On the Occurrence of Bryde's Whales (*Balaenoptera edeni* Anderson, 1878) in an Upwelling Area off Central Chile

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ABSTRACT

A whale sighting cruise was carried out on 1–15 February 1982 on board the high seas stern trawler *Juan 8°* surveying an area between 32°S and 38°30'S and between 75°W and the coast. The cruise covered a total of 1,543 miles and the effective sightings distance was 1,119 miles. A total of 65 great whales were sighted (35 sperm, 25 Bryde's, two blue, two sei and one minke whale). Small cetaceans sighted included bottlenose whales, killer whales and several dolphin species.

The greatest density of Bryde's whale sightings was located between Punta Roncura (35°S) and San Vicente (approx. 37°S), an area which also showed the characteristic features of an upwelling ecosystem, i.e., lower surface temperature, greater surface density and larger phytoplankton biomass. This area is postulated as a feeding ground for Bryde's whales in this season.

INTRODUCTION

The first record of a Bryde's whale (*Balaenoptera edeni* Anderson, 1878) from Chilean waters dates from 1960 (Clarke and Aguayo, 1965) based on a specimen caught off Iquique (20°17'S; 70°09'W). At that time only two other records existed for the eastern Pacific Ocean, one from Columbia and one from Ecuador.

The Bryde's whale has been, and in some aspects still is, a particularly difficult species to study due to its similarity with the sei whale (*Balaenoptera borealis*, Lesson 1828), which can cause some problems in identification at sea. Clarke and Aguayo (1965) for example, suggest that the 15 sei whales sighted during a cruise to the Galapagos Islands in October 1959 (Clarke, 1962) could well have been Bryde's whales, judging by the latitude and sea temperature.

Research on the identification of Bryde's whales began in Japan after World War II, under the leadership of Dr H. Omura. During the subsequent development of a Japanese commercial catch of Bryde's whales in the North Pacific in the mid 1950s, its catches were clearly separated from those of the sei whale (Dr S. Ohsumi, pers. comm.). Whaling stations in the Southeast Pacific, however, continued to confuse these species: until 1973 in Peru (Valdivia *et al.*, 1981); and until 1981 in Chile. Thus catch statistics for sei whales previous to these dates must be understood to comprise both sei and Bryde's whales, probably in varying proportions.

Chile faces the Eastern South Pacific Bryde's whale management stock, which has been classified as an Initial Management Stock (IMS) by the International Whaling Commission (IWC). Based on population assessments carried out using sightings data obtained from Japanese sightings cruises (IWC, 1981a), a catch limit for this stock of 188 animals was set by the IWC for the 1981 (IWC, 1981b) and 1982 (IWC, 1982) seasons. Since very little was known about this species in the vicinity of Chile's whaling grounds, a government authorised whale sighting cruise was carried out from 1–15 February 1982, in the area between 32°S and 38°30'S, and between 75°W and the coast on board the high seas stern trawler *Juan 8°* (Fig. 1). This paper summarises the cruise findings.

MATERIALS AND METHODS

During the cruise two teams of experienced observers were alternated in 3-hour shifts in the crow's nest, from sunrise to sunset. At night the ship drifted or performed small adjusting navigations. In order to assure specific identification of Bryde's whales, two whaling experts supplied by the Japanese Government participated. Of considerable help also was Leatherwood *et al.*'s (1976) guide for the identification of whales, dolphins and porpoises. The speed during active sightings effort was 8.5 knots, and the effective angle of sighting was about 60° on either side of the ship. The maximum actual (not perpendicular) sightings distance was 3 miles. Positions were determined with a Furuno Satellite Navigation System F-SN200. Temperature measurements and water samples for salinity and chlorophyll determinations were taken hourly. Wind intensity and direction, relative humidity, atmospheric pressure and weather conditions were also recorded hourly. Observations of birds and other organisms were noted. As the main objective was not the determination of abundance but to identify and learn about the distribution of the Bryde's whale as accurately as possible in an area within reach of the local industry, a considerable portion of time was spent in approaching sighted whales, observing their diving and blowing behaviour, and obtaining still and moving pictures. From the whaling captains' experience and whaling records, it was expected that the main density of whales would be found in a smaller area within 35°S and 37°S, and this indeed was the case.

RESULTS

The sighting cruise covered a total of 1,543 nautical miles, of which 1,119 were actual sighting miles. The total mileage includes navigation to and from the sighting area, running at night, and drifting.

Abiotic observations

(1) *Meterorological conditions.* Atmospheric data, summarised in Fig. 2, indicate typical summer conditions for the surveyed area. Particularly important are the wind

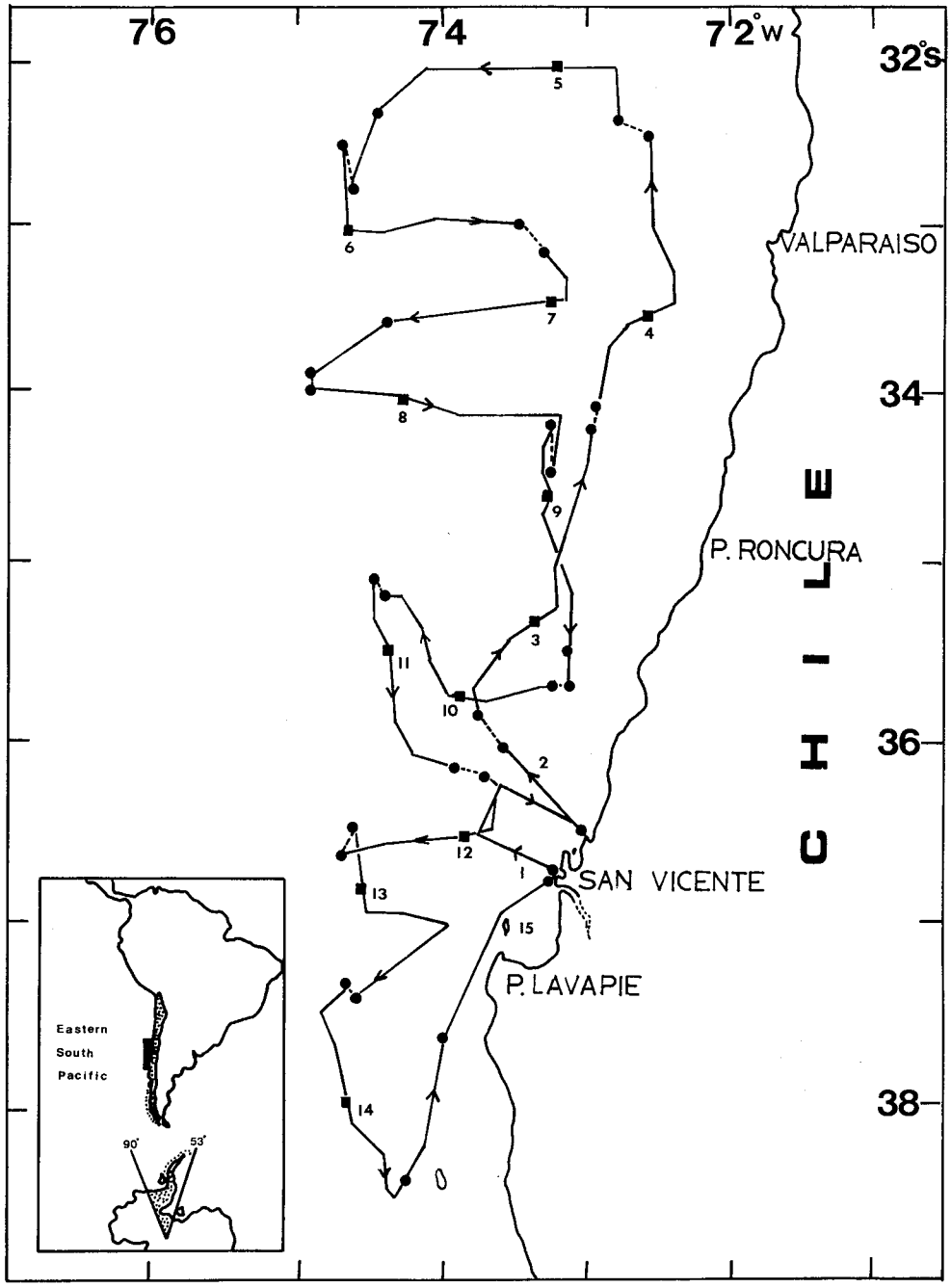

Fig. 1. Track of the whale sightings cruise carried out on board the high seas stern trawler *Juan 8°*, off the central Southeast Pacific region, between February 1–15, 1982. Each daily sightings cycle is represented by two dots and a square (noon position); lines between two dots only, represent navigation without sighting effort and discontinuous lines between dots indicate night drifting.

direction and speed. Winds from the S and SW quadrants, with speeds of up to 20 knots, were encountered throughout most of the sighting cruise.

(2) *Surface density.* The distribution of surface density is seen in Fig. 3, showing a distinct area of upwelling, characterised by a sigma-t of 25.0, between Roncura Pt. and Lavapie Pt.

(3) *Surface temperature.* Fig. 4 shows an extensive area of colder water between Roncura Pt. and Lavapie Pt., where temperatures of 16°C and 17°C were observed. Outside this area the temperature was uniformly higher with values of 18°C and 19°C.

(4) *Surface salinity.* Fig. 5 shows the distribution of surface salinity, which also reveals an upwelling area indicated by the 34.30‰ isohaline. The wedge of higher salinity penetrates westerly, surrounded by waters with a strong salinity gradient, indicating the possibility of an oceanic front associated with the upwelling. Oceanic waters have salinity values of up to 33.8‰ typical for the Superficial sub-Antarctic Waters. South of Lavapie Pt. these waters show uniform values near to or less than 33.80‰.

Biotic observations

(1) *Surface chlorophyll.* Fig. 6 shows an area with high values of phytoplankton biomass (20 mg Chl*a* m^{-3}) between Roncura Pt. and Lavapie Pt., in agreement with the distribution of abiotic factors characterising an upwelling system. Other parts of the studied area revealed a relatively smaller biomass with values of about 5 mg Chl*a* m^{-3}.

(2) *Birds*. Fig. 7 shows a greater concentration of birds between 35° and 37°S and west of 73°W.

(3) *Cetacean sightings*. Table 1 lists the cetacean species identified during the cruise and Fig. 8 shows the approximate sighting localities. The greatest density of sightings was observed in the area between Roncura Pt. and Lavapie Pt. Table 2 sequentially records all great whale sightings together with the most relevant complementary data. A total of 35 sperm, 25 Bryde's, 2 blue, 2 sei and 1 minke whale was seen.

It is clear from Fig. 8 that Bryde's whales were mostly encountered in the area between Roncura Pt. and San Vicente. Only five animals (20%) were observed to the north of this area, although it must be borne in mind that sightings conditions outside this area were very poor. The difference in the behaviour of Bryde's whales within and outside the area of concentration was noteworthy: the former were easy to approach and observe and were probably feeding (and were accompanied by large numbers of birds); the latter by contrast were difficult to approach and were probably 'cruising'. This and the poor sighting conditions made sightings and observations difficult and thus diving behaviour and diving time data were only obtained from feeding whales.

Table 1

List of cetaceans sighted during the whale sighting cruise of the high-seas stern trawler *Juan 8°* carried out from 1–15 February 1982, between 32°S and 38°30'S and between 75°W and the coast.

Order Cetacea	
Suborder Mysticeti—Baleen whales	
Family Balaenopteridae—Rorquals	
Balaenoptera edeni, Anderson 1878	Bryde's whale
Balaenoptera borealis, Lesson 1828	Sei whale
Balaenoptera musculus (Linnaeus, 1758)	Blue whale
Balaenoptera acutorostrata, Lacépède, 1804	Minke whale
Suborder Odontoceti—Toothed whales	
Family Physeteridae	
Physeter macrocephalus, Linnaeus 1758	Sperm whale
Family Hyperoodontidae	
Hyperoodon planifrons, Flower 1882	Southern bottlenose whale
Family Delphinidae	
Orcinus orca, (Linnaeus, 1758)	Killer whale
Lagenorhynchus ? cruciger (Quoy & Gaimard, 1824)	
Cephalorhynchus commersonni Lacépède, 1804	Commerson's dolphin

DISCUSSION

Despite the fact that Chilean whaling started around the 1880s, and statistical records have been kept since 1929, unfortunately little research has been carried out on these resources. Even though most 'sei whales' caught by the Chilean whaling industry may have been actually Bryde's whales, no record on their biology or ecology is available, and the catch data for these and other whales are of limited use for fishery biology purposes. Local whalers tell of differences observed among processed 'sei' specimens, such as different coloration, differences in the baleen (the authors have actually collected baleen plates among the local whalers which with certainty can be attributed to both species) and in meat colour. Fish such as mackerel are said to have been common in the stomach content of some specimens. This information is however of very limited quantitative use and a scientific programme is being designed to collect and evaluate data from future catches.

It is well established that within the surveyed area coastal upwelling processes driven by strong and persistent spring and summer SW winds occur (Brandhorst, 1971; Ahumada and Chuecas, 1979). Hydrographic data gathered during this cruise clearly reflect an upwelling pattern.

From Table 2 it can be seen that Bryde's whales were found in temperatures ranging from 15.88°C to 18.63°C (average t° = 17.53°C). The highest frequency (9 individuals) was found in the 19°C interval and the next highest frequency (6 individuals) in the 16°C interval.

In this connection it is interesting to note that Best (1967) found a wider temperature range for the occurrence of Bryde's whales off the south-western Cape Province, also an area of coastal upwellings. According to Best, Bryde's whales were most abundant in water between 12°C and 13°C, showing a rapid drop in numbers with increasing temperature. A secondary peak in abundance was found at about 18°C to 19°C, before numbers again decreased with increasing temperature.

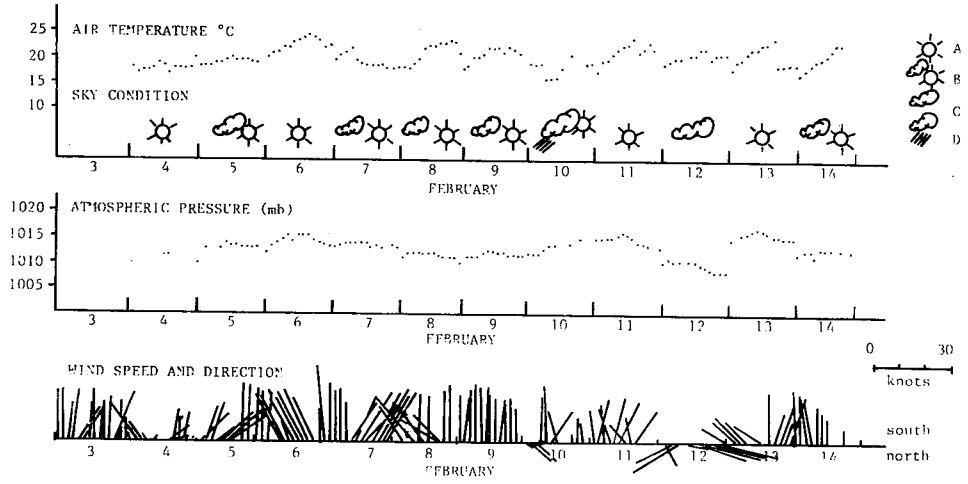

Fig. 2. Meteorological conditions encountered during the whale sightings cruise. Sky condition code: A = clear, B = partially overcast; C = overcast; and D = overcast and rain.

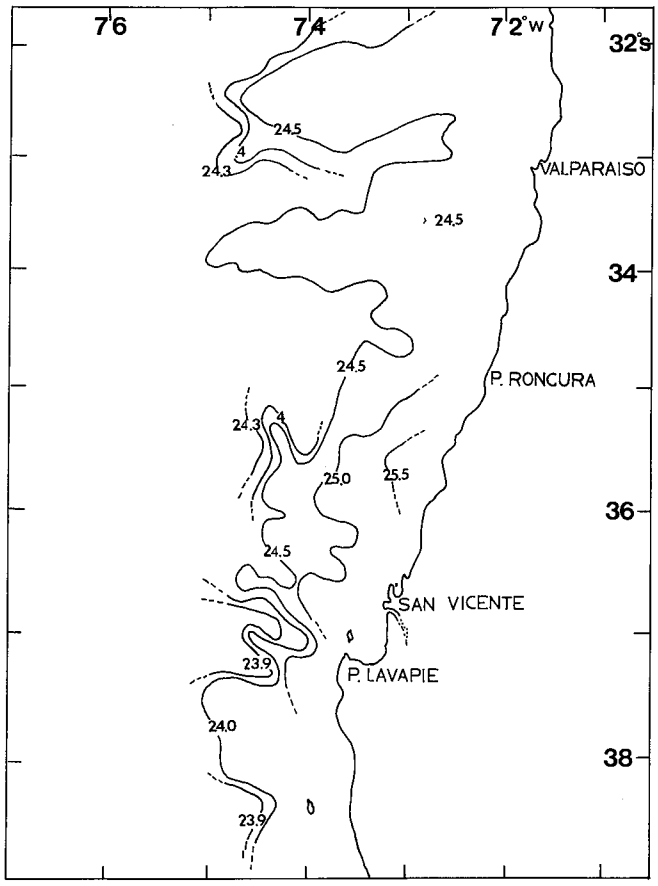

Fig. 3. Surface density distribution in sigma-t.

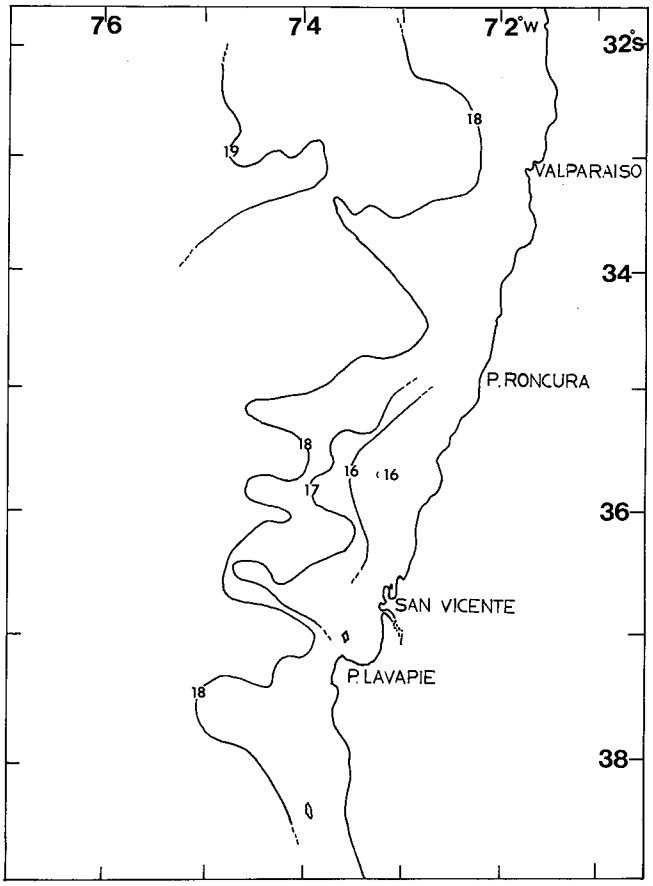

Fig. 4. Surface temperature distribution (°C).

Table 2

Great whale sighting data.

Species	No.	Date	Hour	Lat. (S)	Long. (W)	Water t°C	Salinity ‰	σt	Chl.*a* mg m^{-3}	Dist. miles	Angle L	Angle R	Birds
Sperm	3	03.2.82	09.25	35°31′	73°36′	17.28	34.18	24.84	14	2	—	15	M
Bryde	2	05.2.82	19.20	32°14′	74°27′	18.60	34.06	24.42	5	1	15	—	F
Bryde	2	06.2.82	20.00	32°58′	73°26′	18.63	34.21	24.53	2	3	45	—	F
Bryde	1	07.2.82	11.30	33°27′	73°10′	18.13	34.24	24.68	4	1	—	15	F
Sei	1	07.2.82	19.00	33°33′	74°23′	18.33	34.12	24.53	6	0.5	60	—	F
Bryde	1	10.2.82	08.45	35°40′	73°20′	15.88	34.12	25.12	24	2.5	10	—	M
Minke	1	10.2.82	09.45	35°40′	73°20′	15.88	34.12	25.12	24	2.5	10	—	M
Bryde	5	10.2.82	11.00	35°42′	73°40′	16.00	34.23	25.17	13	0.5	0	0	M
Bryde	3	10.2.82	14.30	35°43′	73°55′	16.71	34.22	25.00	20	2	—	15	M
Bryde	2	10.2.82	15.40	35°45′	74°00′	18.40	33.99	24.42	4	2	0	0	M
Bryde	1	10.2.82	17.10	35°27′	74°10′	18.40	33.99	24.42	4	3	40	—	M
Bryde	1	11.2.82	08.45	35°15′	74°28′	18.08	33.87	24.41	25	2	0	0	S
Bryde	1	11.2.82	09.35	35°31′	74°21′	18.40	33.80	24.28	5	3	—	45	S
Bryde	1	11.2.82	13.45	35°50′	74°17′	17.45	34.31	24.90	4	2.5	0	0	S
Bryde	1	11.2.82	14.20	35°53′	74°15′	17.45	34.31	24.90	4	3	—	40	S
Bryde	1	11.2.82	18.25	36°05′	74°09′	17.65	34.17	24.74	7	3	0	0	S
Sperm	8	12.2.82	10.45	36°30′	73°42′	16.70	34.11	24.92	9	3	—	30	S
Sei	1	12.2.82	12.40	36°30′	73°51′	16.65	34.27	25.06	10	1	0	0	S
Bryde	1	12.2.82	15.20	36°33′	74°25′	17.25	33.56	24.37	8	1	—	10	S
Blue	2	12.2.82	14.35	36°34′	74°11′	17.25	33.56	24.37	8	2	0	0	S
Sperm	20	13.2.82	07.35	36°28′	74°35′	16.70	33.68	24.59	14	2.5	20	—	F
Bryde	2	13.2.82	08.15	36°28′	74°35′	16.70	33.68	24.59	14	1.5	—	10	F
Sperm	1	13.2.82	14.15	37°01′	74°17′	18.48	33.40	23.95	4	2	—	60	F
Sperm	1	13.2.82	16.35	37°09′	74°05′	18.18	33.41	24.03	11	3	0	0	F
Sperm	1	14.2.82	12.55	38°01′	74°04′	18.22	33.55	24.13	9	2	—	45	F
Sperm	1	14.2.82	20.30	38°24′	74°10′	18.25	33.35	23.97	5	1.5	—	30	F

Notes: Water temperature, salinity, density and chlorophyl *a* correspond to nearest hourly measurements. Chlorophyl data rounded to nearest unit. Relative bird abundance according to Fig. 7.

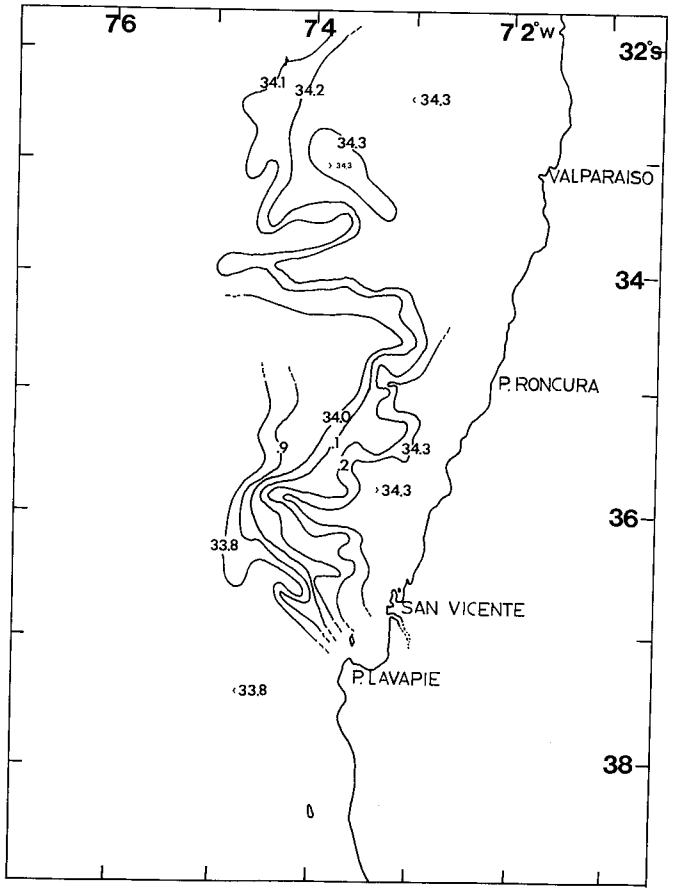

Fig. 5. Surface salinity distribution ($S^0/_{00}$).

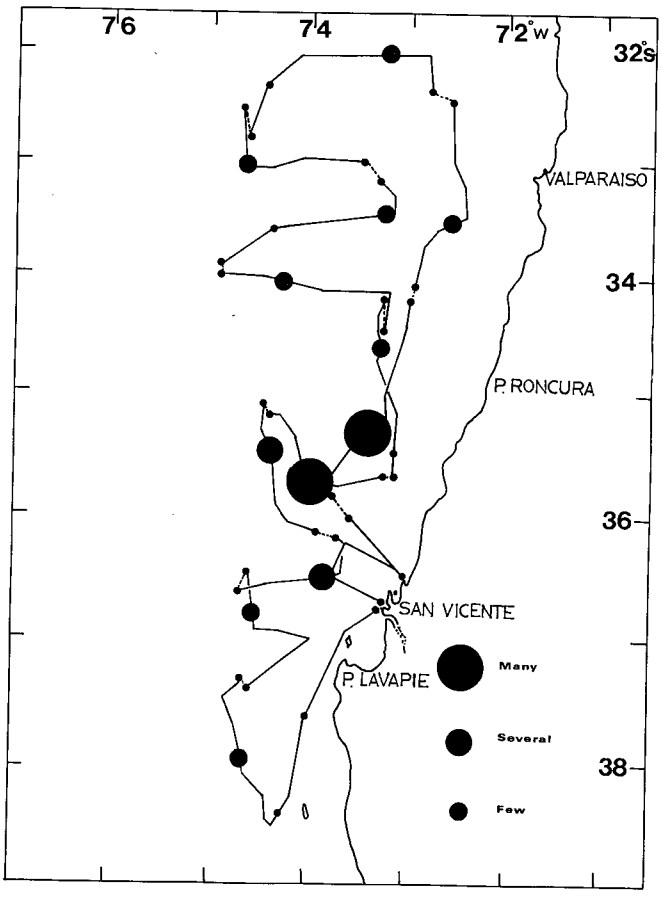

Fig. 7. Relative bird abundance.

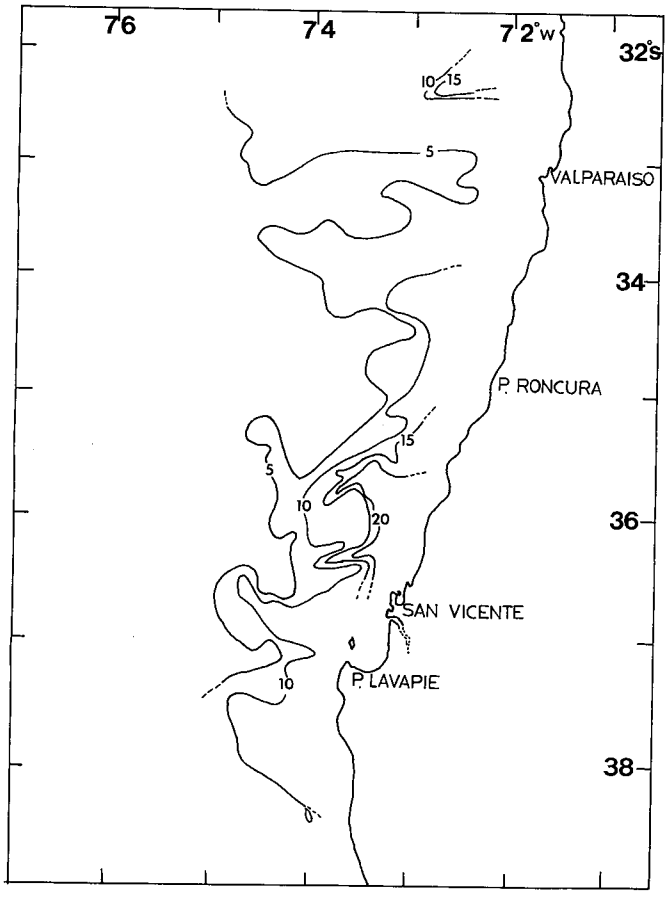

Fig. 6. Surface chlorophyll distribution (mg Chl *a* m^{-3}).

Best in fact demonstrated a high correlation between Bryde's whale distribution and the main characteristics of the Southwest African coastal upwelling ecosystem. He also found that the feeding behaviour of the whales supported this correlation and concluded that the South African west coast whaling ground, which was located roughly from 31°30′S to 36°30′S and from 15°10′E to 19°00′E, is a feeding ground for the species.

On the other hand, Omura and Nemoto (1955) found that in the North Pacific, Bryde's whales live in warm waters of about 20°C or more. Nemoto (1959) reported that Bryde's whales move into waters over 18°C and that in general do not visit waters with temperatures lower than 15°C. Ohsumi (1977) stated that in the North Pacific pelagic whaling ground, the lowest temperature in localities where Bryde's whales were caught was 16.3°C and only 1.3% of the whales were caught in waters below 18.0°C. Moreover, Ohsumi (1978; 1979; and 1980) reported on the catch of Bryde's whales carried out under special permits in the Southern Hemisphere; he found that all Bryde's whales were caught in waters of 20.2°C and over. It would thus appear that the Bryde's whale shows different patterns of temperature association depending on whether records are from coastal upwelling or from oceanic ecosystems. As a rule, coastal upwelling ecosystems exhibit a strong surface temperature heterogeneity. This is the case off the south-western Cape Province, according to Best, and also off central Chile, according to our data (Fig. 4). This fact would account for a lower, widely ranging temperature association as observed for Bryde's whales in these areas. On the other hand, low latitude oceanic ecosystems, besides a higher mean temperature, may be characterised

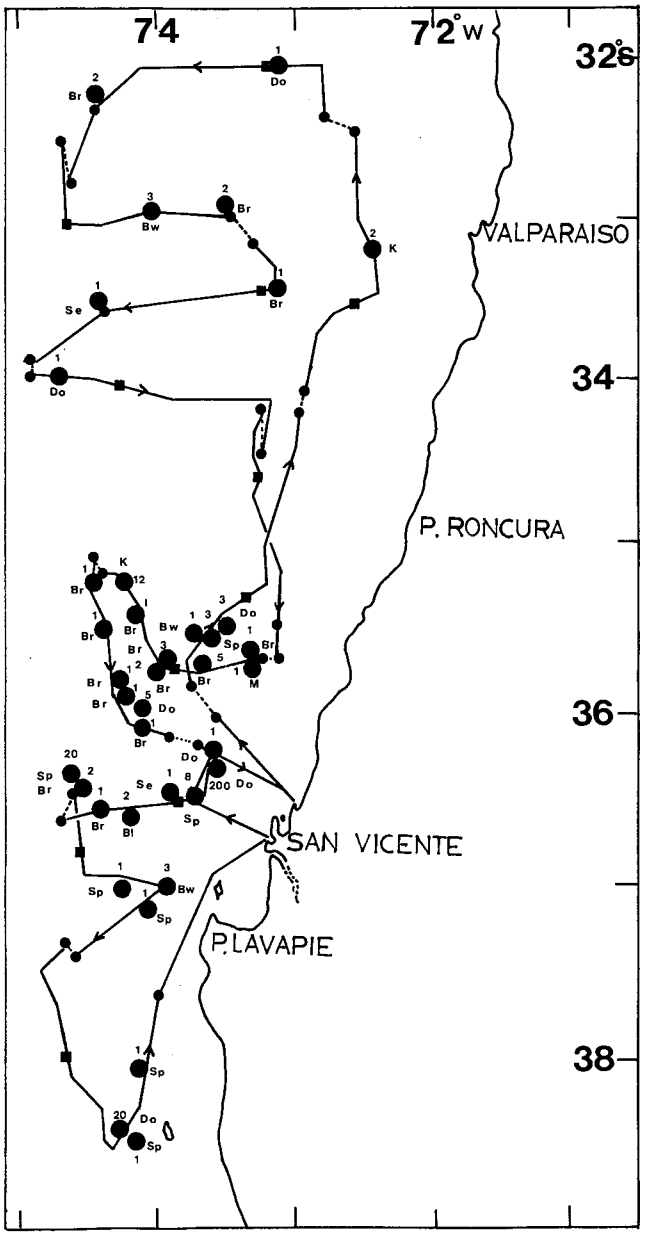

Fig. 8. Distribution of all whales (Mysticete and Odontocete) sightings, according to the following code: Br = Bryde's whale; Sp = Sperm whale; Se = Sei whale; Bl = Blue whale; M = Minke whale; Bw = Bottle-nose whale; K = Killer whale; Do = Dolphins. Numbers indicate quantity.

by a higher temperature homogeneity, accounting for a higher, narrowly-ranging temperature association, as observed for Bryde's whales by Omura and Nemoto (1955), Nemoto (1959), and Ohsumi (1978; 1979; and 1980).

During the present cruise night observations under artificial light disclosed large populations of juvenile jack mackerel in the area of Bryde's whale concentrations. The abundance of birds and the high levels of chlorophyll *a* (even though the summer season was advanced) found in the same area, suggest the possibility that the coastal upwelling area between 35°S and 37°S off central Chile is also a feeding ground for Bryde's whales. If confirmed through the study of captured whales, this will be another ecological similarity between the Southwest African and the Southwest American coastal upwelling ecosystems (Gallardo, 1977).

These observations are in agreement with findings from earlier research on whales which recognised that there were only limited areas in the oceans that contained sufficient food of the right kind to sustain important populations of baleen whales. This in turn defined the location of whaling activities (Mackintosh, 1965). Furthermore, according to recent fisheries ecology literature, it is apparent that feeding grounds for whales are characteristically those which show discontinuously high-amplitude production cycles. These areas are of two kinds: high latitude and low latitude (tropical and subtropical) (Cushing, 1975). In this connection it is interesting to observe that the distribution of feeding grounds of large baleen whales in the Southern Hemisphere shows a regular latitudinal gradient, which appears to fit the distribution of both types of discontinuously high-amplitude production cycle areas (Fig. 9). In this pattern the Bryde's whale is located at one extreme of high-amplitude low latitude production cycle areas of the world, i.e., upwelling ecosystems. These in turn can occur in shallow and deep water (Boje and Tomczak, 1978). Recent research on the food of Bryde's whales suggest that there is comparatively abundant food available for this species, mostly euphausiids, for example, in the Coral Sea, the southwestern Indian Ocean and central South Pacific (Kawamura, 1980) and also fish in the southwestern North Pacific (Kawamura and Hamaoka, 1981).

The Bryde's whale is recognised as the least known of all the balaenopterid whales notwithstanding its early identification (Olsen, 1913). The finding of a feeding population of this species within easy reach of a whaling coastal station and of research institutions could greatly contribute to the understanding of its biology and ecology.

It is unfortunate that local whaling sightings and catch statistics, as mentioned above, refer only to 'sei whales' and do not recognise the existence of Bryde's whales. Nevertheless, an analysis of logbook sightings and catch data for the years 1977–81 shows in fact that 'sei whale' records concentrate between 33°S and 38°S in the first quarter of the year, while during the second quarter numbers are much reduced and located in two areas, one between 30°S and 34°S and one around 20°S. Fourth quarter data show very modest numbers between 33°S and 41°S.

Local whalers tell of an offshore 'sei whale' population that in the summer approaches the coast from the north to feed in the rich fishing grounds of the area and which withdraws from it in late summer. Also 'sei whales' are said to approach a southern area in winter. This conflicting information and the sightings and catch data above make little sense unless they are attributed to two different species.

The picture could be further complicated if sub-populations or different forms of Bryde's whale are involved, such as off Southwest Africa (Best, 1977) and off Peru (Valdivia *et al.*, 1981). Valdivia *et al.* (1981) have suggested the existence of two sub-populations of Bryde's whale off Peru, one the 'Peruvian form' proper and the other the 'southern form' which are distributed to the north and south of about 7°S latitude. Differences noted are size, thickness of blubber, and food; the 'southern form' preferring pelagic fish such as sardine (*Sardinops sagax sagax*), anchovy (*Engraulis ringens*), jack mackerel (*Trachurus murphy*), horse mackerel and *Opistonema bullery*. Euphausiids were also found in a few 'southern form' stomachs, while they were common in the 'northern form'

on some occasions together with small unidentified mesopelagic fish (Myctophidae-like). It is reported, moreover, that the 'northern form' or 'Peruvian stock' is present during the nine Peruvian whaling months, 'following a circular movement and keeping near the coast for 3 to 4 months (February–March and May–June)'.

The questions to be asked are many. For example, is the 'southern form' the same as that which travels south to feed off Chile? Or alternatively, are all feeding populations found off Peru and Chile parts of one or more larger and more widespread central Pacific populations? What is the population structure off Chile and how does it compare with that off Peru?

Obviously much has to be learned about whale biology and ecology off the coast of Chile. Unfortunately due to the high cost of whale research, this cannot be done without cooperative effort between all interested parties, i.e., the whaling industry, government and research institutions.

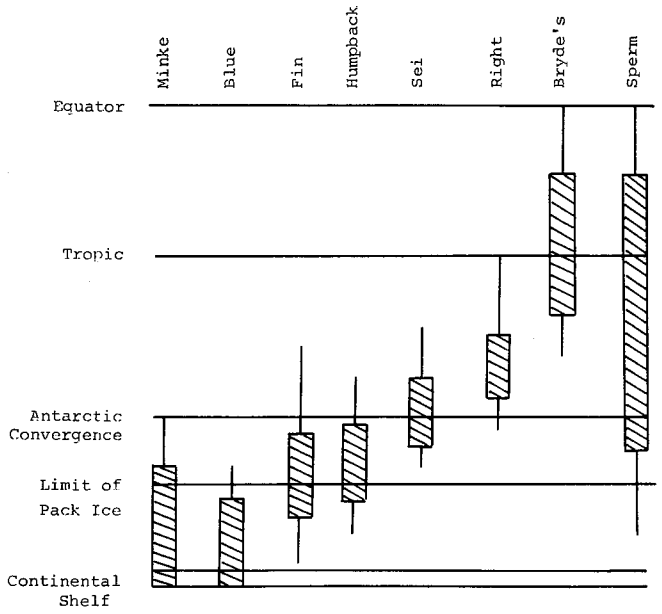

Fig. 9. Diagramatic latitudal distribution of large whale species on the Southern Hemisphere feeding grounds (modified from Allen, 1981).

CONCLUSIONS

1. Notwithstanding the relatively early start of Chilean whaling, very little whale research has been carried out.
2. The finding of Bryde's whales off the coast of central Chile suggests that probably many 'sei whales' caught in the past by the local whaling industry were actually Bryde's whales.
3. A part of the surveyed area (between 35° and 37°S) showed evidence of an active upwelling process, such as has been reported previously for the coastal waters of Southwest South America.
4. The concentration of marine life in this area, including the Bryde's whale, suggests the existence of a strong ecological relationship between the living components and the upwelling system, a physical process, which results in higher rates of primary productivity.
5. The southern portion of the surveyed area is postulated as a feeding ground for Bryde's whale. An analogous situation has been found in Southwestern South Africa.
6. In these coastal upwelling ecosystems, the distribution of Bryde's whale appears to show more correlation with the presence of food of the right kind and in the adequate quantities, than with a given range of temperature.

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