# ASPECTS OF HABITAT USE PATTERNS OF HUMPBACK WHALES IN THE ABROLHOS BANK, BRAZIL, BREEDING GROUND

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The Abrolhos Bank (off the State of Bahia, northeastern Brazil) is the most important breeding and calving ground for humpback whales, *Megaptera novaeangliae*, in the western South Atlantic. The area is shallow with a mean depth of 30m and a group of five islands (the Abrolhos Archipelago) is located in the northern portion of the Bank. Data collected from 1992 to 1998 were analysed to identify possible different habitat use patterns by different humpback whale group types. An analysis of variance found differences in the mean water depths where different group types were recorded: single whales, 18.9m (se = 0.505); pairs, 18.6m (se = 0.386); competitive groups, 19.1m (se = 0.573); mother-calf pairs, 15.8m (se = 0.373); mother-calf-principal escort, 14.9m (se = 0.489); and competitive group with mother-calf pair, 16.4m (se = 0.889). With the exception of competitive groups, those containing calves (mother-calf alone or mother-calf-principal escort) occurred in significantly shallower water than non-calf groups (Tukey test, $p<0.05$). In addition, groups containing calves were found significantly more often nearer the Archipelago (within 4 nautical miles) than other groups (two-sample Kolmogorov-Smirnov test, $D = 0.139$; $\chi^2 = 18.516$, $p<0.05$). Accordingly, a spatially stratified management scheme is recommended in order to protect mother-calf pairs from possible harassment by whale watching operations in the area. ❐ *Humpback whale, Megaptera novaeangliae, habitat use, Abrolhos Bank, Brazil.*

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The humpback whale, *Megaptera novaeangliae*, is a cosmopolitan migratory species (Dawbin, 1966). In summer, animals inhabit high latitude feeding grounds, migrating to breeding and calving grounds in tropical or subtropical waters in winter. These breeding grounds are generally associated with islands, offshore reef systems or continental shores (Dawbin, 1966; Whitehead & Moore, 1982; Clapham & Mead, 1999). The Arabian Sea humpback whale population is an exception that remains in tropical waters year-round (Mikhalev, 1997).

The Abrolhos Bank, Brazil, is the most important breeding and calving ground for humpback whales in the western South Atlantic (Engel, 1996; Siciliano, 1997). An increase in humpback whale sightings has been reported in the north of this area (Dórea-Reis et al., 1996; Zerbini et al., 2000). Using mark-recapture models of photo-identified whales, a population of 1,634 (90% CI, 1,379-1,887) was estimated in this area in 1995 (Kinas & Bethlem, 1998). No positive match between whales sighted at Abrolhos Bank and the Antarctic has been found (Projeto Baleia Jubarte, unpubl. data; Whale Research Team/ Proantar, unpubl. data) and the summer destination of this population is unclear.

According to categories of Forestell & Kaufman (1995), Abrolhos is in a discovery phase of whale watching, which is opportunistically offered by SCUBA operators taking tourists to dive in the Abrolhos Marine National Park/IBAMA (Brazilian Institute of Environment and Renewable Resources). Tourist numbers have been stable, probably due to National Park management and carrying capacity regulations (Morete et al., 2000), with 14,000 visitors in 1995. Development of whale watching in the Abrolhos Bank region may be a source of economic benefit to the local community, nevertheless, its effects on animal behaviour and demographic trends should be assessed scientifically to assist planning.

This study obtained base line information on habitat use of the humpback whale population in the Abrolhos Bank breeding ground, from data

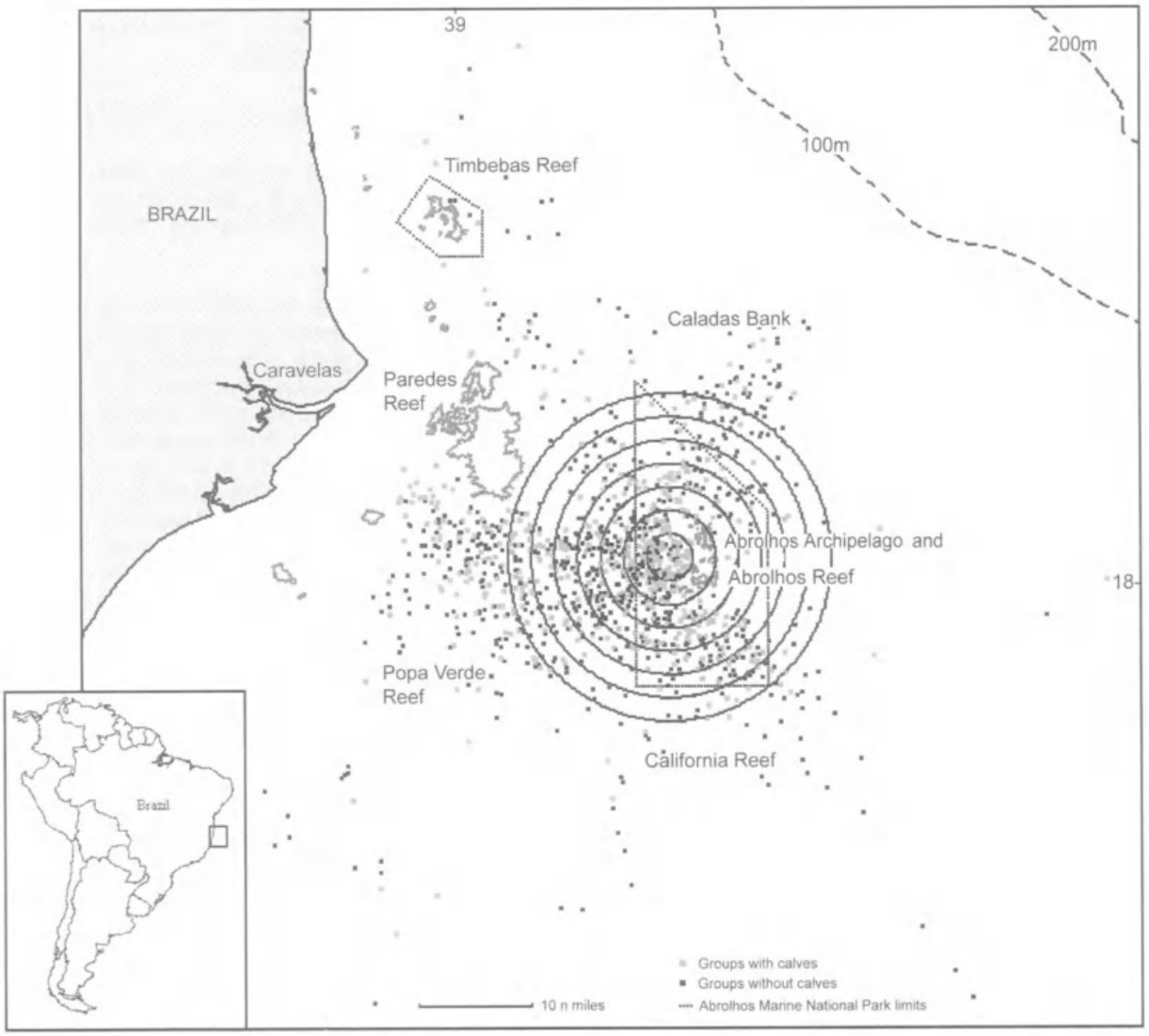


FIG. 1. Distribution map of humpback whale groups sighted in Abrolhos Bank, Brazil, 1992-1998.

collected from 1992-1998, and provides complementary information to the tourism management plan for the Abrolhos region.

## MATERIAL AND METHODS

STUDY AREA. The Abrolhos Bank is located off the northeast coast of Brazil from 16°40'-19°30'S (Fig. 1). It contains a mosaic of coral reefs, mud and calcareous algae bottoms with a mean depth of 30m and covers an area of ~30,000km$^2$ (Fainstein & Summerhayes, 1982). Five small islands comprise the Abrolhos Archipelago in the north: Santa Bárbara, Redonda, Siriba, Sueste and Guarita. The Brazil Current influences the hydrodynamic conditions of the area. Divergence of the current, due to shallow depths of the bank, cause wind to be an important component over the continental shelf (Stamo et al., 1990). Generally winds are from the NE from September-February, S from March-August and E from August-September (IBAMA/FUNATURA, 1991). Average annual sea surface temperatures range from 22°-27°C (winter from 22°-24°C) and show a weak vertical gradient. Tide variation is ~2.3m (Castro & Miranda, 1998). The Abrolhos Marine National Park is located in the northeast portion of the bank, and includes the Abrolhos Archipelago and Abrolhos and Timbebas Reefs (Fig. 1).

DATA COLLECTION. Data were collected from 1992-1998 between July-November. Survey vessels were trawlers and schooners of lengths between 46-65ft, capable of speeds up to 9 knots, with the 46ft IBAMA trawler 'Benedito' used

most often. Systematic searching for whale groups commenced in 1995 when four-day cruises were conducted each week with searches carried out by a team of three people. Surveys were not conducted when winds were >20 knots. Each daily cruise would head to a pre-specified region on the Abrolhos Bank (i.e. Caladas Bank, Popa Verde Reef, California Reef; Fig. 1). Deviation from track lines occurred when a whale group was sighted. Within a maximum observation time of 30 minutes, photo-ID and biopsies of all animals were attempted, after which the vessel returned to the previous course. Because the main objective of cruises was not for the purpose of the present study, but for photo-ID and biopsies, track lines were sometimes abandoned when large numbers of whales were encountered away from the vessel's planned course.

For each sighting we recorded: date, time, size and composition of group, location (by GPS), behavior, presence of marks or scars and photo-ID and biopsy information. Initial positions of all groups were plotted on nautical charts and water depths interpolated from the chart isobaths.

Bathymetric values of the water column in the region were digitised from local charts (DHN 1300, 1310, 1311) to obtain distribution maps of humpback whales in the study area. A digitising tablet (Calcomp Microgrid IV, A0 format) and Autocad XIV software were used. The graphic Autocad file (DWG format) was exported to DXF format from which the output was saved as a text file. Coordinates and water depth of the digitised points were filtered from this file and processed using SURFER software to create a regular grid with 0.0025° (277.8m) resolution. This was executed using the Kriging routine, with a numeric model of the sea floor. From this file the water depth values corresponding to sighting positions of the data sheet were selected by proximity. A geographical reference search routine was developed using Matlab software.

ADOPTED TERMINOLOGY. Solitary animals were termed as single. A group was defined as two or more animals that remained together during the observation period. Generally, members of a group surface and dive synchronously (Clapham, 1993) and maintain the same displacement speed and direction. From Tyack & Whitehead (1983), an escort is a whale that accompanies a female in a competitive group, or that joins a mother-calf pair; principal escort is a whale that remains mostly at a female's side; secondary escort(s) are one or more whales that compete for the position of principal escort; nuclear individual is a female identified by its centrality and its lack of response to the approach of another adult.

To analyse the habitat use patterns in relation to different group types, we adopted six categories: 1) single – lone individual of unknown sex; 2) pair – two individuals of unknown sex; 3) competitive group (CG) – three or more individuals (sometimes possible to identify a nuclear individual); 4) mother-calf pair (MoCa) – a female with its calf; 5) competitive group with a mother-calf pair (MoCa+CG) – a female and its calf accompanied by a principal escort and one or more secondary escorts; 6) mother-calf-principal escort (MoCaPe) – a female and calf accompanied by a principal escort. Since sub-adults could not be reliably distinguished from adults, all non-calves were considered as adults.

## ANALYSIS

A value of Sightings per Unit of Effort (SPUE) was calculated for 1995-1998 when the systematic survey efforts were similar. SPUE values are expressed as the number of whales sighted per hour of effort for each fortnight during the season. SPUE values may be underestimated because the sampling effort not only represents search time but also includes time spent navigating, observing and collecting data.

All sightings from 1992-1998 containing accurate information on group composition and location were used to analyse the relationship with water depth. The latter was selected as the dependent variable to be tested against group category. Each sighting was treated as an independent sample.

Analysis of Variance was used to determine the effect of group type on mean depth. Once the hypothesis of equal mean depth for all group types was rejected ( $\propto$ = 5%), Tukey's post-hoc test was used to verify which group types had significantly different mean depths.

To analyse the distribution of groups in relation to their distance from islands we defined concentric circular areas with radii varying from 2-14 nautical miles (1n m = 1.852km). Concentric areas were centred on 17.9666°S 38.70°W, the geographical centre of the Abrolhos Archipelago (Fig. 1). Groups present in each area were divided into two categories: those containing at least one calf and those without calves. A Kolmogorov-Smirnov test (Zar, 1974) was applied to determine if the distribution of these two categories differed relative to distance from the Archipelago centre.

TABLE 1. Summary of survey effort and sighting rates 1992-1998 on Abrolhos Bank, Brazil (SPUE = Sightings Per Unit of Effort).

| Year | No. of days | Effort (Hours) | No. of Sightings | SPUE |
|---|---|---|---|---|
| 1992 | 58 | 287 | 199 | 0.7 |
| 1993 | 48 | 273.5 | 290 | 1.1 |
| 1994 | 58 | 345.1 | 458 | 1.3 |
| 1995 | 59 | 410.4 | 592 | 1.4 |
| 1996 | 68 | 365.5 | 701 | 1.9 |
| 1997 | 75 | 490.7 | 871 | 1.8 |
| 1998 | 72 | 490.9 | 799 | 1.6 |
| Total | 438 | 2663.1 | 3910 | |

## RESULTS

Table 1 summarises the observation effort, number of humpback whales sighted and counting rates (SPUE) in the Abrolhos Bank region from 1992-1998. For the systematic surveys during the breeding seasons of 1995-1998, SPUE were highest in the first half of September 1995 and 1997 and in the second half of that month in 1996; in 1998, SPUE peaked in the second half of October (Table 2; Fig. 2).

Temporal trends for group categories are shown in Fig. 3. Singles and pairs were the most frequent groups early in the season. The proportion of competitive groups without calves decreased as the number of competitive groups accompanying a mother-calf pair increased. Singles, pairs, and mother-calf pairs were most frequent during the study period; the latter representing up to 70% of sightings at the end of the season.

To test the relationship between mean depth and group occurrence, the position of 1,437 groups (3,336 whales) were plotted: 226 singles, 418 pairs, 195 competitive groups, 62 competitive groups with mother-calf pair, 331 mother-calf pairs, 205 mother-calf-escorts. Mean group size was 2 and the largest group sighted was 9.

Mean ocean depth for all groups was 17.4m (SD=7.6). An analysis of variance rejected the $H_o$ hypothesis of equal distribution of the groups, independent of depth ($F = 13.9$, $p = 0.05$). Groups comprising mother-calf pairs and mother-calf-escort were found in shallower waters than other groups (Table 3; Fig. 4). Competitive groups with mother-calf pairs were found in waters with a mean depth of 16.4m (SD=7), showing no significant difference to other categories. Groups without calves were found in deeper waters than groups with calves (Table 3; Fig. 4).

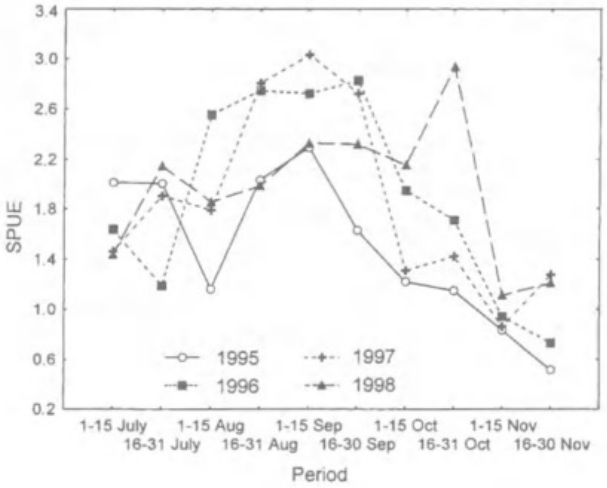


FIG. 2. Sightings per unit of effort for each fortnight from July 1 to November 30, 1995-1998.

Groups with calves occurred in higher proportions <4 nautical miles from the archipelago ($D = 0.139$; $\chi^2 = 18.516$; $p<0.05$) (Table 4). The ratio between groups with and without calves progressively decreases beyond 4 nautical miles (Fig. 5). Within 14 nautical miles of the archipelago centre, 440 groups with calves and 526 groups without calves were sighted. Outside this area, 158 groups with calves and 313 groups without calves were sighted.

## DISCUSSION

Sighting rates (SPUE) are high in July compared with those at the end of the season, suggesting that whales arrive in the breeding ground before surveys began. Anecdotal

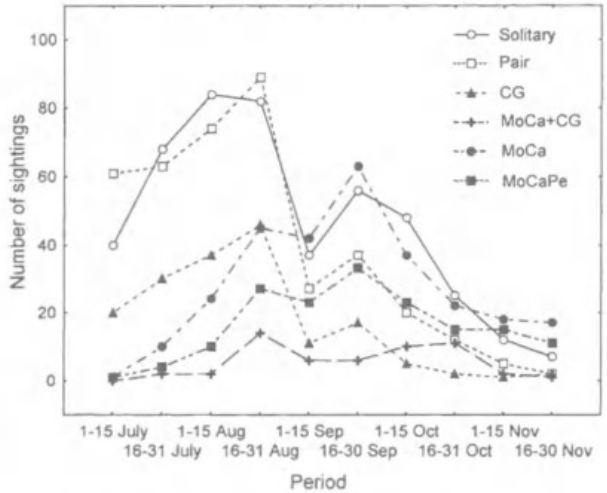


FIG. 3. Number of sightings per group categories for each fortnight from July 1 to November 30, 1995-1998.

TABLE 2. Sightings per unit of effort (SPUE) for each fortnight during the humpback whale breeding seasons, 1995-1998 (n = number of whales sighted, E = sample effort in hours).

| Period | 1995 | | | 1996 | | | 1997 | | | 1998 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | E | SPUE | n | E | SPUE | n | E | SPUE | n | E | SPUE |
| 1 to 15 July | 31 | 15.4 | 2 | 35 | 21.3 | 1.6 | 83 | 56.6 | 1.4 | 72 | 50 | 1.4 |
| 16 to 31 July | 78 | 38.9 | 2 | 44 | 37 | 1.2 | 74 | 38.9 | 1.9 | 91 | 42.4 | 2.1 |
| 1 to 15 August | 44 | 37.8 | 1.1 | 106 | 41.5 | 2.5 | 118 | 66 | 1.8 | 127 | 68.6 | 1.8 |
| 16 to 31 August | 142 | 69.75 | 2 | 153 | 55.6 | 2.7 | 177 | 63 | 2.8 | 211 | 106.3 | 2 |
| 1 to 15 September | 60 | 26 | 2.3 | 71 | 26.1 | 2.7 | 89 | 29.3 | 3 | 62 | 26.6 | 2.3 |
| 16 to 30 September | 108 | 66.3 | 1.6 | 121 | 42.75 | 2.8 | 127 | 46.7 | 2.7 | 54 | 23.25 | 2.3 |
| 1 to 15 October | 36 | 29.5 | 1.2 | 43 | 22.1 | 1.9 | 89 | 68 | 1.3 | 121 | 56.1 | 2.1 |
| 16 to 31 October | 59 | 51.3 | 1.1 | 72 | 42.1 | 1.7 | 36 | 25.25 | 1.4 | 24 | 8.16 | 2.9 |
| 1 to 15 November | 30 | 36.1 | 0.8 | 34 | 36.1 | 0.9 | 25 | 29.1 | 0.8 | 25 | 22.5 | 1.1 |
| 16 to 30 November | 4 | 7.75 | 0.5 | 22 | 30.1 | 0.7 | 53 | 41.5 | 1.3 | 12 | 9.9 | 1.2 |
| Total | 592 | | | 701 | | | 871 | | | 799 | | |

information corroborates this. According to fishermen and tourist vessel skippers many whales are seen in the area in June and one sighting has been recorded in mid May (R.C. Fortes, pers. comm.). Researchers assessing the standing stock in the Brazilian Economic Exclusive Zone (EEZ) also reported the presence of humpback whales near Abrolhos in May (A.B. Greig, pers. comm.).

The highest SPUE of the study period was for the first half of September 1997 (3 whales/hour) (Fig. 2). Time of abundance peak varied little between years. The most atypical was 1998 with peak concentration in the second half of October; a shift of six weeks compared with 1995 and 1997, and four weeks compared with 1996. In this period only one cruise was undertaken, due to poor weather, with high sightings recorded. In September of the same year, a cruise was made north of the Abrolhos Bank to the Porto Seguro region, an area not normally sampled. The SPUE recorded in this area varied between 0.009-0.03 individuals/hr. During the same month, at the Abrolhos Bank area, SPUE varied from 0.025-0.07 ind/hr. This diversion from the main area of humpback whale concentration may have contributed to the decrease in SPUE for September 1998. Changes of three and four weeks in the peak of the breeding season were observed for humpback whales in Hawaii (Baker & Herman, 1981) and of about two weeks for gray whales, *Eschrichtius robustus*, in Laguna Saint Ignacio, California (Jones & Swartz, 1984).

The majority of humpback whale sightings were in the north around the Abrolhos Archipelago. Most survey effort was concentrated in this area and could have biased the results. In areas of low survey effort, where fewer whale numbers were expected (e.g. Porto Seguro), low SPUE values supported the hypothesis that the Archipelago is a concentration area. Nevertheless, in recent years sightings have increased further north on the Abrolhos Bank (Zerbini et al., 2000) to the Fernando de Noronha Archipelago (3°51'S 32°25'W)

TABLE 3. Tuckey test for the depth variable against group categories: single; pair; competitive group (CG); competitive group with mother-calf pair (MoCa+CG); mother-calf pair (MoCa); mother-calf-principal escort (MoCaPe). (M = mean depth for each group category; SD = standard deviation; * significant difference [$p < 0.05$] between the categories).

| Groups | Single | Pair | CG | MoCa+CG | MoCa | MoCaPe |
|---|---|---|---|---|---|---|
| | M=18.9 (SD=7.6) | M=18.6 (SD=7.9) | M=19.1 (SD=8) | M=16.4 (SD=7) | M=15.8 (SD=6.8) | M=14.9 (SD=7) |
| Single | | 0.993 | 0.999 | 0.184 | 0.00004* | 0.00002* |
| Pair | 0.993 | | 0.958 | 0.287 | 0.00003* | 0.00002* |
| CG | 0.999 | 0.958 | | 0.134 | 0.00003* | 0.00002* |
| MoCa+CG | 0.184 | 0.287 | 0.134 | | 0.991 | 0.697 |
| MoCa | 0.00004* | 0.00003* | 0.00003* | 0.991 | | 0.714 |
| MoCaPe | 0.00002* | 0.00002* | 0.00002* | 0.697 | 0.714 | |

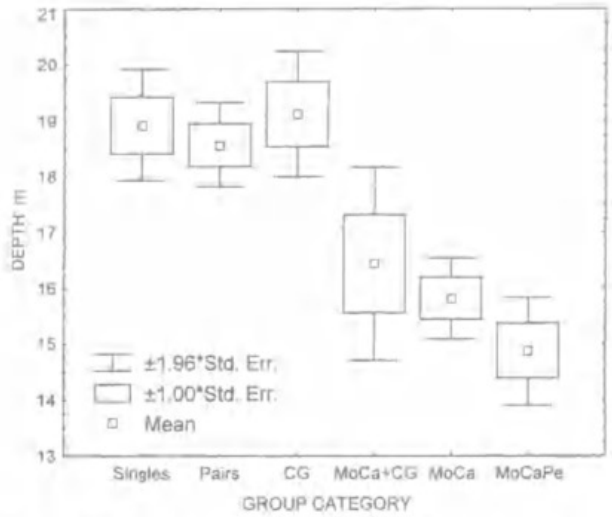


FIG. 4. Mean water depth for each group category: single; pair; competitive group (CG); competitive group with mother-calf pair (MoCa+CG); mother-calf pair (MoCa); mother-calf-principal escort (MoCaPe).

(J.M. Silva Jr, pers. comm.). This may indicate that the species is returning to areas previously occupied before the depletion of stocks by whaling.

GROUP CATEGORIES. Single whales and pairs were the most frequent groups at the beginning of the season (Fig. 3). The proportion of singles decreased from August and that of mother-calf pairs increased. Formation of competitive groups was observed throughout the season. Competitive groups with a mother-calf pair were fewer than other categories. Clapham et al. (1992) noted a similar pattern in the West Indies.

WATER DEPTH. Distribution of groups was strongly related to water depth. Highest mean depths were noted for competitive groups, but there were no significant differences between

TABLE 4. Kolmogorov-Smirnov test for two samples. Groups with (y) and without (n) calves as a proportion of the total in each category, recorded within the distances show from position 17.966°S 38.7°W, the center of the Abrolhos Archipelago.

| Distance (n. miles) | Groups with calves (y) | Groups without calves (n) | D(y) - D(n) |
|---|---|---|---|
| 2 | 0.143 | 0.053 | 0.090 |
| 4 | 0.302 | 0.163 | 0.139 |
| 6 | 0.443 | 0.316 | 0.127 |
| 8 | 0.654 | 0.517 | 0.128 |
| 10 | 0.786 | 0.707 | 0.079 |
| 12 | 0.886 | 0.835 | 0.051 |
| 14 | 1 | 1 | 1 |

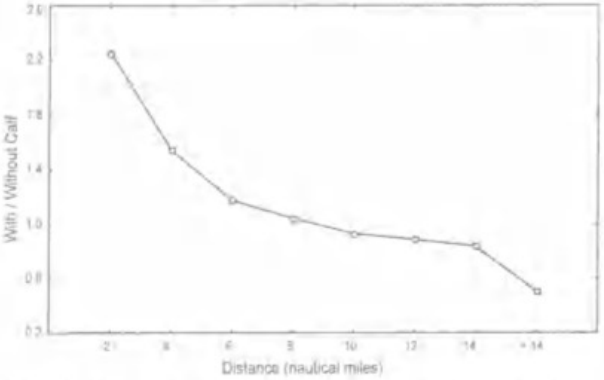


FIG. 5. Ratio of number of groups with calves to those without calves within distances show from the centre of the Abrolhos Archipelago, 17.9666°S 38.7°W.

singles, pairs and competitive groups. All groups with calves were in shallower waters, although there was no significant difference between competitive groups with cow-calf pair and all other categories.

Distribution of mother-calf groups may be influenced by water dynamics. Within 4nm of the Archipelago centre, groups with calves were in higher proportions than groups without calves. A shore based study from an archipelago island (Projeto Baleia Jubarte/IBAMA, 1998) recorded that 49.3% of groups contained a calf in 1997 and 46.9% in 1998, inside a 4nm area from the Abrolhos Archipelago centre; higher percentages than for this study. However, that study site is characterised by the shallowest waters of the Abrolhos Bank (Fig. 1), comprising the Abrolhos Archipelago and the Abrolhos Reef which offer protection from prevailing winds and attenuation of the dynamics of water movement. Such calm water may assist calf suckling, potentially allowing the calf to remain next to the mother with less effort. Studies at Hawaiian and Caribbean wintering grounds demonstrated segregation according to sex, age and/or reproductive status, with humpback whale cows with calf appearing to predominate in shallow, sheltered or coastal water, while other adults were mostly in deeper, more exposed water (Hermam & Antinoja, 1977; Whitehead & Moore, 1982; Mattila & Clapham, 1989; Glockner-Ferrari & Ferrari, 1990; Smultea, 1994).

Disposition of cow-calf pairs towards shallower waters may be a strategy to avoid interactions with competitive groups where behavior within such groups might be harmful to a calf. Cartwright (1999) noted that calf behavior was energetically conservative when alone with its mother, but

became more costly when associated with multiple escorts. In most cases an escort is male (Baker & Herman, 1984), and generally believed to be mature, awaiting an opportunity to copulate with the mother when she comes into oestrus (Clapham et al.,1992). Mother-calf pairs with a principal escort were associated with shallowest waters (Table 3). Behavior of mother-calf-escort groups in frequenting shallow waters may be a strategy of the cow to avoid mating. Jones & Swartz (1984) suggested that competitive groups select deeper waters to avoid collisions with the seabed and coral heads and that shallow waters may discourage courting males.

Payne (1986) studied southern right whales, *Eubalaena australis*, in the Valdes Peninsula, Argentina and observed that cow-calf pairs were distributed along the coast, following the 5m isobath. That author identified three areas occupied by different group categories: one predominantly occupied by mother-calf pairs; one with mature males and females; and one with all the classes including sub-adults and competitive groups. Glockner-Ferrari & Ferrari (1985, 1990) and Salden (1988) recorded a continuous decrease in the cow-calf pair percentage in Hawaiian coastal waters, and associated this with the increase of human activities in the area. However, the Hawaiian population continued to increase (Bauer et al., 1993).

It is important to determine the habitat use patterns of humpback whales in their breeding grounds before the introduction of activities that may alter this pattern (Smultea, 1994). Whale watching activity in the Abrolhos Bank area is opportunistic and most whale groups are observed in tracks of boats proceeding to the Abrolhos Marine National Park (Fig. 1). An agreement in 1999 between the Abrolhos Marine National Park and the Projeto Baleia Jubarte noted that boats would not approach whale groups inside the archipelago area. A shore based study of the impact of whale watching activity on whale behaviour began in 1997. Continuous monitoring of habitat use patterns in the Abrolhos Bank area, with special reference to the Abrolhos Archipelago, could detect possible trends and assist in management of this activity, based on Federal Edict no. 117/96. Aerial surveys are suggested to determine humpback whale population distribution and to monitor possible trends. Such data would contribute to a better understanding of habitat selection by different group types, provide abundance estimates for comparison with data obtained from mark-recapture models of photo-identified whales, and provide essential information for management of whale watching operations in the area.

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