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Distribution of humpback whales along the coast of Ecuador and management implications

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ABSTRACT

As part of a long-term population study of humpback whales breeding on the coast of Ecuador (2°S, 81°W), four sites on the central coast were surveyed: Puerto Cayo, Puerto López, La Plata Island and Salinas. The spatial, temporal and age class distributions of 322 groups positioned during the period of 1996-2003 were analysed regarding their distance from the shore and water depth with two statistical methods: one-way ANOVA and linear modelling. The average sighting distance from shore varied between 5.31km in Salinas and 10.16km in Puerto Cayo with mid values in Puerto López and La Plata Island. Average water depth was similar in Puerto López, La Plata Island and Salinas (36-39m) but lower in Puerto Cayo (19.43m). Differences were highly significant in both cases ($p<0.01$). A progressive but not significant increase in the average distance from shore was found (6.2km in June to 7.17km in September). Sighting depth was constant between June and August (average 35-36m) but decreased significantly in September to 27m ($p<0.01$). This difference was attributed to the presence of mother-calf pairs in shallower water by the end of the season. Age class analyses using ANOVA showed highly significant differences between groups of adults, and adults with subadults with respect to singleton subadults, and groups containing a mother-calf pair for both distance from shore and depth ($p<0.01$); however, linear modelling analyses showed only depth was significant ($p=0.026$). This suggests that depth is a more important determinant of differences in distribution between these age classes than proximity to shore. The sightings distribution showed segregation of both mother-calf pairs (towards shallow waters) and of singleton subadults (towards the boundaries of the surveyed area). Since only eight sightings (2.5%) were in waters deeper than 60m, we propose that depth is a major feature determining humpback whale distribution in these waters. Implications of this coastal distribution are discussed, particularly with respect to bycatch in fishing gear and whalewatching. A review of recent southeast Pacific sightings showed that humpback whales are also abundant in coastal waters to the southwest of Ecuador (3°S) and confirmed that they are scarce offshore. However, whales are more widely distributed in the north of Peru (4°-6°S) where they make the transition between deeper oceanic and shallower coastal waters when arriving at and leaving the breeding area.

KEYWORDS: HUMPBACK WHALE; SOUTH AMERICA; DISTRIBUTION; BREEDING GROUNDS; CONSERVATION; MODELLING; STATISTICS

INTRODUCTION

During the winter months in both hemispheres, humpback whales concentrate in tropical and subtropical zones along continental margins, coastal islands or archipelagos for breeding and calving (e.g. Clapham and Mead, 1999). In most cases, whales are distributed in waters less than 100 fathoms (183m) deep (Winn *et al.*, 1975; Herman and Antinoja, 1977; Urban and Aguayo, 1987; Ersts and Rosenbaum, 2003), although the reasons for this remain unknown. The distribution of humpback whales in open waters during breeding is less well understood. Acoustic studies have demonstrated that some male singers occur in waters deeper than 3,000m and up to 57km from the coast in the Caribbean (Swartz *et al.*, 2003). In Hawaii, Frankel *et al.* (1995) found the concentration of singing males to be 3.6 times higher in coastal waters than in waters of more than 100 fathoms in depth. This suggests that, although they are more widely spaced than in coastal waters, many humpback whales may use deep waters during the breeding season.

A southern humpback whale stock (Group G – see IWC, 1998) migrates along the southeast Pacific between the Antarctic Peninsula and south of Chile where they feed, (Gibbons *et al.*, 2003; Stevick *et al.*, 2004) and the coasts of Ecuador, Colombia and Panama where they breed (Clarke, 1962; Flórez-Gonzàlez, 1991; Scheidat *et al.*, 2000; Félix and Haase, 2001a). Humpback whales are found in Ecuador from May-November, with the greatest numbers occurring in July and August (Félix and Haase, 2001a). During the breeding period in Ecuador, groups of humpback whales appear to show a heterogeneous distribution according to their age and class composition; for example, groups containing mother-calf pairs prefer waters of 20m or less in depth, singleton subadults also prefer shallow waters, whereas groups of adults occur in the deeper waters further from shore (Félix and Haase, 1997; 2001a).

Their coastal habit renders humpback whales vulnerable to certain human activities such as chemical pollution, vessel traffic noise, industrial activities and particularly interactions with fishing gear (Reeves *et al.*, 2003). Reports of humpback whales entangled in artisanal gillnets in Ecuadorian waters are a cause for concern, and evidence suggests that the problem is increasing (e.g. Félix *et al.*, 1997; Alava *et al.*, 2002). This artisanal fishery is directed toward demersal resources (crustaceans, reef and bottom fish) and large pelagic fish (billfish, tuna, sharks, etc.) and limited to 40 n.miles from the coast over the continental shelf (Martínez, 1987). These waters are also used by humpback whales during their breeding season. It was estimated that there were 15,000 artisanal boats by the end of the 1990s in the country (Ormaza and Ochoa, 1999), 50% of which used gillnets up to 3km in length and 15m high with variable mesh sizes (Martínez *et al.*, 1991). Entanglement of large whales occurs more frequently in gillnets directed to large pelagic fishes, with mesh size of 7.3-13cm (Félix *et al.*, 1997). The importance of marine mammal bycatches to their conservation has been highlighted by a number of international organisations (e.g. see Northridge, 1984; Perrin *et al.*, 1994; Reeves *et al.*, 2003).

The development of whalewatching programmes along the coast of Ecuador constitutes another potential source of disturbance for whales. Changes in movement and activity patterns during encounters with tourist boats have been reported in several sites including Ecuador (e.g. Corkeron, 1995; Brtnik, 2001; Félix, 2001; Scheidat *et al.*, 2004). There has been a steady growth of whalewatching activity since the mid 1990s due to increased 'ecotourism' along the coast of Ecuador. Nowadays, the activity is carried out from at least six different sites in the country (Félix, 2003).

This paper investigates the relationship between the distribution of humpback whale groups and some of the physical and geographic features that may be related to or determine whale distribution; specifically water depth and distance from shore. These relationships may be used to predict other regions of high humpback whale population density along the coast of Ecuador and ultimately help to minimise conflict with human activities.

Previous records in Ecuador and in other parts of the Southeast Pacific

It has been known for a long time that the coasts of Ecuador, Colombia and Panamá are breeding sites for humpback whales (e.g. Townsend, 1935; Clarke, 1962). However, recent studies have more accurately identified humpback whale breeding habitat along the northwestern coast of South America. This area of around 2,000km in length includes the coasts of Peru (7°S), Ecuador, Colombia, Panama (Flórez-González *et al.*, 1998) and as far north as 8°N and the Dulce Gulf in Costa Rica (Acevedo and Smultea, 1995). Humpback whales have occasionally been reported around the Galapagos Islands, 1000km off Ecuador, although they are considered uncommon there (Day, 1994; Merlen, 1995; Palacios and Salazar, 2002).

Several expeditions have sighted humpback whales between Ecuador and the Galápagos Islands in the past four decades (e.g. Clarke, 1962; Lyrholm *et al.*, 1992; Clarke *et al.*, 2002). Details of the sightings including date, position and number of animals are provided in Appendix Table 1. With the exception of Clarke (1962), who reported a group of humpback whales 50 n.miles off Isla Santa Clara in the southern part of Ecuador (number 1) and another 25 n.miles further away (without position), humpback whales were only reported in coastal waters, and not in the archipelago. Sightings were also reported during cetacean surveys in the Eastern Tropical Pacific conducted by the United States National Oceanographic and Atmospheric Agency (NOAA) from the late 1980s until 2003. These data include thirteen sightings off the northern coast of Peru between 3°30'S and 6°25'S, seven in coastal waters of the central and southern part of Ecuador, two 120 n.miles off the south of Ecuador, two around the Galapagos Islands, 10 in coastal waters of Colombia and two off (120 and 250 n.miles) the central coast of Colombia (Fig. 1).

Other records for the coastal waters of southern Ecuador were obtained around Santa Clara Island between 1 and 5 July 1998 during a period of seismic prospecting in the Gulf of Guayaquil (Yturralde and Suárez, 1998). The positions, depths and distances to the largest island of the Gulf (Puná Island) of these 35 sightings are shown in Appendix Table 2. Whales were recorded in shallow waters (mean depth 45.7m; SD=18.6) and an average of 25.42km (SD=6.79) offshore showing that humpback whales are also present in the southern coastal waters of Ecuador (Fig. 1).

Excluding the two sightings around the Galápagos Islands, only three of the sightings plotted in Fig. 1 were in deep waters off the south of Ecuador, and the remainder were recorded in coastal waters. The sightings suggest a continuous distribution of humpback whales along the coastal waters of the entire region (4°N-6°S). In contrast, offshore sightings were absent between 84°W and 90°W (Galápagos Islands) and between 2°S (central-south coast of Ecuador) and 4°N (central coast of Colombia). The small number of sightings in deep waters in this area infers that humpback whales are rarely found offshore during the breeding season, although the lack of survey effort is acknowledged.

Off southern Ecuador, however, humpback whales seem to be distributed further offshore. Most catches made between May and November in the period 1961-1966 from land stations located in Paita (5°S, 81°14'W) and Chimbote (7°S, 78°30'W) occurred within 100 n.miles of the coast, with the greatest concentration between 81°30'W and 82°W, although some whales were caught as far as 200 n.miles offshore (Ramírez, 1988). Sightings from the period 1975-1985 show a similar distribution pattern (Ramírez, 1988). More recently, Sánchez and Arias (1998) stated that humpback whales were the most abundant large cetacean observed during a cruise along the northern coast of Peru between August and September 1998, with the highest concentration at 5°S and between 4 and 99 n.miles offshore.

MATERIAL AND METHODS

A population study of the humpback whale on the coast of Ecuador has been carried out aboard whalewatching vessels since 1990 (Félix and Haase, 1997; 2001a). Information is recorded on group size, group composition, behaviour, oceanographic conditions and the geographic position. Position is determined using a portable global positioning system (GPS). This study uses data for a total of 322 groups recorded during 159 trips between 1996 and 2003.

Study area

The study was carried out at four sites along the central coast of Ecuador: Puerto López, Puerto Cayo, La Plata Island and Salinas (Fig. 2). The Puerto López (1°30'S, 80°50'W) region is fairly homogeneous with water depths of 30-50m extending some 40km offshore. Near Puerto Cayo (1°20'S, 80°50'W), the coast forms a wide, shallow embayment of less than 30m depth that extends some 30km along the coast in a northwest direction. La Plata Island (1°15'S, 81°W) is located 24km off the mainland at its nearest point. The water depth on the east side varies between 15 and 50m in a relatively small area, but on the west side the depth changes abruptly to 100m in the first kilometer. Salinas is located on the outermost tip of the Santa Elena peninsula (2°10'S, 81°W), 80km south of Puerto López. Here, the continental shelf is narrow and the depth increases rapidly westward, reaching depths of 200m just 13.5km offshore.

Sites and surveys

Boats departed from three sites: Puerto López, Puerto Cayo and Salinas (Fig. 2).

Puerto López

Trips were conducted from this port in 1996, 1997 and 2000. Boats headed northwest towards La Plata Island 40km offshore, along the 50m isobath. After 3 hours, the boats returned to port.

Puerto Cayo

Trips were conducted in 1996 and 1997. Boats headed westwards up to 20km offshore and then returned to port. The operation was carried out close to shore in waters averaging 20m in depth.

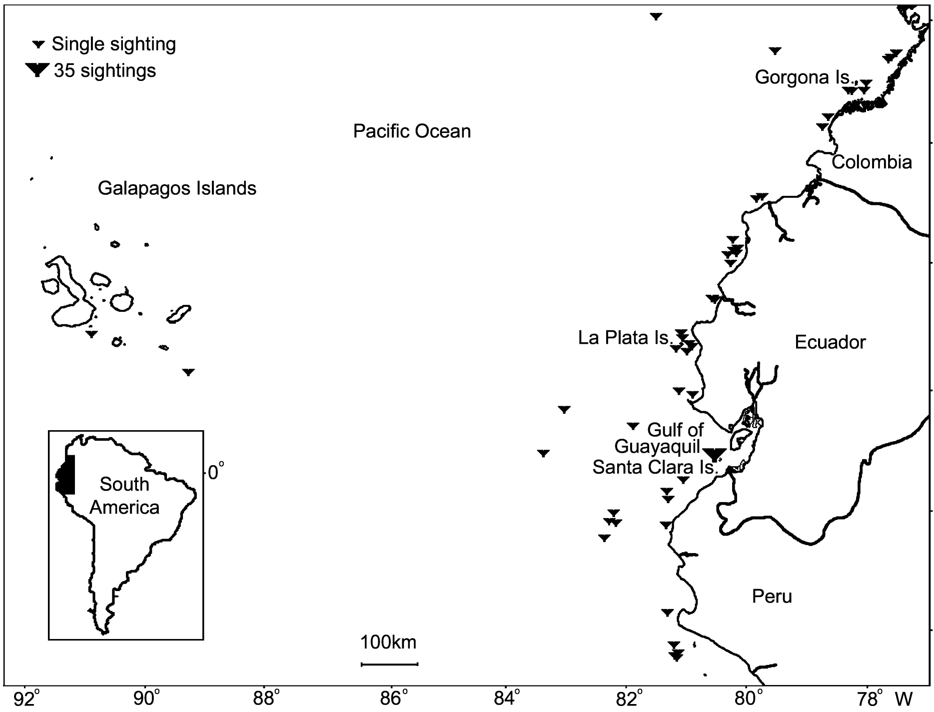

Fig. 1. Sightings of humpback whales along the coast of Ecuador and in other parts of the southeast Pacific by expeditions between 1959 and 2003 (see text).

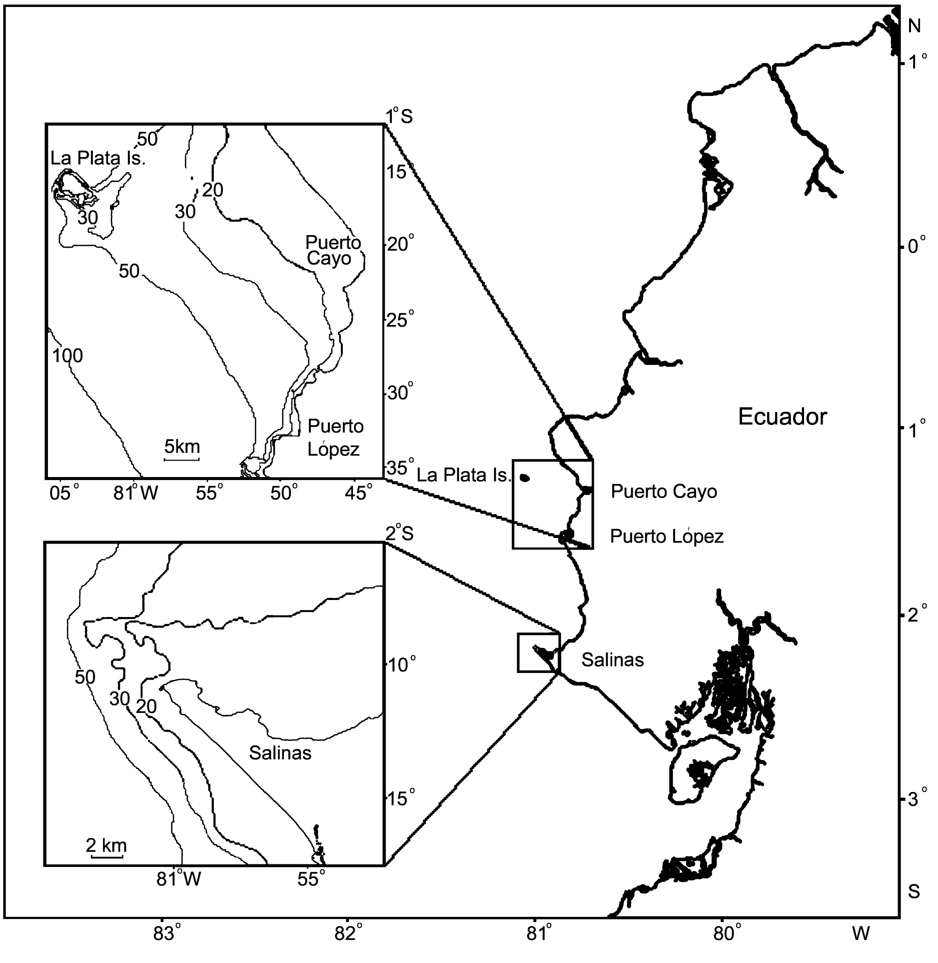

Fig. 2. Map of the coast of Ecuador showing the four study areas.

Salinas

Trips were conducted between 2001 and 2003. Surveys extended 6-10km west and water depths of 50-60m were quickly reached.

Survey effort

Information regarding the number of sightings recorded in each year is shown in Table 1. The effort deployed by month in each site is shown in Table 2. The effort varied during the four months as follows: June, 5.7%; July, 39.5%, August, 38.2%; and September, 16.6%. In general, effort was more homogeneous by month in Puerto López, La Plata Island and Salinas, whereas in Puerto Cayo there was a lower proportion of surveys in July and a higher proportion in September. However, these differences were not statistically different (χ^2_{11}=9.55, p<0.05). June and October were excluded from this comparison because of the low number of surveys.

Table 1

Number of groups sighted in each site and year (period 1996-2003) (n = 322).

	Number of groups					
Site	1996	1997	2000	2001	2002	2003
Puerto López	11	23	9			
Puerto Cayo	23	28				
La Plata Island	24	27	14			
Salinas				39	57	66
Total	58	78	23	39	57	67

Table 2

Number of trips conducted by month in each site (period 1996-2003) (n = 159).

	Puerto López		Puerto Cayo		La Plata Island		Salinas	
Month	*n*	%	*n*	%	*n*	%	*n*	%
Jun.	3	11.1			1	3.2	5	6.8
Jul.	11	40.8	6	22.2	16	51.6	29	39.2
Aug.	9	33.3	12	44.5	11	35.5	28	37.8
Sept.	4	14.8	9	33.3	3	9.7	10	13.5
Oct.							2	2.7
Total	27	100	27	100	31	100	74	100

Group composition

Three different age classes were distinguished based on size: (1) adults, animals estimated to be larger than 10m in length; (2) subadults, estimated to be 6-10m in length; and (3) calves, estimated to be less than 6m in length and always accompanied by an adult animal, presumably the mother (Félix and Haase, 2001a). These results must be treated with caution since lengths were estimated by eye. However, given this proviso, groups were categorised as either: A=all adults, AS=adults with subadults, S=single subadults, MC=mother with calf alone or accompanied by one or more escorts.

Depths and distances

For each group for which a position was obtained, the depth and distance to shore were estimated using the following navigation charts[1]: I.O.A. 104 (Punta Jaramijó to Salango Island), I.O.A. 105 (Santa Elena Bay, Salango Island-Chanduy) and I.O.A. 10 (Cabo Manglares-Punta Malpelo). Sightings were marked on the chart and then distances were measured in a straight line to the nearest point on either the mainland or La Plata Island coast. Depth was recorded as either the nearest known point on the chart with a value or the value of the isobath line if this was the nearer point. If several values marked on the chart were equidistant, then an average value was used.

Statistical analysis

Distance from shore and depth of sightings were analysed using two statistical methods: (1) one-way ANOVA for areas, month and group class; and (2) linear modelling to test combinations of variables and interactions. Linear modelling was conducted using R analysis software (version 1.3.1; *http://www.r-project.org*). Date (days subsequent to May 1), distance and depth were used as response variables. For each, model selection was based upon a fully saturated model including the remaining two variables, as well as group category and site. All terms that were significant at the p=0.05 level were included in the final model.

RESULTS

ANOVA

Spatial distribution

The distributions of whales with respect to both depth and distance from shore were related to the topographic characteristics of each study site (Fig. 3). Off Puerto Cayo, groups were found mainly between 2.5 and 10km offshore in waters of 10-25m in depth. Off Puerto López, groups were more spread out and on average further away from the coast, with most sightings being recorded between 8 and 15km offshore in waters 30-50m deep. Near La Plata Island, around 50% of groups were found within 5km of shore, in waters of 25-40m in depth. Except for one sighting (1.5%) made in waters deeper than 60m, the remaining groups were found up to 17km from shore, in waters of 30-50m in depth. In Salinas, there was also a concentration of sightings within 5km of shore in waters of 20-50m in depth. As with the other sites, water depths at which sightings were made did not increase with distance from shore, and remained between 30 and 60m. Thus despite the narrow shelf off Salinas, only 7 sightings (4.3%) occurred in waters deeper than 60m.

Mean sighting distances to shore varied from 5.31km in Salinas to 10.16km in Puerto Cayo, with moderate values for Puerto López and La Plata Island (Table 3). Sighting distances were significantly different between study sites (ANOVA, $F_{3,318}$=11.08, p<0.01). Sighting depths were more uniform, with similar values for Puerto López, La Plata Island and Salinas (mean 36-39.03m), but significantly lower off Puerto Cayo (19.49m) (ANOVA, $F_{3,318}$=33.47, p<0.01) (Table 3).

Table 3

Comparison of the average values regarding the distance to the shore and depth of the sightings in each study site (n = 322).

	Distance to shore (km)			Depth (m)			
Site	Mean	SD	Range	Mean	SD	Range	*n*
Puerto López	8.05	4.34	0.1-19.7	36	11.45	15-50	43
Puerto Cayo	10.16	4.17	1.2-20.5	19.43	6.7	10-41	51
La Plata Is.	7.04	5.16	0.1-17.1	36.65	10.99	5-56	65
Salinas	5.31	3.1	0.1-14.2	39.03	15.16	10-104	163

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[1] Instituto Oceanográfico de la Armada de Ecuador INOCAR (Oceanographic Institute of the Navy).

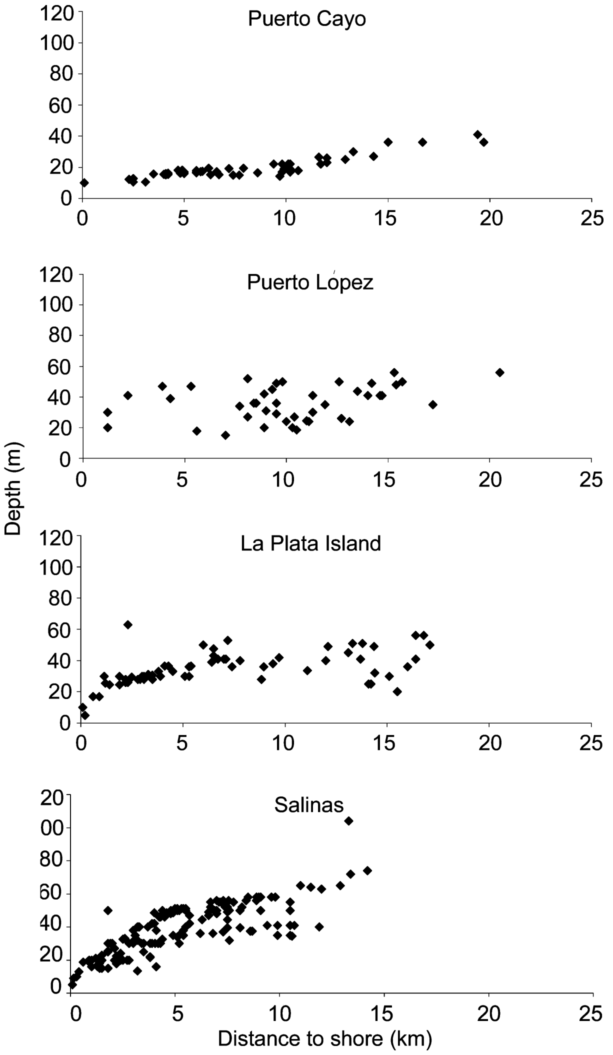

Fig. 3. Distribution of humpback whale groups with respect to their distance from shore and depth at each study site.

Temporal distribution

The monthly distribution of whale groups is shown in Fig. 4. As shown in Table 4, the average distance to the shore increased during the season (but not significantly) from 6.2km in June to 7.17km in September (ANOVA $F_{3,315}$=0.2, p>0.05).

In June, sightings showed a bimodal distribution with respect to distance from shore, with concentrations within 2-5km and 8-11km from shore in waters of 20-60m in depth. In July and August, however, sightings were concentrated within 5km of shore followed by a decrease in numbers with distance. Water depth increased up to 5km offshore and thereafter it maintained a relatively constant level between 20 and 60m. By September, the distribution was again bimodal with one area of concentration in shallow waters of 20m or less extending up to 14km offshore and another one in deeper waters (30-60m) starting at 6km offshore. As shown in Table 4, the average depth of the sightings was constant between June and August (average 35.13-36.60m) but in September decreased significantly by 25% (ANOVA, $F_{3,315}$=6.37, p<0.01).

The apparent contradiction of a higher average sighting distance from shore with a significantly lower depth found in September seems to be the product of a sampling artifact, since in September both the sighting distance range and the depth range are smaller than in July and August (Table 4); because whales were less abundant by the end of the season in September, boats probably had to make longer trips, although these were not necessarily to further offshore.

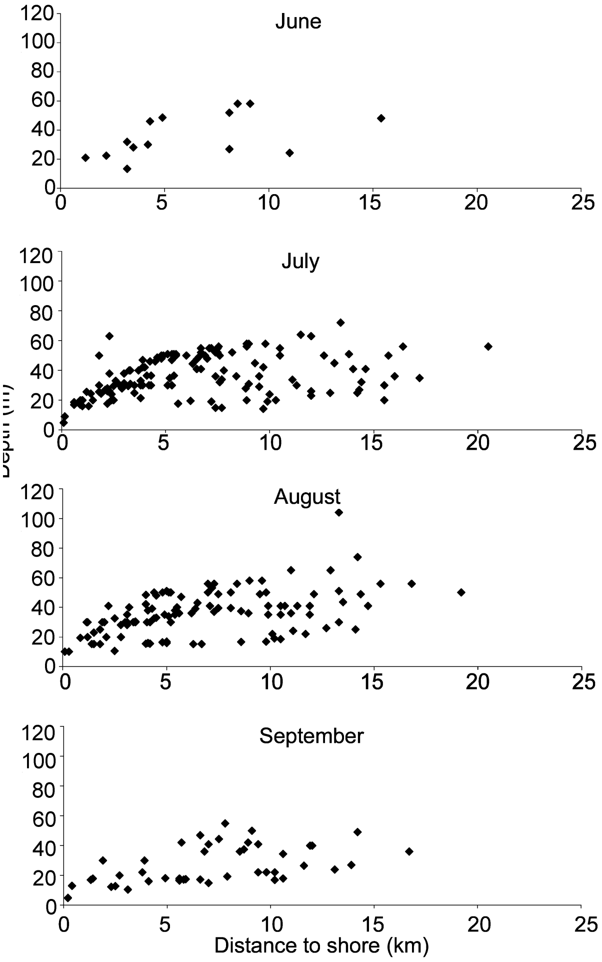

Fig. 4. Monthly distribution of humpback whale groups with respect to their distance from shore and depth.

Table 4

Comparison of the average sighting distance to the shore and depth by month (period 1996-2003) (n = 319).

	Distance to shore (km)			Depth (m)			
Month	Mean	SD	Range	Mean	SD	Range	n
Jun.	6.2	3.9	1.2-15.4	36.33	14.88	13.3-52	14
Jul.	6.54	4.28	0.1-20.5	36.60	13.65	5-72	141
Aug.	6.68	4.27	0.1-19.4	35.13	15.48	10-104	119
Sept.	7.17	3.39	0.2-16.7	26.93	12.59	5-55	45

Age class distribution

Only those groups for which an age class was assigned to every member were considered for analysis (196 out of 322 or 61%) and distribution by age is shown in Fig. 5. A and AS groups showed similar distribution patterns despite A groups being almost three times as abundant as AS groups. These classes were found on average between 7 and 8km offshore in waters of 36m in depth (Table 5). In contrast, S and MC groups showed a more coastal, shallower distribution with an average distance to shore of 5km in waters of 23-28m in depth. Although sightings of S groups were not as abundant as for other classes, the data suggest segregation of subadults toward the edges of the area used by A and AS groups. For MC groups, segregation toward coastal areas is evident. The comparison among the four age class categories shows a highly significant difference between distances from shore (ANOVA, $F_{3,192}$=5.93, $p<0.01$), as well as water depth (ANOVA, $F_{3,192}$=12.51, $p<0.01$). Separate analyses of sighting depths of A and AS groups compared to S and MC groups were performed, and showed that in both cases the difference was significant for S groups (ANOVA, $F_{2,161}$= 4.27, $p<0.05$) and highly significant for MC groups ($F_{2,180}$=18.26, $p<0.01$).

Table 5

Comparison of the average sighting distance to shore and depth by age/class groups (*n*=196).

Age/class group	Distance to shore (km)			Depth (m)			
	Mean	SD	Range	Mean	SD	Range	*n*
A	7.1	4.47	0.1-20.5	35.94	14.59	10-104	110
AS	7.88	4.39	1-19.4	36.78	14.2	15.2-72	41
S	5.1	3.88	0.1-10.6	28.48	18.15	5-56	13
MC	4.8	3.53	0.2-13.1	22.73	11.78	5-44.5	32

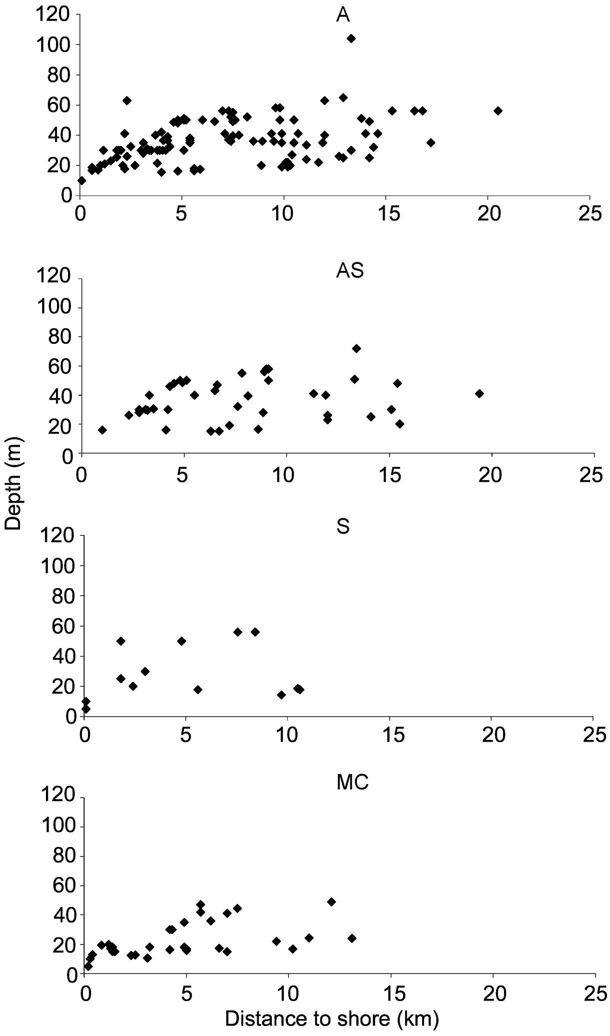

Fig. 5. Distribution of humpback whale groups with respect to their distance from shore and depth by age-class groups.

Linear modelling analyses

In addition to ANOVA, linear modelling was conducted to examine the relationships between the temporal, spatial and age variables detailed earlier. The date of the sighting showed significant relationships with site, depth and age class (*F*=6.6, *F*=9.1 and *F*=14.67 respectively, $p<0.01$), but not with distance from shore. Similar results were obtained using ANOVA (see above). Distance from shore showed significant relationships with respect to both site and depth (*F*=25 and *F*=126.9 respectively, $p<0.01$), but not with age class and this conflicts with the ANOVA results. A significant relationship (*F*=7.5, $p<0.01$) between site and depth was revealed, and also between site and distance from shore (*F*=17.12, $p<0.01$) reflecting the different topographies of the areas. Depth was significantly related to site (*F*=37.2, $p<0.01$), distance (*F*=146.5, $p<0.01$) and age class (*F*=3.14, p=0.026).

The modelling showed no relationship with distance from shore and age class when site and depth were taken into account. This suggests that depth (or a factor related to depth) is a more important determinant of differences in distribution between the different age classes than proximity to shore, and that the relationship between age class and distance observed using ANOVA may be in part an artifact of the correlation between depth and distance from shore.

DISCUSSION

Despite the different topography of the four study sites, the humpback whales appeared to maintain a common pattern of distribution in waters of 20-60m in depth. Only eight sightings (2.5%) were found in waters deeper than 60m. This was confirmed by both data analyses presented here which indicated that depth is the critical factor in determining distribution in breeding areas off the Ecudorian coast. Irrespective of topography whales remained most abundant in waters between 20 and 60m in depth. Due to this preference for shallow waters, the population densities in these sites are correlated to the width of the adjacent continental shelf; higher in places with narrow shelves (e.g. Salinas and La Plata Island) and lower where the shelf is wider (e.g. Puerto Lopéz). For Salinas, as the peninsula projects 15km westward, the corridor narrows to just 10 kilometres in width. Similar funnels can also be found in other parts off the north Ecuadorian coast.

Our data are insufficient to determine the offshore distribution of humpback whales, since they were collected aboard whalewatching boats whose operations were limited to coastal areas. However, as noted in the Introduction the limited records available for Ecuador indicate that humpback whales are uncommon offshore. Clarke *et al.* (2002), who followed a relatively coastal course along the meridian 81°10’W, only recorded humpback whales along the coasts at Salinas (2°10’S) and Manta (1°S). Sightings in 1959 by Clarke (1962) 50 n.miles west of southern Ecuador contrasted with the coastal findings in the central and north records of other expeditions, but were concordant with whaling records and sightings from the north of Peru by Ramírez (1988) and by the NOAA surveys (Fig. 1). It seems that humpback whales are more widely distributed in the north (and perhaps south) of Peru. Although the migratory route of humpbacks in the Southeast Pacific is unknown, Clarke (1962) suggested that it must be off the coast of Chile and Peru to avoid the cold waters of the Humboldt Current running northward along the west South American coast. When the Humboldt Current reaches the northern part of Peru and meets the warmer southerly current at the Equatorial Front[2] around 5°S, it turns westward and joins with the South Equatorial Current in the Galapagos Islands

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[2] The Equatorial Front is a transition zone between warm and low saline southward waters from the Panama bright and the subtropical colder and more saline waters from the Humboldt Current extending westward.

(Cucalón, 1996). Since whales are abundant in the coastal waters within the Gulf of Guayaquil, southwest of Ecuador (see Fig 1), this suggests that the north of Peru (4°-6°S) is where humpback whales from the south begin the transition from oceanic deep-water to a coastal tropical breeding environment. In fact, it may be that the Equatorial Front is the feature that causes the humpback whales to move towards the coast. This may also explain the absence of offshore records between 2°S (central-south of Ecuador) and 4°N (central Colombia). When leaving the breeding area, whales may be expected to follow a similar pattern but in the opposite direction, except when oceanographic events such as El Niño occur. These seem to influence the distribution of humpback whales in this part of the migratory route because of southward displacement of the Equatorial Front (Félix and Haase, 2001b).

Humpback whales show temporal variation in migration related to their reproductive condition and physical maturity (Dawbin, 1966). This is reflected in sighting distributions along the coast of Ecuador in September, when, for example mothers nurse calves in shallow waters (Félix and Haase, 1997; 2001a). Preference for shallow waters and sheltered places is typical for this species and has also been observed in other breeding areas such as Hawaii (Smultea, 1994), the Caribbean (Scott and Winn, 1979; Whitehead and Moore, 1982), Australia (Vang, 2002) and Madagascar (Ersts and Rosenbaum, 2003).

Our data reveal a segregation of singleton subadults toward the edge of the A and AS group distributions. Félix and Haase (1997) noted a concentration of singleton subadults in shallow waters, but the larger series of data presented here shows that they also distribute in deeper waters. Although the sex of these animals is unknown, it is possible that this type of segregation occurs mainly in immature males, who do not participate in the reproduction cycle. Although such segregation of immature individuals is frequently seen in odontocetes (e.g. Wells *et al.*, 1980; Caldwell *et al.*, 1966), it has not previously been reported for humpback whales. However, Scott and Winn (1979) reported a different distribution pattern for immature individuals breeding in the Caribbean. They found a cluster distribution at Silver Bank, and a more uniform distribution at Navidad Bank, attributing this difference, among other reasons, to the presence of a large number of non-calling whales, especially immature animals, at Silver Bank.

Management implications

Knowledge of the explanatory variables affecting humpback whale distribution during the breeding season in Ecuadorian waters can be valuable for the conservation of this population at both local and regional levels. If humpbacks distribute in the northern part of the country in the same way as they do in central and southern parts, it may be possible to predict their distribution along the entire coast of Ecuador, and possibly in the rest of the breeding area further north. Using this analysis as a baseline for whale distribution during the breeding season, will hep in developing measures to reduce potentially harmful interactions with human activities.

Incidental catches in fishing gear

The bycatch of small and large cetaceans in artisanal gillnets is a problem that has been known of for more than a decade in Ecuador (Félix and Samaniego, 1994; Haase and Félix, 1994; Félix *et al.*, 1997; Alava *et al.*, 2002) but it has received little attention from local authorities. The problem has worsened because the artisanal fishing effort doubled over 10 years (Campbell *et al.*, 1991; Ormaza and Ochoa, 1999). The lack of population studies on the distribution, abundance and other ecological parameters of cetaceans makes evaluation and management of the problem difficult. However, bycatch of humpback whales in fishing gear has been identified as their main non-natural mortality along the Colombian coast (Capella *et al.*, 2001) and it is possible that the current level of bycatch in the breeding grounds may affect the recovery of this population.

There have been no studies comparing the distribution of artisanal fishing areas with whale distribution since information on artisanal fishing effort is sparse given the informal nature of the fishery. Most of the studies that are conducted are socio-economic assessments and focus on censuses of boats and fishing gear at port (Ormaza and Ochoa, 1999). Artisanal fishermen do not usually use navigation instruments, charts or GPS devices; rather, details of fishing sites are passed on to the next generation of fishermen by word-of-mouth. To establish effective management measures, it is necessary to identify fishing areas and determine under which conditions interactions with humpback whales and other cetaceans take place.

In order to reduce conflicts with fishing activities we recommend the following:

(1) comprehensive documentation of the locations, areas and times of operation of the fishing areas used by artisanal fishing fleets;
(2) a reduction in the fishing effort using gillnets in areas associated with high population densities of humpback whales, either through closures during the breeding season or by use of alternative fishing gear (e.g. long lines);
(3) evaluation of the use of acoustic devices attached to gillnets[3].

Whalewatching

The present study also has implications for the management of whalewatching. The data presented allow the prediction of sites on the Ecuadorian coast where whales may congregate, and thus where new commercial operations may be established and where protection of important calving and nursery areas should occur. Although whalewatching has become one of the most popular activities on the coast of Ecuador, and is helping to promote other ecotourism activities in an area where traditionally natural resources were previously exploited only consumptively, it is important that it is properly regulated.

Other activities

The information presented here also has implications for other activities currently implemented or planned for the country including: (1) maritime traffic – commercial routes pass through the near coastal waters off Salinas and around La Plata Island that have been shown to support a high population density of whales; (2) military manoeuvres – UNITAS, operates every year off the coast of Ecuador during the humpback whale breeding season; (3) seismic prospecting and offshore oil-drilling – carried out in the Gulf of Guayaquil, an area identified as part of the whale migration corridor; (4) mariculture farms, planned in central and southern parts (La Plata Island and Santa Clara Island) to raise tuna; and (5) marinas and artisanal ports. Future environmental studies for these activities must take into

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[3] This technology has been shown to reduce humpback whale bycatch in other regions by either alerting them to the presence of nets, or detering them from the area (Todd *et al.*, 1992).

account the use of coastal areas by humpback whales, and their impact on the species. This has not been the case for previous studies.

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Appendix Table 1

Sightings of humpback whales recorded in coastal and offshore waters of Ecuador, north of Peru, south of Colombia and around Galapagos Islands, during marine mammal surveys between 1959 and 2003.

Number	Date	Position	Group size	Reference
1	9 Oct 1959	2º37’S, 81º51’W	7	Clarke (1962)
2	1 Nov 1987	4º6’N, 81º39’W	2	Holt and Jackson (1987)
3	20 Sep 1988	1º6’N, 79º50´W	2	Lyrholm *et al.* (1989)
4	20 Sep 1988	1º4’N, 79º44’W	3	Lyrholm *et al.* (1989)
5	21 Sep 1988	0º12’N, 80º11’W	1	Lyrholm *et al.* (1989)
6	21 Sep 1988	0º11’N, 80º11’W	2	Lyrholm *et al.* (1989)
7	21 Sep 1988	0º11’N, 80º11’W	3	Lyrholm *et al.* (1989)
8	21 Sep 1988	0º1’N, 80º14’W	4	Lyrholm *et al.* (1989)
9	22 Sep 1988	1º19’S, 80º56’W	1	Lyrholm *et al.* (1989)
10	22 Sep 1988	1º19’S, 80º56’W	2	Lyrholm *et al.* (1989)
11	22 Sep 1988	1º23’S, 81º7’W	3	Lyrholm *et al.* (1989)
12	3 Oct 1989	2°11.65’S, 80°54.63’W	2	Hill *et al.* (1990)
13	6 Oct 1989	3°1.45’S, 83°21.60’W	1	Hill *et al.* (1990)
14	23 Sep 1990	1°49.12’S, 89°14.84’W	1	Hill *et al.* (1991)
15	31 Oct 1990	4°17.63’S, 82°25.74’W	2	Hill *et al.* (1991)
16	31 Oct 1990	4°45.90’S, 82°35.76’W	4	Hill *et al.* (1991)
17	31 Oct 1990	4°1.73’S, 82°21.41’W	1	Hill *et al.* (1991)
18	7 Oct 1992	3°30.80’N, 79°30.98’W	3	Mangels and Gerrodette (1994)
19	25 Oct 1992	3°24.41’N, 77°36.75’W	2	Mangels and Gerrodette (1994)
20	25 Oct 1992	3°30.23’N, 77°30.71’W	2	Mangels and Gerrodette (1994)
21	25 Oct 1992	3°23.01’N, 77°38.29’W	2	Mangels and Gerrodette (1994)
22	25 Oct 1992	2°58.93’N, 78°1.43’W	1	Mangels and Gerrodette (1994)
23	26 Oct 1992	2°50.61’N, 78°16.22’W	5	Mangels and Gerrodette (1994)
24	26 Oct 1992	2°52.96’N, 78°20.01’W	2	Mangels and Gerrodette (1994)
25	26 Oct 1992	2°53.45’N, 78°3.70’W	2	Mangels and Gerrodette (1994)
26	26 Oct 1992	2°25.94’N, 78°39.62’W	2	Mangels and Gerrodette (1994)
27	27 Oct 1992	2°18.67’N, 78°45.15’W	1	Mangels and Gerrodette (1994)
28	7 Nov 1998	1°0.10’S, 90°53.56’W	2	Kinzey *et al.* (1999)
29	10 Nov 1998	2°30.86’S, 83°1.83’W	1	Kinzey *et al.* (1999)
30	29 Nov 1998	4°18.57’S, 82°20.30’W	1	Kinzey *et al.* (1999)
31	3 Nov 2000	6°39.05’S, 80°49.26’W	3	Kinzey *et al.* (2001)
32	4 Nov 2000	3°44.85’S, 81°0.30’W	1	Kinzey *et al.* (2001)
33	4 Nov 2000	4°20.46’S, 81°24.14’W	1	Kinzey *et al.* (2001)
34	10 Nov 2000	3°4.92’N, 77°56.38’W	2	Kinzey *et al.* (2001)
35	18 Sep 2001	1º59.95’S, 81º9.35’W	3	Clarke *et al.* (2002)
36	18 Sep 2001	0º55.01’S, 80º48.77’W	1	Clarke *et al.* (2002)
37	19 Sep 2001	0º55.52’S, 80º43’13’W	2	Clarke *et al.* (2002)
38	5 Nov 2003	6°13.95’S, 81°10.90’W	4	NOAA database
39	5 Nov 2003	6°22.21’S, 81°7.40’W	4	NOAA database
40	5 Nov 2003	6°24.51’S, 81°10.37’W	2	NOAA database
41	5 Nov 2003	6°24.75’S, 81°10.60’W	6	NOAA database
42	5 Nov 2003	5°41.60’S, 81°17.40’W	2	NOAA database
43	6 Nov 2003	3°43.39’S, 81°17.66’W	1	NOAA database
44	6 Nov 2003	3°50.60’S, 81°19.72’W	2	NOAA database
45	7 Nov 2003	1°6.87’S, 81°3.51’W	2	NOAA database
46	7 Nov 2003	1°16.42’S, 81°2.46’W	1	NOAA database
47	7 Nov 2003	1°45.90’S, 80°58.70’W	2	NOAA database
48	8 Nov 2003	0°24.03’N, 80°13.69’W	3	NOAA database
49	8 Nov 2003	0°9.98’N, 80°18.32’W	2	NOAA database

Appendix Table 2

Sightings of humpback whales at Santa Clara Island, south of Ecuador (from Yturralde and Suárez, 1998).

Date	Position	Group size	Depth (m)	Distance to shore (km)
1 Jul 1998	3°5.6’S, 80°25.1’W	??	55	18
1 Jul 1998	3°5.7’S, 80°27.7’W	2	67	22.8
2 Jul 1998	3°1’S, 80°25’W	2	12	15
2 Jul 1998	3°4.3’S, 80°22.6’W	1	60	13.8
2 Jul 1998	3°4.1’S, 80°23.1’W	2	50	14.4
2 Jul 1998	3°5.7’S, 80°28.2’W	1	55	21
3 Jul 1998	3°5.9’S,80°21.6’W	2	50	15
3 Jul 1998	3°5.9’S,80°21.6’W	2	50	15
3 Jul 1998	3°5.9’S,80°21.6’W	>2	50	15
3 Jul 1998	3°6.2’S, 80°24.9’W	1	52.5	18
3 Jul 1998	3°6.2’S, 80°25.6’W	4	76	22.2
3 Jul 1998	3°6.3’S, 80°27.1’W	1	76	25.2
3 Jul 1998	3°3.6’S, 80°29.3’W	>1??	58	24.6
3 Jul 1998	3°2.9’S, 80°28.7’W	4??	50	22.8
3 Jul 1998	3°1.5’S, 80°27.5’W	1	40	19.2
3 Jul 1998	3°S, 80°32’W	2	50	30
3 Jul 1998	3°1.7’S, 80°33.1’W	4	62	31.8
3 Jul 1998	3°2.1’S, 80°33.7’W	1	60	31.2
4 Jul 1998	3°3.8S, 80°34.1’W	2	60	33.6
4 Jul 1998	3°6.8’S, 80°30.8’W	1	60	31.2
4 Jul 1998	3°7.’S, 80.31’W	3	69	31.8
4 Jul 1998	3°8.6’S, 80°29.6’W	1	50	29.4
4 Jul 1998	3°9.3’S, 80°29.1’W	1	40	30
4 Jul 1998	3°9.5’S, 80°28.9’W	??	40	30
4 Jul 1998	3°9.9’S, 80°28.6’W	1	30	27
4 Jul 1998	3°10.3’S, 80°28.3’W	2	30	27
4 Jul 1998	3°10.5’S, 80°28.2’W	2??	30	26.4
4 Jul 1998	3°10.8’S, 80°28’W	1	20	27.6
4 Jul 1998	3°12.2’S, 80°28’W	2	15	30
4 Jul 1998	3°13’S, 80°28.5’W	1	10	30.6
4 Jul 1998	3°13’S, 80°28.5’W	1	10	30.6
4 Jul 1998	3°14.9’S, 80°28.8’W	1	30	30.6
4 Jul 1998	3°11.2’S, 80°27.7’W	1	20	28.2
5 Jul 1998	3°9’S, 80°38’W	4	63	41.4
5 Jul 1998	2°59’S, 80°32’W	4	41	29.4