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Mixed-species feeding aggregation of dolphins, large tunas and seabirds in the Azores

Éric Clua[a,b]*, François Grosvalet[c]

[a] *Ministère de l'agriculture et de la pêche, 251, rue de Vaugirard, 75732, Paris cedex 15, France*

[b] *ESA 8046 EPHE–CNRS, École pratique des hautes études, 52, avenue de Villeneuve, 66860 Perpignan, France*

[c] *CGCSM, 43, rue Piat, 75020 Paris, France*

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Abstract − Each summer the presence of large concentrations of bait fish in the area of the central Azores Islands gives rise to mixed-species feeding aggregations usually at dawn and dusk. The encircling of prey initiated by common dolphins (*Delphinus delphis*), often mixed with spotted dolphins (*Stenella frontalis*), results in the formation of a compact 'ball' of several thousands prey fish close to the surface. Other dolphins, in particular the bottlenose (*Tursiops truncatus*), also eat the prey fish, whose high concentration makes them easy to capture. Large tunas (*Thunnus thynnus, Thunnus albacares*) sometimes participate in the phenomenon. Seabirds (mainly cory's sheawaters, *Calonectris diomedea borealis*) are always present throughout the few minutes during which the entire collective food hunt takes place. A model of the phenomenon, based on 15 observations, is proposed. It comprises 4 stages: a preparation phase, an intensification phase, a mature phase, and a dispersion phase. These observations allow a better understanding of the tuna-dolphin aggregation process. They show that it is the tunas that generate and beneficiate from the aggregation with dolphins, rather than the contrary. © 2001 Ifremer/CNRS/Inra/IRD/Cemagref/Éditions scientifiques et médicales Elsevier SAS

mixed-species feeding aggregations / predation / dolphin / tuna / seabird / Azores / Atlantic Ocean

Résumé − Agrégations mixtes à des fins alimentaires entre dauphins, grands thonidés et oiseaux marins aux Açores. La présence massive estivale de poissons «proies» aux abords des îles centrales des Açores entraîne, généralement le matin et le soir, un comportement de « chasse » collective. L'encerclement initié par des dauphins communs (*Delphinus delphis*), souvent accompagnés de dauphins tâchetés *(Stenella frontalis*), aboutit à la formation en surface d'une « sphère » compacte de plusieurs milliers de petites proies. D'autres espèces de dauphins, dont le grand dauphin (*Tursiops truncatus*), viennent alors se nourrir de ce poisson-fourrage dont la concentration facilite la prédation massive. De grands thonidés (*Thunnus thynnus, Thunnus albacares*) s'associent parfois à la chasse collective. Les oiseaux marins (en majorité le puffin cendré, *Calonectris diomedea borealis*), sont présents du début à la fin de ce processus qui ne dure que quelques minutes. Une modélisation du phénomène, basée sur 15 observations, est proposée. Le phénomène est décomposé en 4 phases : préparation, intensification, maturation et dispersion. Ces observations contribuent à une meilleure compréhension du processus d'agrégation entre thons et dauphins. Elles montrent que ce sont les thons qui génèrent et bénéficient de l'association avec les dauphins, plutôt que l'inverse. © 2001 Ifremer/CNRS/Inra/IRD/Cemagref/Éditions scientifiques et médicales Elsevier SAS

agrégations mixtes à des fins alimentaires / prédation / dauphins / thonidés / oiseaux marins / Açores / Océan Atlantique

1. INTRODUCTION

The association of yellowfin tuna (*Thunnus albacares*) with dolphins has been observed in all oceans of the world (Hassani et al., 1997; De Silva and Boniface, 1991; Fréon and Dagorn, 2000), but particularly in the eastern tropical Pacific Ocean where a major part of the tuna catches have been taken by directly fishing on

*Correspondence and reprints.
E-mail addresses: eclua@hotmail.com (E. Clua), fgrosval@club-internet.fr (F. Grosvalet).

schools associated with dolphins herds (Scott and Cattanach, 1998). On the contrary, little information exists about such an association with bluefin tuna (*Thunnus thynnus*), except in the Mediterranean Sea (Hernandez, 1990; Hall, 1998). The global development of sustainable fisheries around the world, involving both ecological and fisheries issues, is partly based on a better understanding and knowledge of the biology of fishes and of their environment (including other marine animals).

The question of knowing whether it is the tuna that seeks the company of the dolphins or the contrary is not resolved. Edwards (1992) analysed the factors behind the durable association between yellowfin tuna and dolphins, and cites the effects of a high thermocline, of similar diets, and of the comparable size of the fish and the cetaceans (allowing similar cruising speeds connected to hydrodynamic constraints). She concludes that it is the tuna that follows the dolphins, rather than the opposite, especially when the prey – whether many or few – are widely dispersed. She refers to the theory that attributes a greater aptitude in detecting prey to dolphins (through echolocation) than to tuna. Scott and Cattanach (1998), who studied the behaviour of large-sized yellowfin tuna, noted the simultaneous aggregating phenomena on the part both of cetaceans and fish. He set forth the hypothesis that it is the association with dolphins that induces the large-sized yellowfin tuna to gather during the day. On the other hand, some reports (Au and Pitman, 1986, 1988; Edwards, 1996) suggest that in some areas the tuna increase the accessibility of the prey to the competing species, such as cetaceans, by making the prey rise to the surface. In that case, dolphins would be the one to beneficiate from the association.

While the eastern tropical Pacific is well known for the frequent associations between tuna and dolphins, the eastern central Atlantic is the site of similar, although less known, phenomena. A better understanding of the tuna-dolphin association – in particular whether it is the tunas that generate it or the contrary – requires new observations; this is the purpose of this work.

This paper describes visual observation of aggregations of prey (small fish) and predators (dolphins, birds and sometimes tuna). We call this phenomenon a ‘hunt’, for which we propose the following definition: “a predation event characterized by the attack of large pelagic vertebrates on a concentrated aggregation of small prey”. The description of this phenomenon in the Azores is followed by an analysis of the tuna-dolphin aggregation process.

2. MATERIAL AND METHODS

Observations were made during three summer periods (two in 1997 and one in 1998), corresponding to respectively 10 and 15 field days, on the south of Faïal and Pico islands (*figure 1*). Observations were made by two freedivers/photographers equipped with a 5.40 m outboard motor boat mounted with a sonar, which allowed to move rapidly within a perimeter of several nautical miles. One observer was always staying on the boat while the other one was diving. Observations were starting at 08h00 and ending at 21h00. Between these two limits, the team was remained scrutinizing the area of observation with lenses. No attempt was made to observe potential night time hunt. The study area was divided in 6 zones (*figure 1*), and a portable GPS specified the location of the observations. The water temperature at the surface was taken once a day with a hand thermometer. During over a hundred freedives between depths of 1 to 15 m, date, time, species and their average abundance, approximate location of the hunt were recorded (*table I*). When the situation allowed it, photos, both underwater and external, were taken.

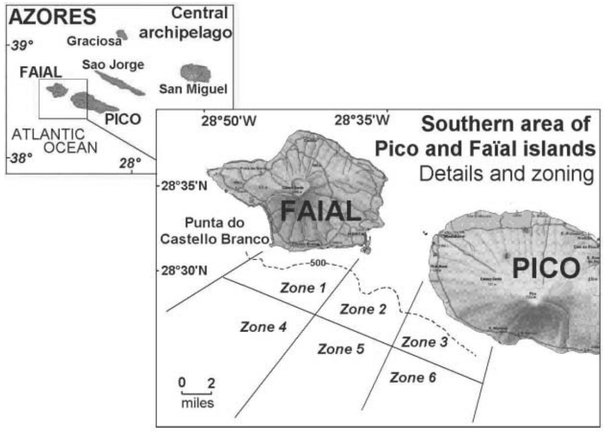

Figure 1. General view and details of Faïal and Pico Islands (central archipelago of Azores). Zoning and located bathymetry.

3. RESULTS

During the three field periods 22 hunts were observed. However, the mature stage of the hunts was observed only 15 times. Despite considerable effort (15 field days in 1998 vs. 10 in 1997), the summer of 1998 offered few opportunities for observations (3 vs. 12 in 1997, *table I*).

3.1. Description of the hunts

The hunt can be arbitrarily described into 4 stages:

– Preparatory phase: rapid circular movements of dolphins around the prey fish, followed by a mobilization of birds.

– Intensification phase: the dolphins herd the fish into a compact ‘ball’ comprising tens of thousands of small fish and the dolphins begin to forage.

– Mature phase: characterized by the simultaneous presence of several species of predators (i.e. dolphins, birds and occasionally tuna) that participate in large-

Table I. Date, time, water temperature, location and average abundance of the species involved in the 15 hunts.

Hunts	Date	Time	Water temperature (°C)	Zone*	Dolphin				Tuna		Seabird
					Dd	Sc	Sf	Tt	Ty	Ta	Cd
A	9 Aug. 1997	10h00	21	2	+++			++	++		+++
B	11 Aug. 1997	09h45	21	2	+++	+	+	+	++	++	+++
C	18 Aug. 1997	18h30	21	3	+++			++		++	+++
D	19 Aug. 1997	18h48	21	3	+++		+	+	+	++	+++
E	10 Sept. 1997	16h30	22.5	1	+++		+	+	+	++	+++
F	10 Sept. 1997	17h30	22.5	1	+++		+++	+++	+++	++	+++
G	11 Sept. 1997	17h15	22.5	2	+++		+++	+++	+++	+++	+++
H	12 Sept. 1997	16h20	22.5	3	+++		++	+++	+++	+++	+++
I	13 Sept. 1997	15h30	22.5	6	+++			++	++	++	+++
J	15 Sept. 1997	16h05	22.5	1	+++			++	++	++	+++
K	15 Sept. 1997	17h40	22.5	6	+++			++	++	++	+++
L	16 Sept. 1997	16h40	23	3	+++		++	++	++		+++
M	12 Jul. 1998	19h00	22.5	1	+++		++	++	+	++	+++
N	13 Jul. 1998	19h40	22.5	1	+++		++	++	+	++	+++
O	14 Jul. 1998	20h15	22.5	2	+++		++	++	+	++	+++

* See *figure 1*. +: 1 to 3 individuals; ++: 3 to 10 individuals; +++: > 10 individuals; Dd: *Delphinus delphis*; Sc: *Stenella coeruleoalba*; Sf: *Stenella frontalis*; Tt: *Tursiops truncatus*; Ty: *Thunnus thynnus*; Ta: *Thunnus. Albacares*; Cd: *Calonectris diomedea.*

scale feeding while the dolphins maintain the concentration of prey fish.

– Dispersion phase: begins when the prey fish have been mostly consumed.

3.1.1. Preparatory phase

During the day, seabirds often sit on the water surface, sometimes in groups of several hundred. A few scattered birds in flight keep watch, alternating hovering at sea level with flights to altitudes of up to 100 m. Between 80 and 90% of these birds were cory's shearwater (*Calonectris diomedea borealis*). The rest was composed of puffins (*Puffinus* sp.), petrels (*Oceanodroma castro* and *Bulweria bulwerii*), sterns (*Sterna* sp.) and seagulls (*Larus* sp.). Just prior to down and dusk, birds from all around the islands become more active and take flight in circles at 50 to 100 m.

Dolphins initiate the hunt by a clearly delineated underwater activity (between 0 and 25 m) (*figure 2a*), the signs of which birds are attracted to at once. Attractors may be surface mirror-like reflections (coming from the sudden changes of direction by panicked prey fish), eddies or tufts of foam set off by the dolphins, who also sometimes jump and/or beat the water on the surface with their tail, mouth or head (*figure 3*). The rapidly converging birds station themselves above the dolphins. Their slow smooth flight becomes rapid and agitated, as dives, sudden ascents, and stationary periods alternate.

3.1.2. Intensification phase

Underwater, a group of dolphins consolidates the school of fish by encircling them (*figure 4*). At that stage, underwater sound signals of the cetaceans were easily perceived by the diver.

The major part of the dolphins observed were common dolphins (*Delphinus delphis*), but it was not unusual at this stage to see spotted dolphins (*Stenella frontalis*) or striped dolfins (*S. coeruleoalba*) (between 10 and 50 individuals in total). Although they sometimes appeared in a tight group of ten, the dolphins usually moved around in groups of two to four. The diameter of their circular movements diminished along with the tighter concentration of prey fish. Particularly at this stage, it was common to see young dolphins close to adults.

During this phase, the hunt does not have a nucleus, and several scattered spots of underwater activity develop in a haphazard manner. The prey fish consist of single-species schools of young members of the endemic blue jack mackerel (*Trachurus picturatus*), less commonly mackerel (*Scomber japonicus*). Under the impetus of the encircling and systematic dolphin sweeps, the growing school is structured into an organic metallic-like ball (1–3 m), completely opaque, suspended in shallow water, and composed entirely of between 10 000 and l00 000 individuals. The intensification phase ends when this 'ball' takes form, allowing the dolphins to start foraging on it.

3.1.3. Mature phase

The dolphins, which had been scattered, swim in concentric circles of a radius of 1 to 20 or 30 m at the farthest around the sphere, with the prey fish remaining at a depth of one to five meters. While the majority of the dolphins maintained this compact ball, isolated individuals or groups of two or three are taking turns attacking the prey fish and snatching the prey open-mouthed, thus maintaining a tangential path to the ball, which they only approach on the periphery (*figure 5*).

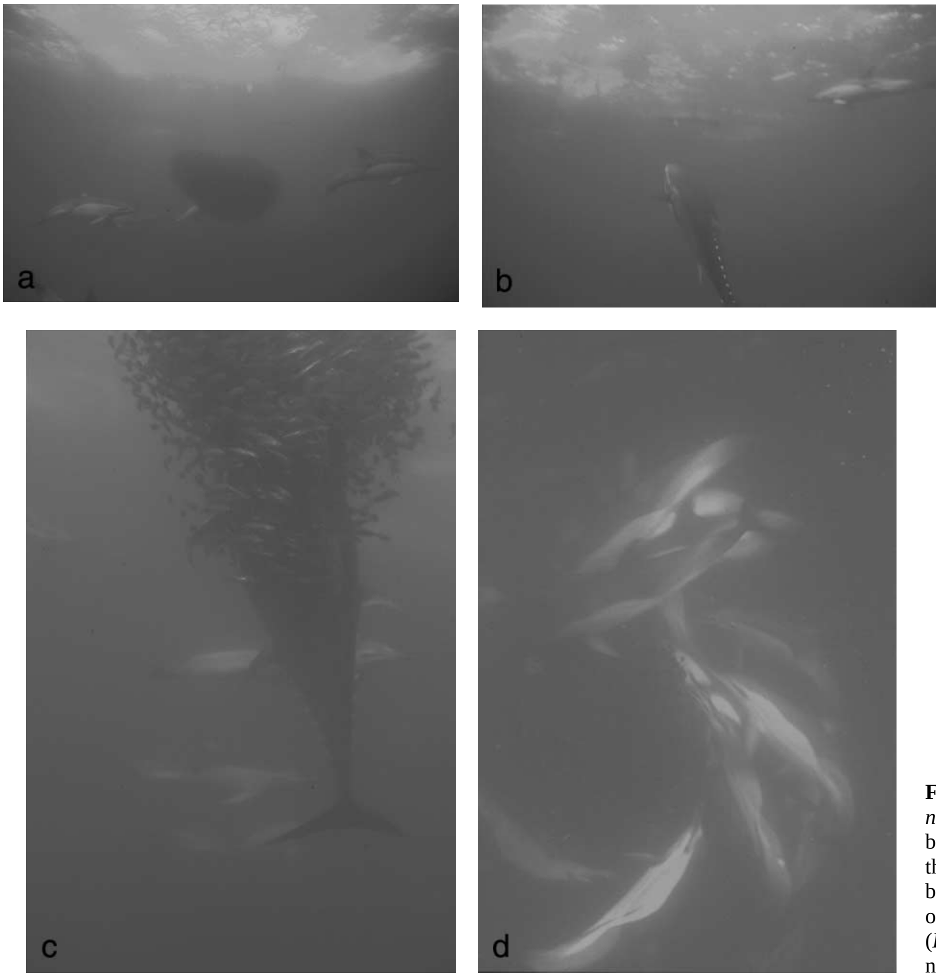

Figure 2. (a) Common dolphins (*Delphinus delphis*) circling the prey-fish; (b) bluefin tuna (*Thunnus thynnus*) targeting the bait-ball with vertical trajectory; (c) bluefin tuna (*Thunnus thynnus*) foraging on the bait-ball; (d) common dolphins (*Delphinus delphis*) foraging on a terminal 'ball'.

Bottlenose dolphins (*Tursiops truncatus*) sometimes appeared at this stage. They chased the common dolphins away to take temporary command of the 'ball', although the common dolphins sometimes returned. They never mixed and we did not observe any signs of fighting between the dolphin species, although the substitution of one species by another was always preceded by specific hissing and clicking sounds.

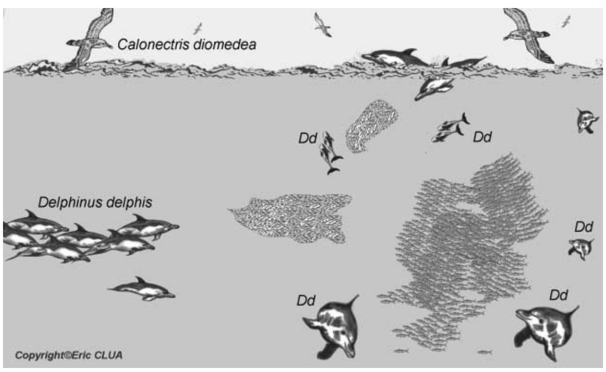

Figure 3. Diagram of preparation phase: common dolphins (*Delphinus delphis*) concentrate the prey fish with rapid circular movements.

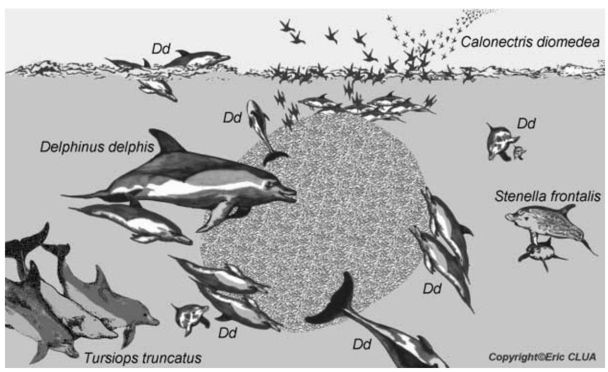

Figure 4. Diagram of dispersion phase: once the ball is structured, common dolphins (*Delphinus delphis*) begin to forage. *Stenella* sp. and *Tursiops* sp. may participate.

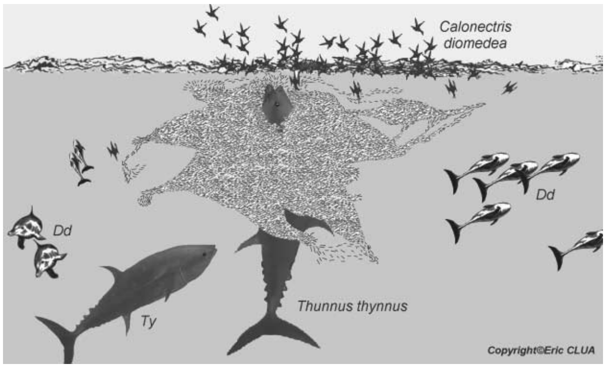

Figure 5. Diagram of intensification phase: giant tunas penetrate the ball with vertical trajectory while dolphins scatter.

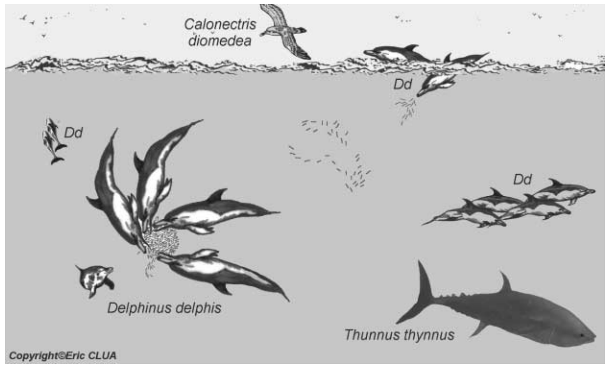

Figure 6. Diagram of mature phase: some dolphins keep on foraging on the terminal ball while most of the predators disperse.

The 'ball' diminishes noticeably in diameter, and the prey fish disperse, usually into small compact groups. The dolphins' unceasing activity at times allows the almost instantaneous re-formation of this same or of other secondary balls, sometimes split between the common dolphins and the bottlenose dolphins. These successive balls reform at distances of 20 to 200 m away from the original focus before the dolphins resume their attacks. At this stage, the centre of the hunt is moving quickly by successive leaps of tens or even hundreds of meters in a few seconds. Shearwaters follow the progress of the hunt with small flights, landing systematically right above the 'ball'. Most of them are keeping their head under water, snapping bait-fishes just below the surface. They also regularly dive down to depths of 1 to 3 m (average depth of 1.5 m), less commonly deeper, with exceptional dives to 10 m or more, to catch their prey with their beak.

At this stage small schools (< 10 individuals) of bluefin tuna (*Thunnus thynnus*) or yellowfin tuna (*T. albacares*), that usually fed individually, sometimes appeared. The observed bluefin tuna weighed a minimum of 200 kg, the yellowfin 100 kg. They were located at a greater depth than the dolphins (between 15 and 25 m) and quickly swam up to the 'ball' and, mouth open, entered it (*figure 2a,b*). Tuna attacks were generally preceded by a rapid scattering of dolphins, avoiding the tuna. As the ball was almost on the surface, the tuna's attacks ended by chasing them out. If dolphins can be said to preserve the ball's integrity when they snatch prey from it, the same cannot be said of the tuna, which dive to the heart of the mass, which explodes under their impact. Between two attacks of tunas, the dolphins are continuing to circle, thus reconstituting the partially broken-down ball.

Birds, tuna and dolphins make alternate lunges at the prey, with each involved in a different aspect of the attack: parallel to the surface, dolphins make a tight circle, which reduces the size of the ball at each pass, birds operate from above, while the tuna attack from below. Breaking up the ball takes from thirty seconds to five minutes depending on the number of predators present.

3.1.4. *Dispersion phase*

Four or five passes by the tuna generally destroys the school of fish. The hunt breaks up when the school is reduced to a small (< 0.3 m) sphere (*figure 6, figure 2d*).

3.2. Duration and time, and location of the hunts

The longest hunt observed lasted 20 min (maximum time observed), the shortest 5 min. Morning and afternoon hunts rarely lasted more than an hour (time from the beginning of the first phenomenon to the end of the last one), and late afternoon is by far the preferred time. The hunts took place most often between 16h00 and 19h00, occasionally from 08h00 to 10h00, and rarely between 10h00 and 16h00 (*figure 7a*). Several hunts can take place in a relatively limited area (1–10 ha), such as when two hunts go on at the same time in a fairly limited area, or more typically, if the same prey fish break up into secondary balls. While the team had the opportunity to observe the phenomenon up to several miles offshore, hunts occurred more frequently near the coastline. Of the coastal zones, the most frequented was Zone 1 including Castello Branco cape (*figure 7b*), where there is a 'step' parallel and close to the coast, located at a depth of about 350 m which climbs abruptly from a depth close to 1 000 m (*figure 1*).

4. DISCUSSION

4.1. Duration and time, and location of the hunts

Duration of the phenomenon is apparently a direct function of the quantity of prey fish available and of the number of predators present. The presence of tuna has a sizable impact on the disappearance of the prey fish.

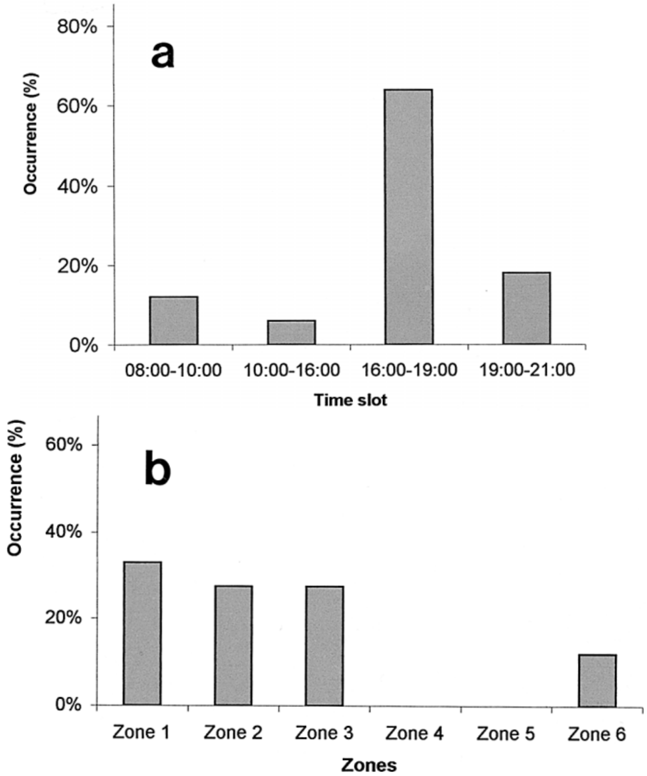

Figure 7. Time and space repartition of the hunts: (a) percentage of hunts by time slot; (b) percentage of hunts by zone.

The presence of weak light (whether increasing or decreasing) might be a potential cause for the start of the hunt, as the only observation of a hunt between 10h00 and 16h00 (*table I*) took place on a day with high cloud cover.

Our observations fit with the hypothesis that the yellowfin tuna is rather a diurnal predator (Buckley and Miller, 1994) even if nocturnal feeding activity has been proved (Holland et al., 1990). This preference for daytime eating has recently been confirmed by Scott and Cattanach (1998). To our knowledge, there are few studies on the bluefin tuna. Lutcavage et al. (2000) showed a higher predation rate (based on increases of speed end course) at light transition period. Our own observations in Azores confirm this predominance of feeding activity at dawn and dusk, and have shown a noticeable resemblance between the behaviour of the bluefin tuna and that of the adult yellowfin.

The common dolphin, the species we have most often observed, is known as an opportunistic predator that prefers to feed at night (Gallo-Reynosso, 1990). However, in the Gulf of California they gather in large numbers for diurnal attacks on large schools of prey fish (Gallo-Reynosso, 1990), consistent with our observations.

The most logical explanation for the hunts' location is the characteristics of the ocean floor. A steep slope creates currents and local upwellings that favour the presence of prey fish. Castello Branco cape, located in the most frequented zone, is well known by local fishermen, because of the presence of pelagic predators.

4.2. Tuna–dolphin association

The association between dolphins and bluefin tuna (Magnaghi and Podesta, 1987; Hall, 1998; Hernandez, 1990), seems to be much less frequent than the association between yellowfin tuna and dolphins, especially in the eastern tropical Pacific (Sund et al., 1981; Fonteneau, 1997; Hall, 1998) and the Indian Ocean (De Silva and Boniface, 1991). If this same link with yellowfin tuna is much less common in the eastern tropical Atlantic (Levenez et al., 1980), the tuna-dolphin association is, according to Pereira (1985), considered usual in the Azores and are well known by Azorian fishermen, whether professional or amateur game fishermen. Local professional tuna fishermen (Elio Neves, personal communication) report that in rare case dolphins are caught on rods as the tuna, as a sign of especially close convergence in feeding behaviour between fish and cetaceans. The dolphins, more easily located through their ascents to the surface, are thus sought after because of the strong probability of finding tuna or billfishes by their side. The same association is observed in the Mediterranean and is used to locate bluefin tuna. In contrast, the use of dolphins to signal the presence of tuna is infrequent in the eastern tropical Atlantic (Levenez et al., 1980) and purse-seine fishermen use rather whales to locate tuna schools.

Concerning the origin of the tuna-dolphin association, our observations allow to underline two points: at first the cetacean were the ones concentrating the prey-fish by circling it, and secondly the tuna always appeared for foraging at the mature phase, when the concentration was optimal and the predation eased. This might be commensalism ('food sharing') of the tuna toward the dolphins, without major prejudice for them with respect to the large quantity of fish-bait available, or 'synergy' between dolphin and tuna, if we had a proof of a potential role for the tuna in making the prey rise to the surface before being concentrated by the dolphins.

Furthermore, while dolphins could easily form the ball and forage on it without the presence of tuna, the converse has never been observed during the study. This point meets also the hypothesis in favour of the tuna generating the aggregation with dolphins and not the contrary, at least in the circumstances of our study.

Feeding seems to play a major role in the associations observed in the Azores. It seems obvious to us that the association is dependent on the environmental conditions that determine the distribution and copiousness of prey. The observed absence of tuna from their traditional places (as noted in 1997) in the summer months of July and August 1998 buttresses this line of thought, although an earthquake measuring 7 on the

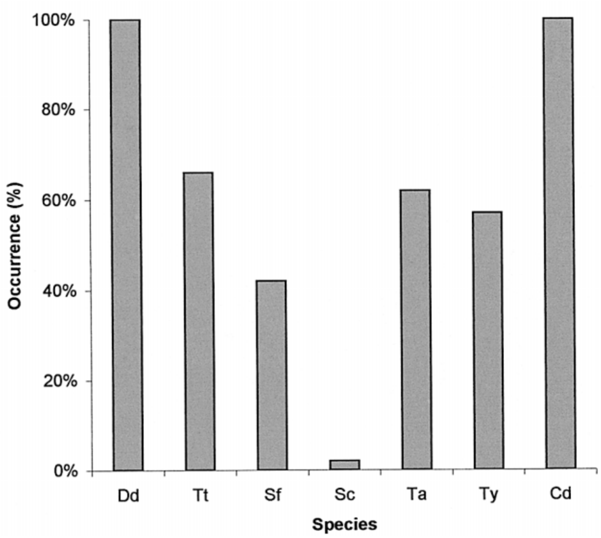

Figure 8. Occurrence of the main species: Dd: *Delphinus delphis*; Sc: *Stenella coeruleoalba*; Sf: *Stenella frontalis*; Tt: *Tursiops truncatus*; Ty: *Thunnus thynnus*; Ta: *Thunnus albacares*; Cd: *Calonectris diomedea*).

Richter scale, occurring on July 8, 1998 on Faïal Island, may have been a determining factor in the absence of cetacean surface activity.

4.3. Species of dolphins

By far the dolphin most commonly found in association with yellowfin tuna, particularly in the eastern tropical Pacific, is the pantropical spotted dolphin (*Stenella attenuata*) (Fréon and Dagorn, 2000). A striking aspect of our observations was the prevalence of common dolphins and, to a lesser degree, bottlenose dolphins, when the Atlantic spotted dolphin was found in smaller numbers (*figure 8*). This balance was clear in 1997. The distribution of cetacean species shifted in favour of the spotted dolphin between the summer of 1997 and that of 1998. This trend for the summer of 1998 was confirmed by another observer, who also noted the virtual absence of the common dolphin in observations that took place in 1999 (Rick Rosenthal, personnal communication). As a matter of fact, the two species mainly involved in the concentration of the prey-fish were the common dolphin and the spotted dolphin. The bottlenose dolphin was rather appearing at the mature phase of the hunt.

4.4. Bird observations

Seabirds, especially shearwaters, are good indicators and indeed signal the existence of a high level of predatory activity, whatever the place around the world, and specifically for the Eastern Atlantic near the Azores (Pereira, 1985, 1990). Seabirds are present at all the hunts that we observed. They vary in number from about fifty to more than one thousand, depending on the size of the hunt, which itself seems to be linked to the abundance of prey fish. A very large majority of the seabirds were identified as cory's shearwater (*Calonectris diomedea borealis*). During the hunt, they usually do not dive beyond 2 m to catch a prey. Our observations show an average depth of 1.5 m, which is deeper than that reported (0.3 m) in the same Azores (Monteiro et al., 1996). This difference could be explained by the relative abundance of prey at the time of observation, as well as by the chicks' stage of development, both factors which play a determinant role (Mougin and Mougin, 1998). This average depth is closer to the averages (2.5 m) reported for the cory's shearwaters of Salvagem (Madeira archipelago) (Mougin and Mougin, 1998).

Our observations confirmed that an appreciable number of seabirds reach depths approaching or passing definitely 10 m. If cory's shearwaters (genus *Calonectris*) form the great majority of the seabirds, it is possible that some individuals of the genus *Puffinus* (especially *P. gravis*), which are also present in the Azores and are generally thought to reach greater depths (Mougin and Mougin, 1998), were also present in our observations. The limited attention gave to identifying accurately the birds does not at this time allow us to be certain about the identity of the birds which reach these depths.

5. CONCLUSION

These observations on the predatory behaviour of tuna and dolphins suggest a temporary close association between fish and dolphins, rarely seen in the Atlantic. They define factors which favour such an association: the presence in substantial quantity of small prey in the epipelagic zone, a certain level of light suitable for triggering the hunting phenomenon (morning and evening), as well as the presence of several kinds of predators displaying different foraging behaviour. A model of feeding behaviour for cetaceans and large tuna in the eastern central Atlantic has been outlined. The analysis of the role played by each participant suggests that, with respect to the hypothesis concerning the species looking for the aggregation, the tuna benefit more from the dolphins than the contrary. This association nonetheless requires particularly rare conditions, as is confirmed by the testimony of local fishermen. In all of August 1998, which was devoted to attempting more detailed observations, results were weak: only two yellowfin tuna, alone in a school of dolphins, were observed in 15 field days. Some signals picked up by the sonar would suggest that their congeners were cruising at greater depths (60 to 80 m), but they never came up in the epipelagic zone, at least in the presence of the observers.

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