

Blue whale (*Balaenoptera musculus*) occurrence off the Galápagos Islands, 1978-1995

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ABSTRACT

Twenty-three blue whale (*Balaenoptera musculus*) sightings made in the vicinity of the Galápagos Islands (~00°S, 90°W) between 1978-1995 are analysed. Blue whales occurred seasonally in the austral winter/spring months. A significant proportion of the sightings (13 or 56.5%) had a tendency to occur on the same day or on consecutive days in a given year. Five (21.7%) of the sightings were of groups of three or more individuals. Distribution was to the west and southwest of the Galápagos archipelago, where a plume of cool, upwelling-enriched surface water with high planktonic biomass develops during this season. Blue whales were observed feeding on surface swarms of the euphausiid *Nyctiphanes simplex* in 1993. Defecation was commonly seen. The external appearance of these whales suggests they were true blue whales (*B.m. intermedia*). Much of the evidence from this study suggests a Southern Hemisphere stock feeding west of the Galápagos during the austral winter/spring months. Alternatively, they may belong to a presumed eastern tropical Pacific stock of blue whales which exploits the productive habitats of the Costa Rica Dome and the Peruvian/Ecuadorian coast.

KEYWORDS: BLUE WHALE; PACIFIC OCEAN; SOUTH AMERICA; SANCTUARIES; OCEANOGRAPHY; SURVEY - VESSEL; INCIDENTAL SIGHTINGS; PHOTO-ID; FEEDING; EUPHAUSIIDS; HABITAT; FEEDING GROUNDS; MOVEMENTS

INTRODUCTION

All major blue whale (*Balaenoptera musculus*) populations were severely depleted by whaling operations which lasted until 1966, when they were afforded full worldwide protection by the IWC (Yochem and Leatherwood, 1985; Klinowska, 1991). In spite of this measure, and taking into account the difficulties in estimating abundance and trends in severely depleted species, their global numbers still appear to be depressed except for a stock inhabiting the eastern North Pacific from California to Baja California, whose numbers appear to be increasing (Baskin, 1993; Barlow, 1994; Barlow *et al.*, 1995; Clapham *et al.*, 1999). Hence, observations from areas where their presence is less well known are valuable in understanding their current distribution and status.

Information on blue whale occurrence in the general area of the Galápagos Islands can be summarised as follows. In 1975, a Soviet/American expedition to the eastern tropical Pacific (ETP) aboard the whaling vessel *Vnushitely* sighted aggregations of blue whales, twice in late March and once in mid-June, in a small area bounded by 08°55'N-09°07'N and 93°34'W-93°55'W (Berzin, 1978; also reported in Wade and Friedrichsen, 1979). Based on their 'behaviour and markings', Berzin (1978) identified them as pygmy blue whales (*B.m. brevicauda*), and assigned them to the 'Galapagos biostock' (a term he applied to cetacean populations presumably resident to the ETP that are characterised by their smaller body sizes). Perhaps this has led some authors (e.g. Yochem and Leatherwood, 1985; Klinowska, 1991) to state that these sightings were made 'near the Galápagos Islands', when in fact they were made in the vicinity of a productive oceanic eddy known as the Costa Rica Dome (~09°N, 89°W), some 1,100km north of the Galápagos Islands, where blue whales appear to be present year-round (Reilly and Thayer, 1990). A distinct

concentration of blue whale sightings, nonetheless, has been reported off the Galápagos Islands as well (Reilly and Thayer, 1990).

Unlike sperm whales (*Physeter macrocephalus*), blue whales apparently were never hunted off the Galápagos Islands. The only expedition in the modern whaling era to visit the Galápagos was the floating factory *Tioga* in 1912, but unfortunately the catch by that expedition has not been recorded (Risting, 1922; Clarke, 1962). The waters around the Galápagos Islands are now part of a Cetacean Sanctuary created by the Government of Ecuador in 1990, covering its entire 200 mile zone of control (Evans, 1991; Merlen, 1992).

This paper discusses 23 blue whale sightings from two sources, covering the years 1978 to 1995 and discusses the possible population affinities and sub-specific identity of the whales, their behaviour and their distribution off the Galápagos in relation to the local regime of oceanic biological production.

MATERIALS AND METHODS

Study area

The Galápagos Islands are an oceanic archipelago that straddles the equator between 01°40'N-01°25'S and 89°15'W-92°00'W. The nearest land, continental Ecuador (to whom they belong), is approximately 960km to the east. They are the product of 'hotspot activity' (ocean floor volcanism) and are formed by the emerging tips of submarine volcanoes that rise from the 40,000km² wide Galápagos Platform, at a depth of 1,300m (Jackson, 1993).

The local climate in the Galápagos reflects large-scale oceanographic and atmospheric conditions in the ETP. There are two main seasons: from about December to May there is a hot/wet period and from about July to October there is a cool/dry period, locally known as *garúa*. The region has a strong austral character and an unusually dry climate. This is

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because the Intertropical Convergence Zone is situated north of the equator in the ETP, leaving the islands under the regime of the southeast trade winds (Chavez and Brusca, 1991). The 'thermal' equator also lies north of the geographic equator in the ETP (Fiedler *et al.*, 1992). Sea surface temperature ranges from 16-28°C, depending on season and site (Jackson, 1993).

The Galápagos are located in a region where horizontal currents and their associated water masses are particularly dynamic. The main current systems affecting the islands are: (a) the cool westward surface South Equatorial Current which bathes the Galápagos region most of the year, fed by the Peru Current System and driven by the southeast trade winds; (b) the cool eastward subsurface Equatorial Undercurrent, which is 'trapped' along the equator and is modified significantly by the Galápagos when it collides with the westernmost islands, Fernandina and Isabela, causing local topographically-induced upwelling; and (c) the warm surface North Equatorial Countercurrent, which seasonally flows eastward north of the Galápagos. A rather abrupt boundary between the water masses in the North Equatorial Countercurrent and the South Equatorial Current is known as the Equatorial Front. The Equatorial Front has a marked seasonal variation, with displacements to the north and south. At the Galápagos, it is typically between the equator and 1°N (Chavez and Brusca, 1991). Upwelling, which occurs throughout the year but increases during the cold season, brings cool, nutrient-rich waters to the surface, creating the conditions for elevated biological production (Houvenaghel, 1978; 1984). A productive oceanic habitat extends seasonally several hundreds of kilometres downstream (west) of the Galápagos (Feldman, 1986).

These mean conditions are modified periodically by the El Niño phenomenon, which causes significant changes in circulation in the tropical Pacific, increased water temperatures, decreased productivity (e.g. Fiedler *et al.*, 1992) and has important 'negative' effects on the marine life of the islands (e.g. Robinson and del Pino, 1985; Trillmich and Limberger, 1985; Smith and Whitehead, 1993).

Data sources and collection

(a) SWFSC sightings database, 1975-1993

S.B. Reilly of the National Marine Fisheries Service, Southwest Fisheries Science Center (SWFSC, La Jolla, CA, USA), compiled a sightings database for the years 1975-1993. It comprises sightings made by scientific observers aboard US research and tuna vessels operating in the ETP, as well as sightings collected by Inter-American Tropical Tuna Commission (IATTC, La Jolla, CA, USA) scientific technicians aboard US and non-US commercial tuna vessels. Reilly and Thayer's (1990) study of blue whale distribution in the ETP was based on 211 sightings through 1988 from this database, of which seven were made near the Galápagos Islands. Further SWFSC ETP cruises through 1993 resulted in 11 additional sightings from the Galápagos area being added to this database (Table 1).

Because blue whale distribution in the ETP is highly clustered in four productive upwelling areas (the Costa Rica Dome, the coast of Baja California, the Galápagos Islands and the coasts of Ecuador and northern Peru), sightings for the Galápagos in the SWFSC database were easily separated visually from those for the other areas when plotted on a map (e.g. fig. 1 of Reilly and Thayer, 1990). A criterion used in assisting this selection was to only include those sightings made south of 5°N and west of 85°W. These seemingly arbitrary boundaries are useful for two reasons. First, they are at approximately the mid-point between the two other nearby centres of blue whale abundance: the Costa Rica Dome to the north and the South American coast to the east. Blue whale sightings relative to search effort decrease as one moves away from these three centres (e.g. fig. 3 in Reilly and Thayer, 1990). Second, these boundaries approximately correspond with natural areas of lower productivity separating the productive upwelling habitats (cf. Longhurst, 1998, p.281). Indeed, other cetacean species in the ETP have similar gaps in their distribution (e.g. Wade and Gerrodette, 1993; Dizon *et al.*, 1994) that mirror the productivity gradients. The computed search effort around the Galápagos area for the years 1975-1988 combined was at least 185km

Table 1
Blue whale (*Balaenoptera musculus*) sightings off the Galápagos Islands, 1978-1995.

Date and time	Position	Number of individuals	Distance to Galápagos centre (km)	Source and vessel
9 Apr. 1978, 0701hrs	01°23'S, 93°40'W	1	362.2	SWFSC, tuna vessel
6 Oct. 1980	00°35'N, 92°37'W	6	264.2	SWFSC, tuna vessel
15 Jun. 1981, 0850hrs	02°05'S, 94°13'W	3	445.2	SWFSC, RV <i>Oceanographer</i>
15 Jun. 1981, 0912hrs	02°06'S, 94°09'W	1	439	SWFSC, RV <i>Oceanographer</i>
15 Jun. 1981, 0927hrs	02°06'S, 94°06'W	2	433.8	SWFSC, RV <i>Oceanographer</i>
15 Jun. 1981	02°05'S, 94°12'W	2	443.2	SWFSC, tuna vessel
21 Sep. 1981	02°27'S, 93°18'W	1	374.8	SWFSC, tuna vessel
19 Sep. 1986, 1616hrs	01°32'N, 101°32'W	2	1,244.6	SWFSC, RV <i>D.S. Jordan</i>
20 Sep. 1987	03°13'N, 106°06'W	1	1,780	SWFSC, tuna vessel
21 Oct. 1988, 1353hrs	02°52'S, 96°19'W	5	694.2	SWFSC, RV <i>McArthur</i>
24 Sep. 1989, 0826hrs	01°14'S, 91°19'W	2	117.5	SWFSC, RV <i>McArthur</i>
24 Sep. 1989, 0904hrs	01°16'S, 91°17'W	2	117.2	SWFSC, RV <i>McArthur</i>
20 Nov. 1989, 0739hrs	00°53'S, 109°28'W	2	2,105.8	SWFSC, RV <i>McArthur</i>
22 Sep. 1990, 1120hrs	01°48'S, 91°53'W	1	206.1	SWFSC, RV <i>McArthur</i>
22 Sep. 1990, 1340hrs	01°50'S, 91°32'W	1	182.2	SWFSC, RV <i>McArthur</i>
19 Oct. 1990, 1349hrs	03°38'S, 100°06'W	1	1,117.7	SWFSC, RV <i>McArthur</i>
21 Oct. 1990, 0847hrs	03°43'S, 95°39'W	2	670.4	SWFSC, RV <i>McArthur</i>
23 Oct. 1990, 1220hrs	09°07'S, 93°40'W	1	1,015.3	SWFSC, RV <i>McArthur</i>
15 Jun. 1993, 1550-1850hrs	01°10'S, 91°22'W	1	117.3	WCI, RV <i>Odyssey</i>
17 Aug. 1993, 0825-1800hrs	00°10'S, 91°41'W	6	133.9	WCI, RV <i>Odyssey</i>
18 Aug. 1993, 0900-1800hrs	00°02'S, 91°38'W	9	134.3	WCI, RV <i>Odyssey</i>
13 Sep. 1993, 1448-1800hrs	01°14'S, 91°40'W	1	148.6	WCI, RV <i>Odyssey</i>
Early Sep. 1995	01°11'S, 90°48'W	2	78.5	D. Day, pers. commn.

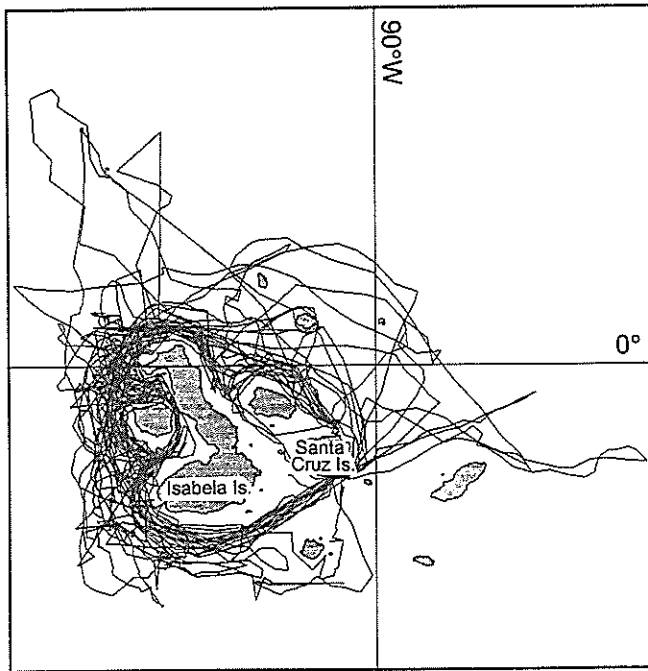


Fig. 1. Tracklines of 16 cruises off the Galapagos Islands, March 1993-March 1994, aboard R/V Odyssey.

per 1° latitude-longitude blocks (range: 185-1,850km). Search effort extended to 130°W, but was limited west of 100°W (see fig. 2 in Reilly and Thayer, 1990).

(b) WCI database

The second source of blue whale sightings is a database at the Whale Conservation Institute (WCI), Lincoln, MA, USA. This database consists of sightings made during 16 marine mammal cruises, conducted between March 1993 and March 1994 in waters of the Galapagos Islands, aboard the 28m ketch R/V *Odyssey* (Palacios, 1994). Fig. 1 shows the tracklines of the 16 cruises, which were spaced roughly at monthly intervals and searched mainly within the 'Galapagos Marine Reserve' [which is defined as the waters within 15 n.miles (28km) from a line joining the extremities of the islands (Comisión Permanente para las Islas Galapagos, 1992)]. One additional sighting, collected during a naturalist trip in early September 1995, was contributed by D. Day (*in litt.*, 18 January 1996), a WCI associate living in Puerto Ayora, Isla Santa Cruz, Islas Galapagos, Ecuador (Table 1).

Although topographically-induced upwelling occurs close to shore as a result of the Equatorial Undercurrent colliding with the steep slopes of the western islands, the westward flow of the South Equatorial Current carries this enriched water downstream of the Galapagos, creating a productive offshore habitat in water depths greater than 2,000m. Therefore, the great circle distance from each sighting (in both databases) to the centre of the Galapagos Islands [00°32'S, 90°31'W (Snell *et al.*, 1995)] was computed as a measure of the dispersion of the sightings about the archipelago (Table 1).

Whenever blue whales were sighted during the *Odyssey* cruises, the ship was diverted from its course to close on the animals and stay with them for as long as daylight conditions permitted. Behavioural data, identification photographs and

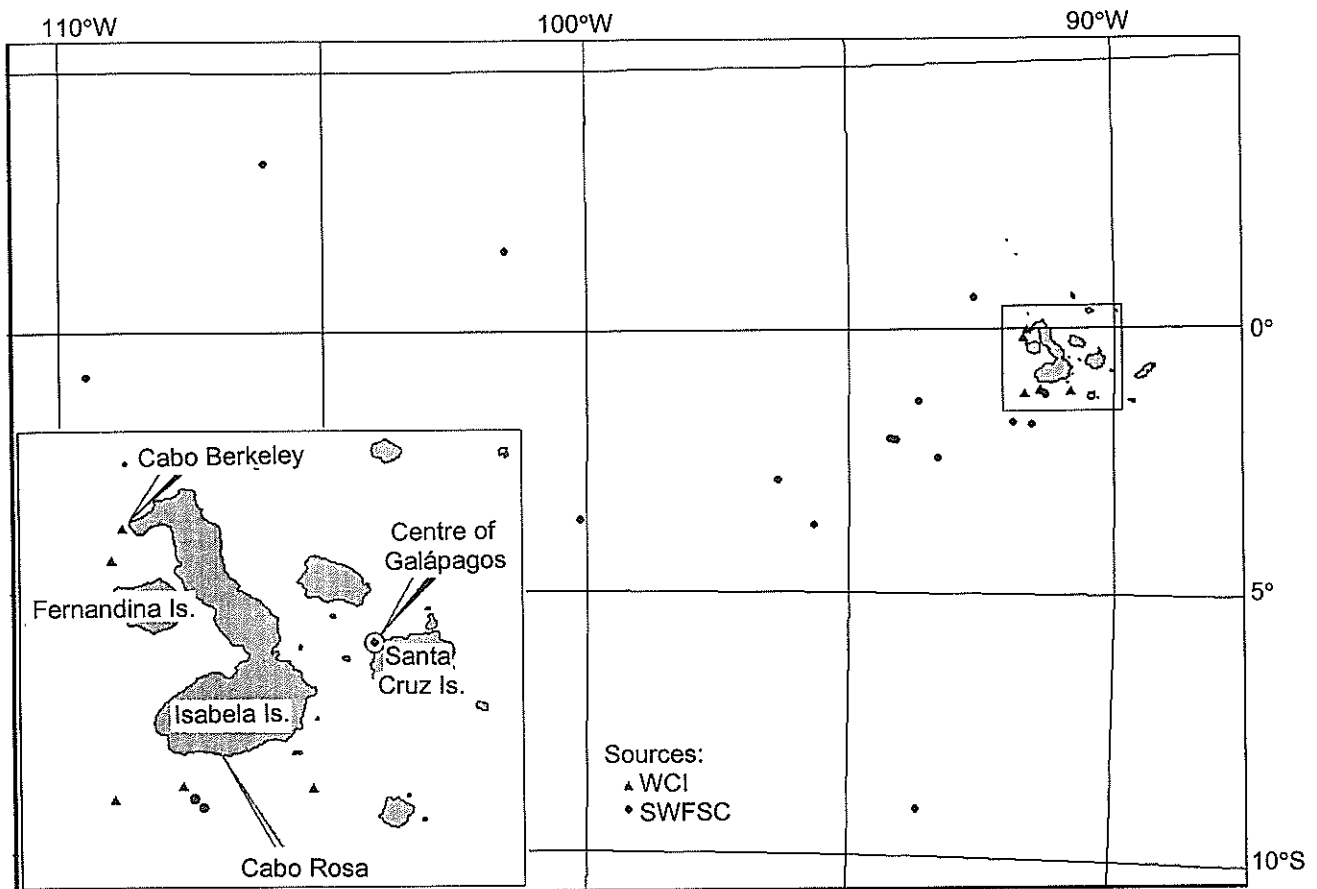


Fig. 2. Twenty-three blue whale sightings made off the Galapagos Islands, 1978-1995.

zooplankton samples were collected. Two skin biopsies from a presumed mother-calf pair were taken with biopsy darts for genetic studies (to be performed by T. Lyrholm, Department of Medical Genetics, Biomedical Center, Uppsala University, Stockholm, Sweden).

During one of these sightings (18 August 1993), a number of whales were observed dispersed over a large area. In order to estimate the number of whales present, the vessel was allowed to drift behind the whales, with the bow pointing towards them. Two observers conducted five-minute scans from a crow's nest on the main mast, 18m above the waterline, with 7.5X binoculars with a built-in compass. During each scan, observers gave the distance and the bearing of surfacing whales on either the port or the starboard bow to a third person who recorded this information. The scans were conducted over a two-hour period, with five-minute rest intervals between them. The maximum number of surfacings in each five-minute scan was averaged over the two-hour period to obtain an estimate of the total number of whales present in the area. A 'group' was defined as an aggregation of three or more animals within 100m of each other (but 'group size' could be as low as one individual, see below).

RESULTS

Seasonal and spatial distribution of the sightings

Eighteen blue whale sightings were included in the analysis after applying the above criterion to the SWFSC database. There were five sightings in the WCI database, for a total of 23 sightings involving 55 whales (Table 1). Except for one sighting on 9 April 1978, all sightings occurred in the austral winter and spring months (June through November). A significant proportion of the sightings (13 or 56.5%) had a tendency to occur on the same day or on consecutive days in a given year (4 sightings on 15 June 1981, 2 on 24 September 1989, 2 on 22 September 1990, 3 on 19-23 October 1990 and 2 on 17-18 August 1993).

Group size ranged from 1-6 animals. It was estimated that nine whales were present in the area during the sighting of 18 August 1993. The modal group size for all sightings was one, with single whales accounting for 43.5% (10) of the sightings. Pairs accounted for 34.8% (8 sightings) and groups of three or more accounted for 21.7% (5 sightings).

The spatial distribution of the sightings is presented in Fig. 2. All sightings were distributed on the western side of the Galápagos. Their distance to the centre of the archipelago ranged from 78.5-2,106km. The closest sighting to shore was made on 18 August 1993, 5.5km off Cabo Berkeley, Isabela Island. Seven of the sightings were made off the southern shore of Isabela Island. The four 1993 sightings collected aboard the R/V *Odyssey*, were made in water 2,000-3,500m deep with Beaufort sea states of 3-5. Sea surface temperature ranged from 16.7-20.9°C for these sightings.

Observations collected during the 1993 sightings aboard the R/V *Odyssey*

Physical appearance

Detailed data on the appearance and behaviour of the blue whales sighted from the R/V *Odyssey* in 1993 were collected and are summarised here. At least two pairs in the group of six individuals seen on 17 August consisted of large calves accompanied by adults (presumably their mothers, Fig. 3a);

all other animals appeared to be adults, but lengths were not estimated. Coloration and pigmentation patterns were quite variable among individuals, but in general they appeared light grey, sometimes with a purplish hue. The backs were silvery grey with darker mottling; the extent of the mottling varied from light to heavy. The heads were darker and 'chevron' patterns behind the blowhole demarcated the unmottled head from the mottled back.

The calf in one of the mother-calf pairs had several small remoras of an unidentified species on the head and the back. Sessile barnacles (probably *Xenobalanus globicipitis*) clung from the tip of the dorsal fin of this animal and from the trailing edge of the flukes of another individual. One of the whales seen on 17 August had what appeared to be 'white scarring' (*sensu* Sears *et al.*, 1990) along the apex of the back in front of the dorsal fin and on its right flank (Fig. 3b). The vertebral processes were apparent behind the dorsal fin of the single animal seen on 13 September, indicating some malnourishment.

Behaviour

The single animals seen on 15 June and 13 September tended to be wary of the approaching vessel and changed directions frequently. The six individuals seen on 17 August were mostly in pairs and allowed close approach. Identification photographs and skin biopsies of one of the mother-calf pairs were obtained; one of the calves approached the vessel on two occasions. The *Odyssey* remained in the area overnight and the next morning encountered blue whales not far from where they had been seen the previous day (see Table 1). It was apparent that the number of whales had increased and that they were dispersed over a larger area. They appeared to be travelling on a general southward heading and most animals swam singly or in pairs. Rather than attempting to approach them, five-minute scans were conducted as described in the Methods.

'Side-fluking' (swimming on one side and exposing one lobe of the flukes) was frequently observed at the surface during these sightings. 'Fluking-up' (raising the flukes completely out of the water as an animal makes a deeper dive) was also seen several times, and the whales usually defecated on these occasions, leaving a large brownish-orange discoloration in the water. Large swarms of a small crustacean of similar colour to the faeces were observed in the immediate vicinity of the whales. Samples were collected with a dip-net and were identified as the euphausiid *Nyctiphanes simplex* (now in the Planktonic Invertebrates Collection of the Scripps Institution of Oceanography, La Jolla, CA, USA, under accession number PIC-960515-0001).

Photo-identification

Photographs of the flanks of six animals were compared to a catalogue of over 1,070 individuals from the eastern North Pacific population, collected in their summering grounds off the United States (compiled by Cascadia Research Collective, Olympia, WA, USA). No matches were found between the Galápagos and the North Pacific blue whales from this catalogue (J. Calambokidis, pers. comm.). A document containing photographs of the six blue whales identified off the Galápagos in 1993 (Palacios, 1998) is deposited at the SWFSC's cetacean photo-identification database (under the care of J. Barlow).

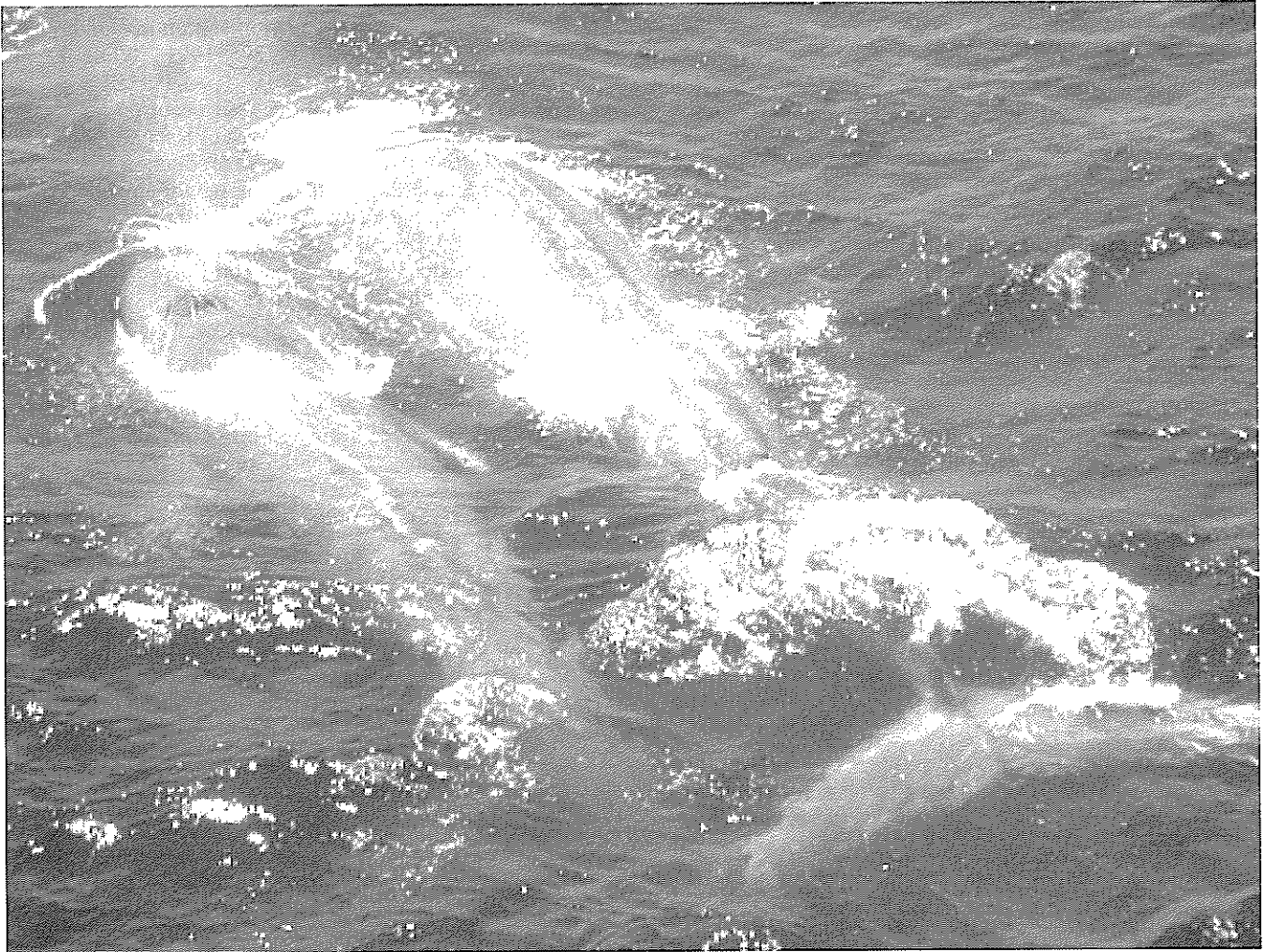


Fig. 3. (a) Mother-calf pair seen on 17 August 1993 north of Fernandina Island.

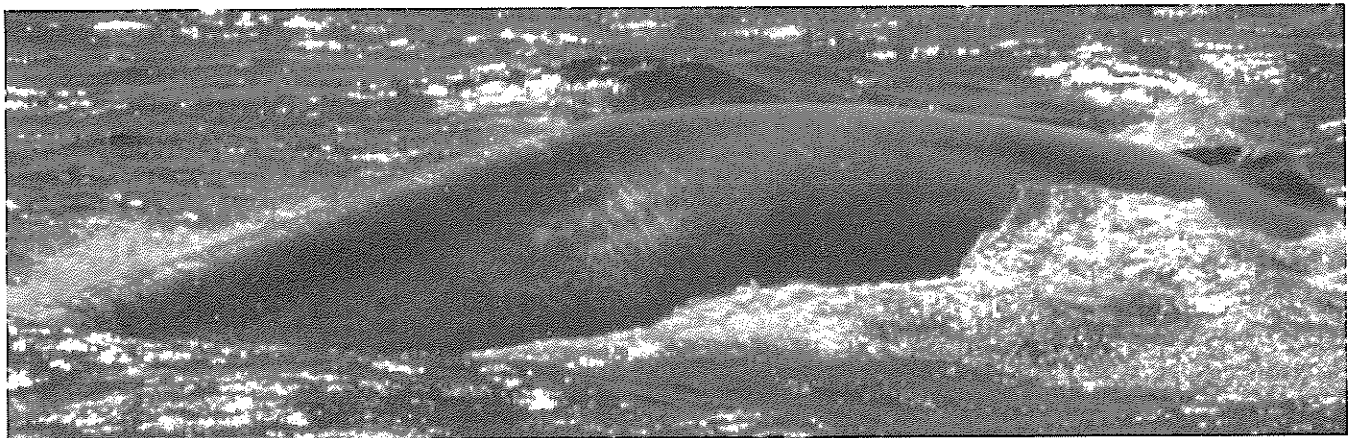


Fig. 3. (b) Presumed 'white-scarring' on the right flank and along the apex of the back of an individual seen on 17 August 1993.

DISCUSSION

Seasonality and distribution

The sightings showed a marked seasonality; all but one occurred during the austral winter and spring months. Although search effort was not uniform during the year (Reilly and Thayer, 1990; Palacios, 1994), the lack of blue whale sightings in the reports of several other researchers that have recorded cetacean presence off the Galápagos at other times of the year constitute additional evidence of seasonality (Clarke, 1962; Norris, 1967; Balridge, 1968; Whitehead, 1986; Le Boeuf *et al.*, 1988; Lyrholm *et al.*, 1992). For example, no blue whales were seen in 3,975

daylight hours of searching for and studying whales off the Galápagos between 1985-1995 during the months of January-June by a research team from Dalhousie University, Canada (H. Whitehead, pers. comm.).

The tendency for the sightings to occur on the same day or on consecutive days in a given year suggests that blue whales congregate off the Galápagos. This is supported by the relatively large fraction of groups (5 of 23) with three or more whales, as was found in Reilly and Thayer's (1990) study. This is similar to Berzin's (1978) and Wade and Friedrichsen's (1979) observations of blue whale aggregations in the Costa Rica Dome area during the first part of the year.

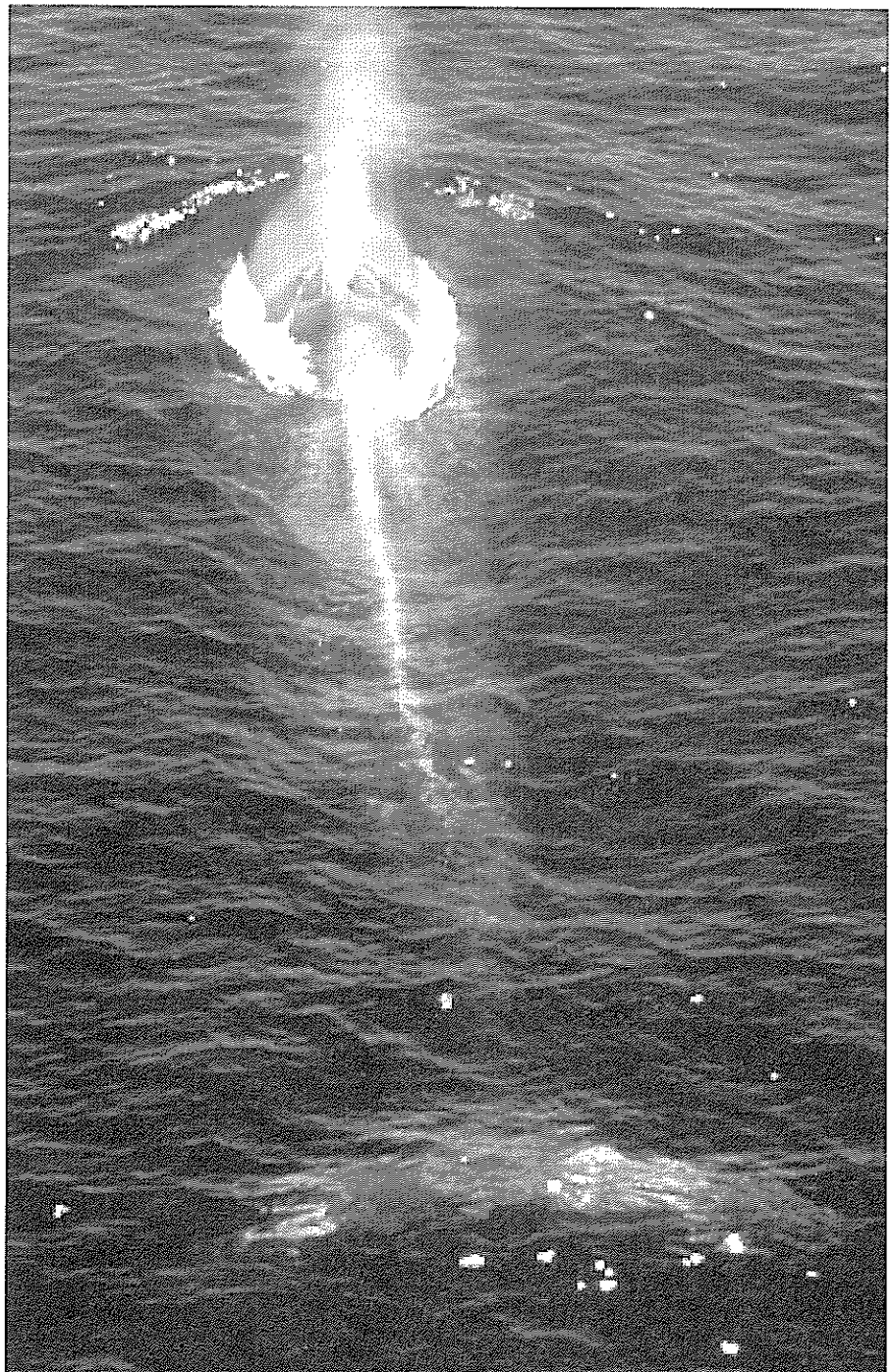
The area of blue whale occupation in the Galápagos extends from a few kilometres off the islands to at least 2,000km offshore, mostly west and southwest of the islands of Isabela and Fernandina (Table 1, Fig. 2). As a result of upwelling to the west of these islands and the increased westward flow of the South Equatorial Current during the austral winter/spring months, a productive habitat, clearly visible in satellite images as a plume of high phytoplankton biomass extending for hundreds of kilometres, develops seasonally downstream (west) of the Galápagos (Feldman, 1986). This distinct portion of the ocean has been termed the 'Pacific Equatorial Divergence Province' by Longhurst (1998). Several of the offshore sightings occurred near the south and north (poleward) edges of the productive plume. This distribution may be associated with the banded distribution of the equatorial zooplankton community (and that of euphausiids in particular) parallel to the plume of maximum phytoplankton biomass, with higher trophic levels

being further away from the phytoplankton maximum (e.g. Vinogradov, 1981; Mackas *et al.*, 1991; White *et al.*, 1995).

The fact that several sightings also occurred near shore (including those off the southern coast of Isabela), in the core area of upwelling [where biological production has not yet developed because the nutrient-rich, newly upwelled water has not been organically conditioned (Barber and Ryther, 1969; Houvenaghel, 1978; 1984)], is perhaps related to the reproductive activity of the euphausiid *Nyctiphanes simplex* (on which the blue whales were feeding, as discussed below). This species requires the cooler waters found near centres of upwelling for breeding (Brinton, 1979; Gómez-Gutiérrez *et al.*, 1995).

It is interesting to note that blue whales had not been reported locally, either from sightings (Day, 1994) or from strandings (Palacios, 1995), prior to the 1993 observations aboard the R/V *Odyssey*, despite regular tourist vessel

Fig. 4. (a)-(d) Several aspects of the external appearance of the blue whales from multiple sightings during 1993. Presumably these are true blue whales. Notice the small remoras on the head of the animal on the left (photographs (a)-(b) by D. Day, (c) by L. Leonhardt and (d) by the author).



operation in some of these localities and the presence of experienced observers in the Galápagos for over 25 years (D. Day, G. Merlen and T. de Roy, pers. comm.). This is probably because the main blue whale aggregations appear to be well offshore. Since then, local incidental blue whale sightings have been reported by other sources: two blue whales were seen southeast of Cabo Rosa, Isabela Island, in early September 1995 (H.M. Snell, pers. comm.). Merlen (1998) also recorded a blue whale south of Fernandina Island in 1997.

Feeding observations

Based on the distribution of blue whale sightings in four productive areas of the eastern tropical Pacific (the Baja California and the Peruvian/Ecuadorian coasts, the Costa

Rica Dome and the Galápagos Islands), Reilly and Thayer (1990) hypothesised that blue whales may select habitats which permit foraging while in their low latitude grounds. These habitats are all characterised by coastal or equatorial upwelling and high standing stocks of euphausiids. The side-fluking behaviour, defecation and dip-netted samples during the 1993 sightings strongly suggest that the whales were feeding on surface swarms of *N. simplex*. Blue whales have also been reported feeding in two other low latitude grounds: the southwest Gulf of California (Sears, 1987; Gendron and Sears, 1989; 1993), and off northeastern Sri Lanka, Indian Ocean (e.g. Leatherwood, 1986; Alling *et al.*, 1990). Therefore, Reilly and Thayer's hypothesis for the ETP may well apply to other productive habitats in the tropical/subtropical oceans (cf. Ballance and Pitman, 1998).



Fig. 4. (b) See legend on p. 46. Note the white scarring.

N. simplex is a neritic euphausiid that thrives in the cool, upwelling-modified extensions of the California and Peru Currents in the ETP. A third population centre to the west of the Galápagos Islands is supported by the equatorial divergence and the South Equatorial Current-Equatorial Undercurrent system (Brinton, 1979). It is one of the most important euphausiids in terms of biomass off central Chile (Antezana, 1970), in the Gulf of California (Gendron, 1992) and off the west coast of Baja California (Brinton, 1979; Gómez-Gutiérrez *et al.*, 1995). Surface swarming in *N. simplex* has been related to reproductive activity during the spring months (Gendron, 1992). There is a close relationship between this phenomenon and blue whale abundance in the southwest Gulf of California (Gendron and Sears, 1989; 1993; Gendron, 1992). Before blue whales were reported feeding on this euphausiid in the Gulf of California (Sears,

1987), *N. simplex* had not been reported as part of their diet (see review by Yochem and Leatherwood, 1985). Off the Galápagos, several other euphausiid species, particularly in the genus *Euphausia*, with important population centres to the west of the Islands (Cornejo de González, 1977; Brinton, 1979), could also constitute prey for blue whales.

'White scarring'

White scarring similar to that on the animal in Fig. 3b has been observed on the backs of blue whales in the Gulf of St. Lawrence, western North Atlantic, and has been attributed to contact with ice as a whale comes to the surface to breathe among ice floes (Sears *et al.*, 1990). In the event that the scarring on the Galápagos animal was indeed caused by ice, this would indicate that this individual had visited polar latitudes previously.

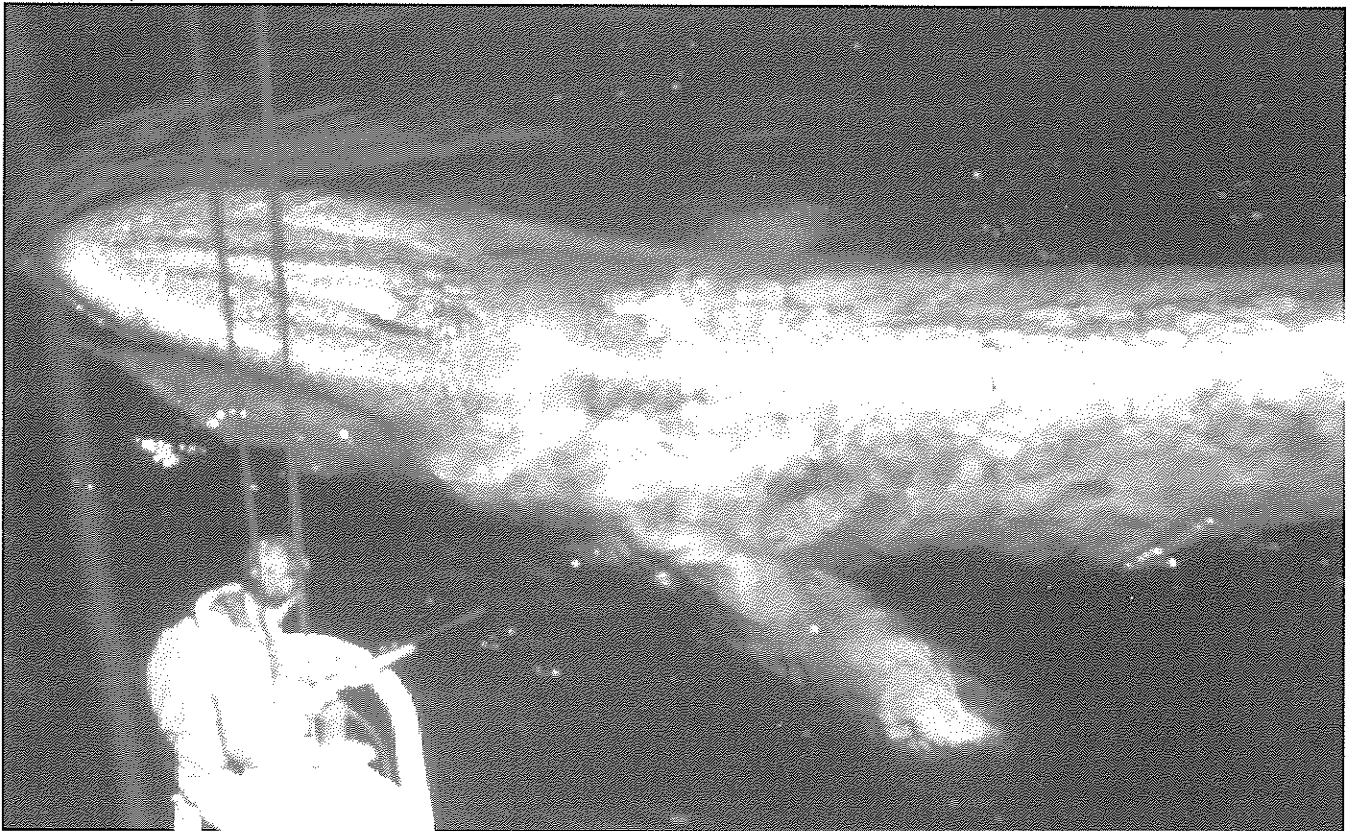


Fig. 4. (c) See legend on p. 46.

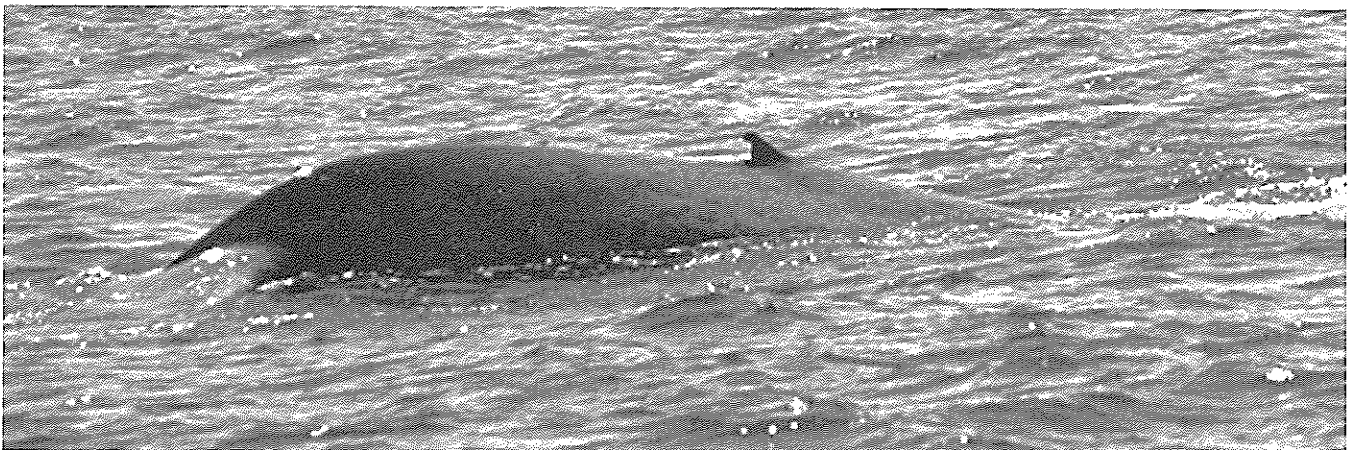


Fig. 4. (d) See legend on p. 46.

Population affinities and sub-specific identity

Although the migratory habits of blue whales are poorly understood, it has been traditionally postulated that they move between the cold and productive waters of the polar regions, where they feed in spring and summer, and the subtropical and tropical waters of the lower latitudes, where they breed in winter (e.g. Mackintosh, 1965; 1966). On these grounds it could be interpreted that the blue whales sighted off the Galápagos belong to a Southern Hemisphere stock, which visits the islands as part of its low latitude distribution during the austral winter and spring months. This is supported by the observation of two calves on 17 August 1993. The absence of matches with photographically identified blue whales in the eastern North Pacific and the possibility that the scarring observed on one individual could have resulted from contact with ice, all constitute additional support for assigning the animals discussed here to a southern stock of blue whales.

However, this view is confounded by the direct feeding observations of 1993 and their distribution in four areas of high productivity in the ETP, which indicate that blue whales select low latitude grounds which enable them to feed (Reilly and Thayer, 1990). This contrasts with Gaskin's (1982) view that 'the breeding grounds of rorquals are determined by relatively simple parameters of which [warm] sea temperature is probably the most important'. In addition, recent theoretical thermoregulation models suggest that the reason for the low latitude migration in blue whales should be other than calving, since even their neonates should be able to tolerate the temperatures of polar seas (Lavigne *et al.*, 1990; Watts *et al.*, 1993).

Year-round sightings of blue whales in the vicinity of the Costa Rica Dome have been interpreted as belonging to a resident stock (Reilly and Thayer, 1990). Actual peaks in sightings and catches during the summer months off Peru (Ramirez, 1983; Donovan, 1984) appear to indicate these whales are not from a southern stock. Thus, as an alternative hypothesis, it is possible that the blue whales off the Galápagos Islands are linked to those in these two nearby areas, i.e. as part of a resident ETP stock that exploits seasonally abundant peaks in euphausiid production.

The issue of stock identity is further complicated by the purported presence of both true (*B.m. intermedia*) and pygmy blue whales in the region. Pygmy blue whales were identified in the vicinity of the Costa Rica Dome (Berzin, 1978) and probably off the coast of Peru (Donovan, 1984). However, true blue whales were also caught off Peru (see summary in Donovan, 1984). Although reliable characteristics for distinguishing true from pygmy blue whales in the field have not been developed (Donovan *et al.*, 1996), it is believed some experienced observers are capable of separating them by their behaviour and body proportions (see review by Kato *et al.*, 1995). Photographs of the animals seen in the Galápagos during 1993 (Figs 4a-d) were examined by H. Kato (National Research Institute of Far Seas Fisheries, Japan) and his impression was that they were true blue whales. The dorsal profile of the head in the whales in Fig. 4 of this paper, particularly at the rostrum level, appears to be narrower than that of fig. 1c in Kato *et al.* (1995) of a pygmy blue whale off Australia.

The question of population identity of the whales seen off the Galápagos must, however, remain open until more adequate information is gathered, particularly on the genetic structure of the blue whales that occupy the different areas of the ETP, and their relationship to whales in high latitude summer grounds both in the northern and Southern Hemisphere. Sub-specific identification is the subject of a

major IWC research effort that includes photo-identification, genetic and acoustic studies involving animals in several areas of concentration in both Antarctic and sub-tropical waters (e.g. see IWC, 1997; 1998, pp.78-80). Satellite telemetry is another useful tool (e.g. Mate *et al.*, 1997), which may help elucidate the population identity of blue whales in the ETP by demonstrating poleward movements or year-round residency. Finally, combining the techniques above with studies of their prey and their habitat (e.g. Fiedler *et al.*, 1997) may advance knowledge of their ecology in low latitude grounds.

ACKNOWLEDGEMENTS

This work would not have been possible without the support of the Whale Conservation Institute. Additional support for completing this manuscript was received from Oregon State University's Marine Mammal Endowment Program. I am grateful to the crew of the R/V *Odyssey*: I. Kerr, K. Marshall, B. Wallace, C. Rogers, E. Lettevall, D. Day, B.J. Brennan, P.L.R. Brennan and L. Galley for their hard work in collecting the 1993/94 data. S.B. Reilly kindly provided detailed records of the sightings in his database at the SWFSC and T. Gerrodette provided additional details of the research vessel sightings. D. Day contributed an additional observation, photographs, expertise and, above all, friendship. L. Leonhardt and B. Wallace allowed the use of their photographs. E. Brinton and D. Gendron helped with the identification of the euphausiids. T. Follett provided assistance with computer graphics. Helpful comments and insights on earlier manuscripts were offered by B.R. Mate (OSU, HMSC, Newport, OR 97365, USA), K.M. Stafford (NOAA, PMEL, Newport, OR 97365, USA), P.C. Fiedler (NMFS, SWFSC, La Jolla, CA 92038, USA), R. Clarke, G. Merlen, and by reviewers H. Whitehead and J.C.D. Gordon. The Servicio Parque Nacional Galápagos, the Charles Darwin Research Station, the Ministry of Defense of Ecuador, and the Capitania de Puerto Ayora granted the permits necessary to undertake WCI's research and provided logistic support. TAME airlines of Ecuador provided discounted transport between continental Ecuador and the Galápagos Islands. This is Contribution No. 560 of the Charles Darwin Foundation for the Galápagos Islands.

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