'Zig' and 'Www' were only photographed in 1981 and we have never recognized them again since then. The animal 'Pin', which was not seen in 1986, is a somewhat special case because it used to be the first to approach our boat, surfacing and leaping very close to us and we have come to recognize it quite easily. Anyway, it showed new scars and scratches at an impressive rate (including a deep cut in the caudal peduncle) and we believed that it is now dead. None of the stranded bottlenose dolphins seems to correspond to any of these individuals.

Calves are observed commonly throughout the year, and we don't have any indication of seasonality of births.

Groups of less than 16 individuals represent 67% of our sightings, and groups of more than 30 are rare. Single individuals are also uncommon.

Our general impression is that adults swim either in groups of several individuals with one or more calves, or else in separate subgroups of only 2. Juveniles often swim in homogenous subgroups of about 6.

We found that the flushing distance of the groups was very variable, and it possibly depends on the composition of the group approached, on its current activity and also on physical circumstances, like water turbulence or turbidity. It is common that some animals show 'tailslaps' when we approach, especially the larger individuals, and it's possible that these function as a warning signal, as believed by Würsig and Würsig (1979) and others.

We have not seen any direct interaction between bottlenose dolphins and other cetaceans. Such encounters should be considered as rare, at least inside the estuary. Fishermen say that groups of orcas sometimes enter the estuary (we have only one direct observation of this) and that in these occasions the bottlenose dolphins quickly swim to shallow waters far upstream.

Some birds are often seen in the proximity of bottlenose dolphins, such as gulls, as described above. We believe that these birds benefit from the dophins' activity, although their share of fish debris is negligible as compared to the dolphins' apparent catch. One other species that shows tolerance to the proximity of the dolphins is the razorbill, *Alca torda*.

According to local fishermen, bottlenose dolphins used to be more abundant than today, and they were considered as a great nuisance to the fisheries, in part because of direct competition but especially because of severe damage that they caused on nets. The dolphins reportedly followed operating fishing boats and if the trawling nets were full they would tear the nets open and eat all the fish inside.

This is an ancient conflict, and fishermen tried to kill the dolphins for meat consumption and sale at the local fish markets. To catch bottlenose dolphins was considered difficult and time-consuming and in most cases was only accomplished opportunistically by trapping the animals in shallow waters at ebb tide and clubbing them to death once immobilized.

Nowadays dolphins seem to avoid fishing boats and their *nylon* nets, and the persecution is practically over. We found evidence that one of the stranded dolphins (No 5) had been shot (although this was unrelated to her death), but it seems more likely that the person responsible was one of the very common bird hunters that operate in upper estuarine waters.

Clearly, the main problems concerning wildlife in this estuary are industrial pollution and overfishing. Many industrial waste discharges are illegal and uncontrolled, and the more fish stock are reduced by pollution and overfishing the more fishermen utilize illegal techniques and gear, in an effort to compensate for their decreasing catches.

We believe that the dolphins' feeding adaptability and efficiency are important to their survival in this area, but the fact that they had to abandon the Tejo estuary in the 60's indicates that their tolerance is not unlimited.

Acknowledgements

We are grateful to Francisco Reiner and João Pedro Cardoso for their support and contributions to this study. The interest, criticism and encouragement we have received from Vítor Almada was invaluable.

We also thank the following people and institutions: Carlos Reis, A. Antunes Dias (Serviço Nacioanl de Parques, Reservas e Conservação da Natureza), Damásia Dias, Aldina Inácio (Aquário Vasco da Gama), Torralta, Capitania do Porto de Setúbal e Clube Naval Setubalense. Carlos Cruz and José 'S. Tomé' Carvalho helped us in the field work. We are grateful to all the people from the Sado region who have talked to us about the estuary and the dolphins.

The following people provided helpful discussions and comments on the manuscript: Stefan Harzen, Ronald Kroger, Folker Behrens, Jan van Haaften, Giogio Caporin and Paul Basinski.

References

dos Santos, M. E. (1985). Estudo Preliminar da População Sedentária de Roazes (*Tursiops truncatus*, Montagu 1821) (Cetacea, Delphinidae) no Estuário do Rio Sado. Graduation Report, University of Lisbon, Faculty of Sciences, 185 pp.

Hamilton, P. V. & Nishimoto, R. T. (1977). Dolphin predation on mullet. *Florida Science*, **40**(3), 251–252.

Hoese, H. D. (1971). Dolphin feeding out of water in a salt marsh. *Journal of Mammalogy*, **52,** 222–223.

Hussenot, E. (1982). Premier recensement du grand dauphin *Tursiops truncatus* dans l'estuaire du Sado au Portugal. Données sur leur ecologie et leur comportement. *VIéme Colloque National des Mammifères*, La Rochelle, October 1982.

Leatherwood, S. (1975). Some observations of feeding behavior of bottlenose dolphins (*Tursiops truncatus*) in the Northern Gulf of Mexico and (*Tursiops* cf. *T. gilli*) off Southern California, Baja California and Nayarit, Mexico. *Marine Fisheries Review*, **37,** 10–16.

Norris, K. S. (ed.) (1961). Standardized methods for measuring and recording data on the smaller cetaceans. *Journal of Mammalogy*, **42,** 471–476.

Reiner, F. (1981). Guia de identificação dos cetáceos e focas de Portugal Continental, Açores e Madeira. *Memórias do Museu do Mar (Portugal)*, **1**(11), 1–60.

Reiner, F. (1985). Mammifères de l'Atlantique Portugais et le Phoque Moine de Madère. Thèse d'Université, Université d'Aix-Marseille III, 244 pp.

Ross, G. J. B. (1984). The smaller cetaceans of the South-east coast of Southern Africa. *Annals of the Cape Provincial Museums (Natural History)*, **15**(2), 173–410.

Shane, S. H., Wells, R. S. & Würsig, B. (1986). Ecology, behavior and social organization of the bottlenose dolphin: a review. *Marine Mammal Science,* **2**(1), 34–63.

Tavolga, M. C. (1966). Behavior of the Bottlenose dolphin (*Tursiops truncatus*): Social Interactions in a Captive Colony. In, *Whales, Dolphins and Porpoises* (ed. K. S. Norris), pp. 718–730. University of California Press, Berkely.

Teixeira, A. M. (1979). Marine mammals of the Portuguese coast. *Zeitschrift für Saügetierkunde,* **44,** 221–238.

Teixeira, A. M. (1981). Sobre a presença do roaz corvineiro *Tursiops truncatus* no estuário do Sado (Portugal). *Actas de les las Jornadas Ibéricas sobre Mamiferos Mariños,* Santiago, 1981, pp. 47–54.

Teixeira, A. M. & Duguy, R. (1981). Observations de Delphinidés dans les eaux côtières portugaises. *Relatórios de Actividades do Aquário Vasca da Gama,* no 9, 1–9.

Würsig, B. & Würsig, M. (1977). The photographic determination of group size, composition and stability of coastal porpoises (*Tursiops truncatus*). *Science, N. Y.,* **198,** 755–756.

Würsig, B. & Würsig, M. (1979). Behavior and ecology of bottlenose porpoise, *Tursiops truncatus,* in the South Atlantic. *Fisheries Bulletin,* **77,** 399–442.