Abundance, Seasonal Distribution and Population Composition of Balaenopterid Whales in the Canal De Ballenas, Gulf of California, Mexico

Bernie R. Tershy[1], Dawn Breese[2] and Craig S. Strong[3]

ABSTRACT

The Canal de Ballenas, in the Gulf of California, Mexico, is sub-tropical but has high rates of year-round productivity. It is used by four balaenopterid species of whales. Between May 1983 and April 1986 2,758 hours were spent in a small boat censusing and photo-identifying balaenopterid whales in a 20 x 45 km section of the Canal. A total of 9 individual blue whales, 148 individual fin whales, 160 individual Bryde's whales and 6 individual minke whales were identified. At the same time 9 blue, 291 fin, 307 Bryde's and 17 minke whales were seen. The number of sightings per identified individual suggests that blue and fin whales are more transient to the study area than Bryde's and minke whales. This indicates that photo-identification data can improve the interpretation of sightings data.

The numbers of whales sighted per hour suggests that blue whales were most abundant in April and May while minke whales were equally abundant throughout the year. Fin and Bryde's whales were found in the study area in all months of the year but fin whales were more abundant in the winter and spring and their numbers were negatively correlated with water temperature. Bryde's whales were more abundant in the summer and fall and their numbers were positively correlated with water temperature. The percentage of identified individual adults that were females with calves was 10.6 for Bryde's and 2.7 for fin whales. Known female Bryde's whales showed the same within season distribution as Bryde's whales of undetermined sex but were more resident to the study area. When lactating they were thinner than pregnant or resting females, or whales of undetermined sex.

INTRODUCTION

The Gulf of California is a sub-tropical sea with areas of high year round productivity where concentrations of whales of the genus *Balaenoptera* are known to occur. Because it has never been an area of intensive commercial whaling, little is known about large whales there. From 1983–86, we used a combination of photo-identification, census and behavioral studies to examine the abundance, seasonal distribution and population composition of balaenopterid whales in one part of the central Gulf of California, the Canal de Ballenas.

Data from a number of cruises, combined with incidental observations, have provided a broad picture of distribution and abundance of balaenopterids in the Gulf. Blue whales have been reported in the Canal de Ballenas (Wells, Würsig and Norris, 1981), the northern Gulf (P. Turk pers. comm.), the eastern Gulf off Sonora (Vidal, Findley, Robles, Carvallo and Maldonado, 1986), the Loreto area (Vidal *et al.*, 1986; Sears, Bérubé and Gendron, 1987) and at the mouth of the Gulf (Leatherwood, Reeves, Perrin and Evans, 1982; Aguayo, Urbán, Sanchez and Rojas, 1986). They are most abundant in late winter and spring with the largest concentrations off the Loreto area (Leatherwood *et al.*, 1982; Sears *et al.*, 1987; Vidal *et al.*, 1986), although not in all years (D. McIntyre pers. comm.).

Because fin whales are seen in the Gulf of California throughout the year, and sightings near the mouth of the Gulf are rare, many authors have speculated that they are a resident, possibly isolated population (e.g. Wells *et al.*, 1981; Leatherwood *et al.*, 1982; Gambell, 1985). Fin whales are the most frequently observed mysticete with sightings in all parts of the Gulf (Van Gelder, 1960; Wells *et al.*, 1981; Leatherwood *et al.*, 1982; Aguayo, Findley, Rojas and Vidal, 1983; Rojas, 1984; Cummings, Thompson and Ha, 1985). They seem to be most abundant around the Midriff Islands (Aguayo *et al.*, 1983).

Bryde's whales have been sighted in the southern Gulf (Rice, 1977; Leatherwood *et al.*, 1982; Cummings *et al.*, 1985; Flores and Fleischer, 1987; 1988; Salinas and Bourillon, 1988), both sides of the central Gulf (Balcomb, Villa-R and Nichols, 1979; Rojas, 1984; own data) and the northern Gulf (Vidal, Aguayo, Findley, Robles, Bourillon, Vomend, Turk, Garate, Maronas and Rosas, 1985; G. Silber, pers. comm.). They have not been reported as often as fin whales but it is probable that they have at times been mistaken for fin whales, adding confusion to the data on distribution and abundance for both species (B. Würsig, pers. comm.; own data).

Minke whales have been reported in the central (Balcomb *et al.*, 1979) and northern Gulf (Wells *et al.*, 1981). Apart from the sei whale (*B. borealis*), which has only been sighted at the mouth of the Gulf (Aguayo *et al.*, 1986), the minke whale is the least often sighted balaenopterid in the Gulf.

STUDY AREA

We conducted research between 1983 and 1986 in a 20 x 45 km area in the Canal de Ballenas, between Isla Angel de la Guarda and the Baja California peninsula (Fig. 1). The oceanography of the study area is described by Roden (1964) and Alvarez-Borrego (1983). Three important features of the area are: (1) extreme spatial habitat variability including rocky points, islands, pelagic waters with depths exceeding 1,500 m and shallow sandy bays; (2) extreme temporal habitat variability with temperate water conditions and prevailing northwest winds in the winter and spring, and tropical water conditions with southeast

[1] Moss Landing Marine Laboratories, P.O. Box 450, Moss Landing, CA 95039-0450, USA; present address: Section of Neurobiology and Behavior, Seeley G. Mudd Hall, Cornell University, Ithaca, NY 14853, USA.
[2] Environmental Field Program, University of California, Santa Cruz, CA 95064, USA; present address: 177 Burns Road, Brooktondale, NY 14817, USA.
[3] Moss Landing Marine Laboratories, PO Box 450, Moss Landing, CA 95039-0450, USA.

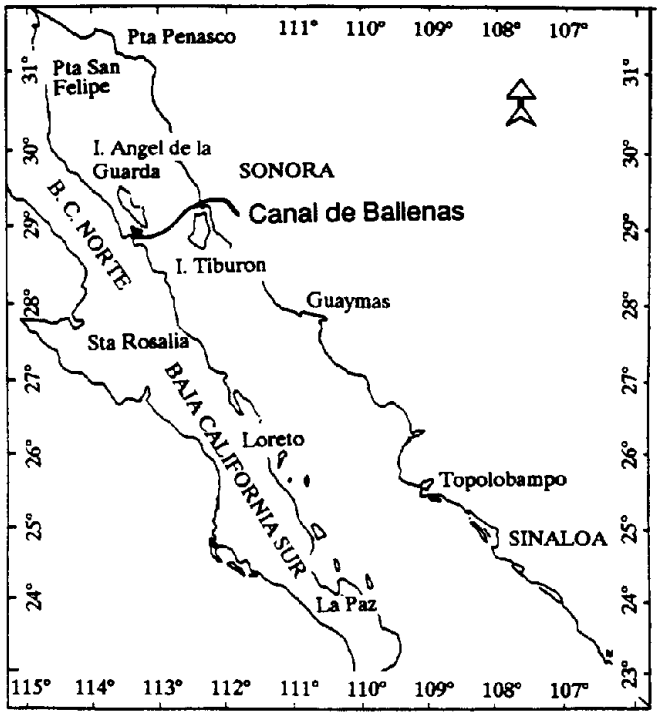

Fig. 1. The study area.

winds in the summer and fall (Fig. 2); and (3) strong tidal currents (up to 3m/sec, Alvarez, Badan-Dangon and Robles, 1984) which flow through the Canal, extensively mixing the water column. This keeps photic zone nutrient levels high enough to sustain year-round primary productivity comparable to major upwelling zones (Alvarez-Borrego, 1983). Sea surface temperatures in the Canal de Ballenas are persistently lower than in the rest of the Gulf of California (Alvarez-Borrego, 1983; Badan-Dangon, Koblinski and Baumgartner, 1985). For example in July mean sea surface temperatures are 27–29.5°C throughout the Gulf (Robinson, 1973), but about 25.5°C in the Canal de Ballenas.

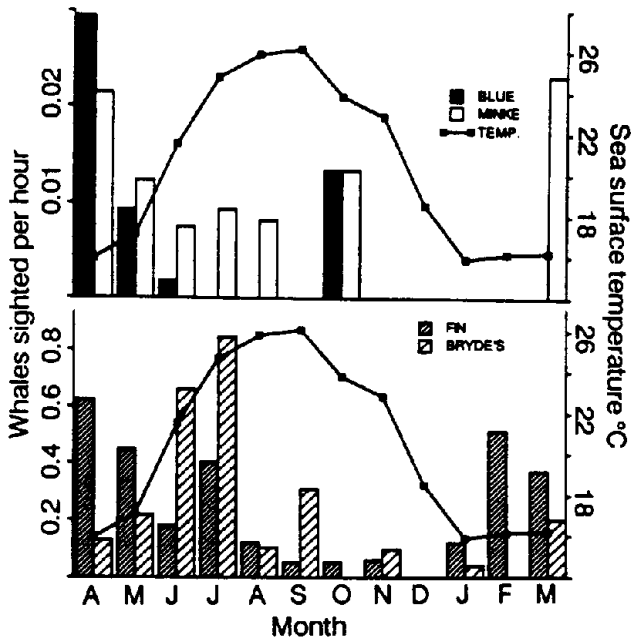

Fig. 2. Mean monthly sea surface temperature and the number of (A) blue and minke whales sighted per hour and (B) fin and Bryde's whales sighted per hour. Data for all years combined.

Table 1

Dates of field work and hours of boat time

Year	Dates in Field	Boat Hours
1983	25 May - 29 August	588
1984	3 April - 28 August	788
1985	6 April - 9 November	1,131
1986	14 January - 28 March	251

METHODS

We worked from a 4.2 m inflatable boat whenever seas were Beaufort 2 or less (approximately 74% of the days from April through August, and 52% of the days from September through March). Table 1 and Fig. 3 summarise dates and hours worked. Our primary goal was to photo-identify as many individual whales as possible. While doing this we censused whales and other marine animals with a consistent but non-random search method in which we ran the boat in a straight line at planing speed for 5 or 10 minutes then shut off the engine for 15 minutes to listen for the blows or exhalations of whales (blows were often audible from a distance of over 5 km). All cetaceans were counted regardless of distance from the boat and no attempt was made to correct for interspecific differences in sightability. At each of these 15 minute stops we recorded our location by triangulation from known landmarks with a hand held sighting compass. We then made a 360° binocular scan, and recorded the number of whales and other marine animals sighted. Several times a day we measured sea surface temperature and secchi disc depth. We made no attempt to randomize the search effort on a daily basis and frequently concentrated our efforts in areas where we felt whales were most abundant. However, on a weekly basis we made an effort to cover most of the study area. Observer consistency within and between years was high because one of us (BRT) was present and consistently collected data for over 95% of the boat days (a detailed description of research methods can be found in Tershy, 1984).

When a whale was sighted we recorded the location, behavior (using the ethogram in Tershy, 1984) and group size or number of aggregated whales. Following Wilson (1975) we defined an aggregation as a number of individuals gathered in the same place but without obvious internal organization or cooperative behavior, and a group

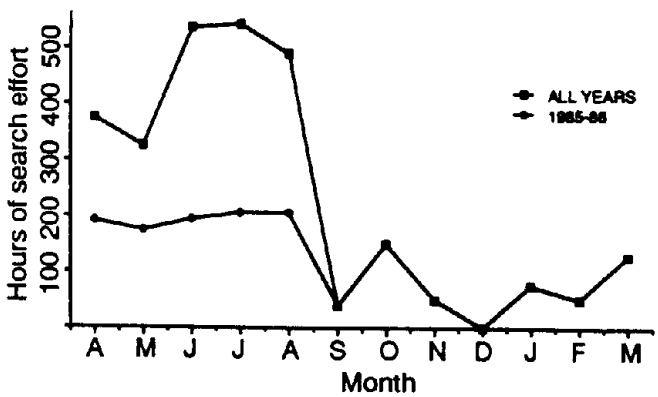

Fig. 3. The distribution of research effort from all years combined, open squares, and from 1985–86 when we were in the field during all four seasons of the year, closed triangles.

as a set of organisms that remain together for a period of time while interacting with one another to a distinctly greater degree than with other conspecifics. In practice this meant two or more animals swimming within 50m of each other engaged in the same behavior at the same time with coordinated swimming and respiratory behavior. We attempted to identify individuals by photographing the unique shape of the dorsal fin as well as scars and pigmentation-patterns on the dorsal surface. We took photos when our boat was parallel to and within 60m of the whale using a 300mm f4.5 lens with either *Kodachrome* 64 and *Ektachrome* 200 (in 1983) or *Fujichrome* 100 (from 1984 to 1986) slide film.

This technique was first described for *Tursiops truncatus* by Würsig and Würsig (1977), and subsequently modified by Dorsey (1983) for minke whales, Sears, Williamson, Wenzel, Bérubé, Gendron and Jones (1990) for blue whales and Agler, Beard, Bowman, Corbett, Frohock, Hawvermale, Katona, Sadove and Seipt (1990) for fin whales.

This is the first published study of individually identified Bryde's whales and thus we will briefly describe the features used. Most of the individually identifiable Bryde's whales had one (58%) or more than one (25%) distinctive tear or notch in the trailing edge of the dorsal fin. The remaining identifiable individuals had notches in the tip (4%), or leading edge (4%) of the dorsal fin, had the dorsal fin completely torn off (4%), had an odd shaped dorsal fin (4%), or had obvious deformities such as a hunchback or a broken rostrum (1%). In the study area, Bryde's whales had less variable pigmentation patterns than the blue, fin or minke whales and rarely had noticeable scars. When present, scars and pigmentation patterns were only used as supplementary identifying features.

RESULTS

Relative abundance and numbers of identified individuals

In 1985/86, when research was conducted throughout most of a year, the four most frequently sighted mysticetes were the Bryde's, fin, minke and blue whale, in decreasing order of numbers of sightings (Fig. 4). However sighting effort was not distributed evenly throughout the year (Fig. 3) and periods of greatest fin whale abundance (see below) were under-sampled.

The mean number of identifications per identifiable individual for the entire study suggests that individual fin and blue whales are less resident to the study area than individual Bryde's and minke whales (Fig. 5).

In 1983, the first year of our study, we made an equal effort to photograph all individuals regardless of apparent identifiability. Thus (assuming no difference in behavior between identifiable and non-identifiable individuals) we were able to approximate the percentage of individuals distinctive enough to be identifiable with our methodology. We took 392 good quality photographs of Bryde's whales from which we made 138 (35.2%) positive identifications. The respective values for fin whales were 240 and 65 (27.1%). As was found by Sears *et al.* (1990), all blue whales sighted were distinctive enough for individual identification. Similarly the few minke whales seen were identifiable.

We photo-identified 9 individual blue whales, 148 fin whales, 160 Bryde's whales and 6 minke whales. Dividing the number of individual fin and Bryde's whales identified by the percentage of all individuals which were identifiable

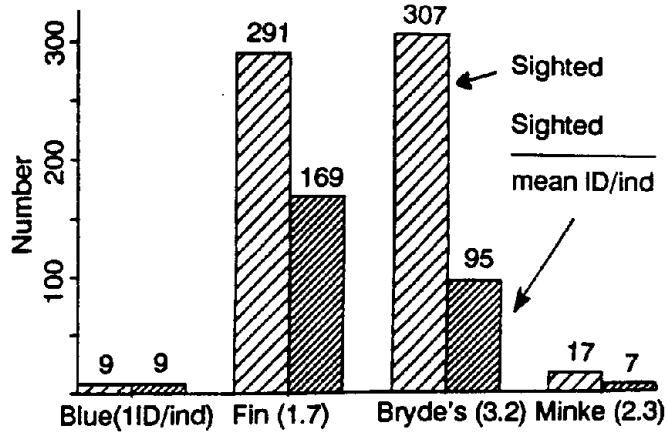

Fig. 4. The relative abundance of *Balaenoptera* whales in 1985–86. The number sighted during censuses is an indicator of relative occurrence of whales, but it is probably not representative of the relative number of individuals using the study area, since each species has different residency patterns. The number sighted, divided by the mean number of within-year sightings per identified individual, a measure of residency, is a better indicator of the relative number of individuals of each species using the study area.

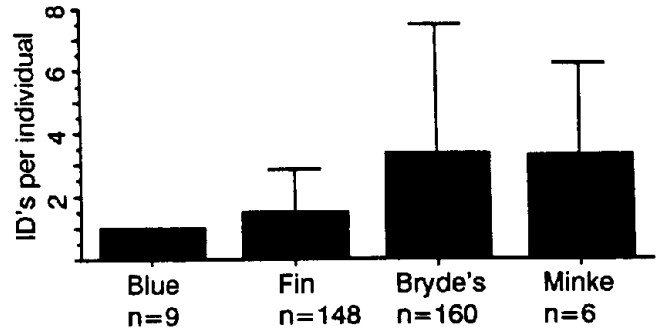

Fig. 5. The mean number of identifications per individual from all years combined. Differences between fin and Bryde's whales are significant (Mann-Whitney U, $P<0.001$).

gives an estimate for the number of individuals which used the Canal de Ballenas between 1983 and 1986 of 546 fin whales and 454 Bryde's whales.

Seasonal distribution

To examine the seasonal distribution of the blue and minke whales we combined sightings from all years of field work and divided the number of individuals sighted each week by the number of hours of observations in that week (Fig. 2). Blue whales occurred in the study area primarily in April and May, but one individual was sighted in June and one cow/calf pair was sighted in October (just after the peak of sightings off central California (Calambokidis, Steiger, Cubbage, Balcomb, Ewald, Kruse, Wells and Sears, 1990)). Minke whales may be most abundant in the spring, but were sighted in all months of the year except those with less than 100 hours of boat time (Figs 2 and 3).

We observed fin and Bryde's whales in the study area throughout the year in waters ranging from 15–28°C. Fin whales were most abundant in late winter and spring (mean date of occurrence 20 April, circular standard deviation of 48 days). The mean number sighted per hour per week was negatively correlated with water temperature ($r=-0.530$, $df=34$, $t1=3.645$, $P<0.0005$ for 1985, and $r=-0.564$, $df=18$, $t1=2.899$, $P<0.005$ for 1984). Bryde's whales, in

contrast, were most abundant in summer and fall (mean date of occurrence 23 June, circular standard deviation 47 days). Their abundance was positively correlated with water temperature ($r=0.327$, $df=34$, $t1=2.019$, $P<0.05$ for 1985 and $r=0.733$ $df=18$, $t1=4.567$, $P<0.0005$ for 1984) (Fig. 2). Mean weekly counts of fin and Bryde's whales were not significantly correlated with each other.

Photo-identification matches with other areas

Between year matches of photo-identified blue, fin and Bryde's whales have been made between the study area and several locations in the Gulf of California (Table 2). One blue whale we identified in the Canal de Ballenas in the spring of 1985 was resighted in the fall of 1986 in Monterey Bay, off central California (Calambokidis *et al.*, 1990). These matches provide valuable information on the ranges of individual whales but provide little information on seasonal movements. Comparisons between identified fin or Bryde's whales from the Gulf and the North Pacific whales have not been made.

Table 2

Matches between the Canal de Ballenas and other areas expressed as No. matches / No. of individuals checked in the other area. Names are of the researchers who provided the photos.

	1 Bahia Kino Guaymas	2 Northern Gulf	3 Loreto B.C.S.	4 Central California
Blue	0/1	-	4-6/? R. Sears	1/? J. Calambokidis
Fin	2/12 L. Findley O. Vidal	1/4 G. Silber	-	-
Bryde's	1/1 B. Agler	-	3/17 S. Flores L. Fleishcher	-
Minke	-	-	-	-

Population composition

We combined data for all years, and looked at population composition of whales in the study area in two ways. First we used census data to estimate the percentage of adult and subadult whales that were females accompanied by a calf: Bryde's 7.5%; fin 1.0%; minke 3.5%; and blue 23.1%. Second we used photo-identification data to estimate the percentage of all adult and subadult identified individuals that were known to be females: Bryde's 10.6%; fin 2.7%; minke 16.7%; and blue 11.1% (Fig. 6).

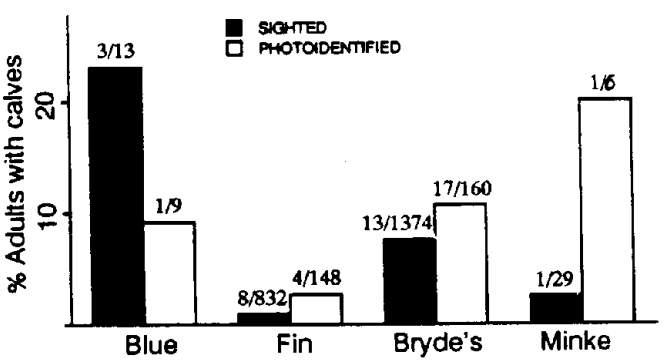

Fig. 6. The percentage of females accompanied by calves for each species of *Balaenoptera* whale. Data from all years combined for two different data sets – 1) sighting data from censuses and 2) from photoidentified individuals.

Differences between the sexes

Only in Bryde's whales were cow/calf pairs and known females abundant enough to examine differences between sexes. There is no apparent difference in within-year seasonal distribution of known females and unknown sex individuals from sighting data (Fig. 7). However, resighting data from known females suggest that they are more resident to the study area than Bryde's whales of undetermined sex, at least some of which are probably males. The mean number of identifications per known female Bryde's whale, 4.6 (78 identifications of 17 individuals), was significantly greater ($P<0.001$, Mann-Whitney U test) than the mean for undetermined sex whales, 1.9 (274 identifications of 143 individuals).

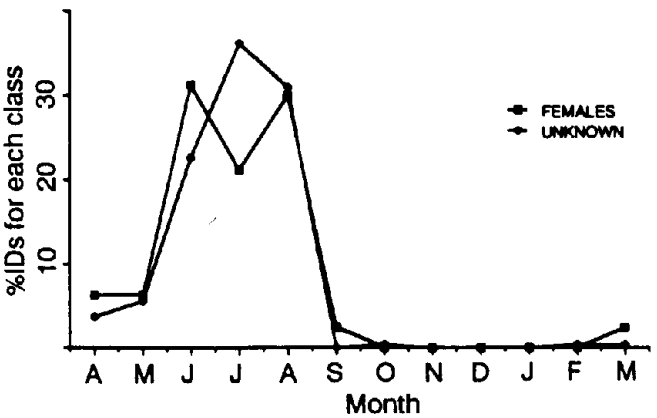

Fig. 7. The percent of all sightings of known individual females (n=78, open boxes) and known individuals of undetermined sex (n=274, closed triangles) from in each month. Data from all years combined.

Some Bryde's whales were so thin that their vertebral processes were protruding and their back had a distinctive corrugated, dorsally thin, appearance (Fig. 8a). Others appeared to be more robust and their back had a normal rounded, dorsally fat, appearance (Fig. 8b). We analyzed photographs of known individuals in which the anterior dorsal surface is clearly visible and found that females accompanied by a calf, and presumably lactating, have thinner blubber layers than do individuals of undetermined sex or known females which were not accompanied by a calf and were presumably immature, resting or pregnant (Table 3).

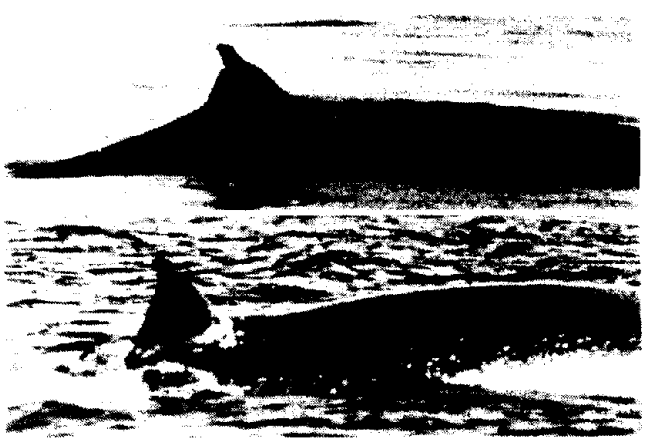

Fig. 8. (A) A female Bryde's whale, Flo, just after weaning her calf in July of 1984. The corrugated, dorsally thin, appearence of her back suggests that she is very thin. (B) The same individual in August of 1985. She is now at least 6 months pregnant and her back appears rounded or dorsally fat.

Table 3

The number of Bryde's whales which were dorsally thin and dorsally fat for three different reproductive classes.

	Undetermined Sex	Pregnant (4) or Resting (2)	Lactating	Total
Dorsally thin	3	0	12	15
Dorsally fat	17	6	5	28
Total	20	6	17	43

chi-squared= 16.24 P < 0.001

DISCUSSION

Relative abundance

Van Horne (1983) has shown that for small mammals, census data alone often give a distorted picture of both habitat importance and abundance. Our data on known individuals suggest that this is also true for *Balaenoptera* whales in the study area. The low resighting rates for blue and fin whales indicates that individuals use the Canal de Ballenas infrequently and that census data underestimate their abundance relative to that of Bryde's and minke whales, which have a higher resighting rate.

There are no estimates of the number of Bryde's whales in the Gulf of California. Aguayo *et al.* (1983) and Rojas, (1984) used census data to estimate a minimum population size for fin whales of 100 and 188 respectively. Our estimate from the number of photo-identified individuals divided by the estimated proportion of individuals which are identifiable is substantially higher for both fin (546) and Bryde's whales (454).

Many papers have commented on the large numbers of fin whales in the Gulf of California while mentioning Bryde's whales only in passing (e.g. Van Gelder, 1960; Wells *et al.*, 1981; Leatherwood *et al.*, 1982; Aguayo *et al.*, 1986). Our data, however, demonstrate that Bryde's whales were at least as abundant as fin whales in the Canal de Ballenas. Detailed studies off La Paz, B.C.S., in the Southern Gulf of California have also found relatively large numbers of Bryde's whales (J. Urbán pers. comm.; S. Flores pers. comm.). The small numbers of Bryde's whales reported in previous studies may be due to Bryde's whales being mistakenly identified as fin whales, or to these studies being conducted primarily in winter and spring when fin whales appear to be more abundant than Bryde's whales.

Seasonal distribution

Blue whales are found in the southern Gulf primarily between February and June with a peak in sightings between mid-March and mid-April (Sears *et al.*, 1987; Vidal *et al.*, 1986). They have also been reported in the Gulf during the fall (Leatherwood *et al.*, 1982; Yochem and Leatherwood, 1985). Matches of photo-identified individuals confirm that blue whales migrate between the Canal de Ballenas, Loreto (Baja California Sur) and the Pacific coast of central California where they peak in abundance between mid-August and mid-October (Table 2; Sears *et al.*, 1987; Calambokidis *et al.*, 1990). Except for the two individuals sighted in October (a cow/calf pair) our sightings support this general pattern.

Minke whales in some temperate and sub-tropical areas are present year-round (Leatherwood *et al.*, 1982; Dorsey, 1983), and in other areas their migrations are more protracted than those of sei and fin whales (Best, 1982). In the Canal de Ballenas minke whales are probably present in all months of the year. Identified individuals have a relatively high resighting rate, although much lower than was found for Washington state (Dorsey, 1983).

The seasonal distribution and apparent water temperature preferences of fin and Bryde's whales found in the Canal de Ballenas are similar to those found in other parts of the world. Ohsumi (1977) showed that 97% of the fin whales taken in the North Pacific by the Japanese fleet were in water colder than 15°C and 92% of the Bryde's whales were taken in water 18°C or warmer. The distribution of Bryde's whales is often considered to be limited by the 20°C isotherm (Omura, 1959; Privalikhin and Berzin, 1978). However, in coastal upwelling areas the inshore form is found in temperatures as low as 12°C and frequently in waters between 15° and 18°C (Best, 1960; Gallardo, Arcos, Salamanca and Pastene, 1983).

Bryde's whales are generally considered less migratory than their congeners but are known to undertake limited north-south migrations in several areas (Best, 1960; 1977; Valdivia, Franco and Ramirez, 1981; Leatherwood & Reeves, 1983). During the winter and spring, Bryde's whales most likely concentrate in other parts of the Gulf of California or disperse over a large area. Although concentrations of Bryde's whales, including some individuals identified in the Canal de Ballenas, have been reported in Loreto during the summer (Flores and Fleischer, 1987; 1988), winter and spring concentrations have not been recorded.

If the fin whales in the Gulf of California are a resident or isolated population, then the low numbers of fin whales in the Canal de Ballenas we observed during the summer and fall are curious because summer sea surface temperatures are 2–5° lower there than in any other part of the Gulf of California (Badan-Dangon *et al.*, 1985; Alvarez-Borrego, 1983). Furthermore, Urbán, Aurioles and Aguayo (1988) reported that 77.4% of all fin whale sightings in the southern Gulf of California were in the winter and spring; a similar seasonal distribution is seen in the Guaymas region of the eastern Gulf (L. Findley, pers. comm.). If, however, they are part of the eastern North Pacific stock, the observed seasonal distribution makes more sense. Tagging studies in the eastern North Pacific (discussed in Leatherwood *et al.*, 1982) indicate that fin whales summer from the Aleutian Islands and Gulf of Alaska down to central California and winter from California south (see also Gambell, 1985).

The larger scale seasonal distribution of fin and Bryde's whales in the Gulf of California could be better understood by: (1) conducting simultaneous studies in several parts of the Gulf using consistent photo-identification and censusing methodology; (2) pooling existing data on abundance and seasonal distribution from Gulf of California census cruises and analyzing it in a consistent manner; and (3) making a comprehensive effort to compare balaenopterid photo-identification data from the rest of the Gulf of California and the North Pacific with our data from the Canal de Ballenas.

Population composition

Sex and/or age segregation has been inferred from catch data for fin (Laws, 1961; Martin, 1982) and minke whales (Jonsgård, 1962; Kasamatsu and Ohsumi, 1981; Best, 1982). The fact that cow/calf pairs made up only 1% of the fin whales observed over the course of this study indicates that the Canal de Ballenas is used more heavily by

immatures, resting females, or adult male fin whales. Bryde's whale cow/calf pairs, in contrast, make up over 7% of all sightings. This is close to the 9% observed by Rice (1979) in the equatorial eastern Pacific.

The pattern of greater residency observed amongst known female Bryde's whales is fairly common in mammals. Whether it is due to the different energetic demands experienced by males and females (Clutton-Brock, Guinness and Albon, 1982), the general tendency for males to emigrate from their natal territory (Lee and Cockburn, 1985; Eisenberg, 1981), or differing reproductive strategies (Sherman, 1981), is not clear.

The tendency for lactating females to be thinner than pregnant or resting females and undetermined sex whales indicates that lactation and other forms of maternal investment are a substantial energetic cost for female Bryde's whales, as has been found in blue, fin, and sei whales (Lockyer, 1981; 1987).

Best (1977) has demonstrated the existence of sympatric offshore and inshore forms of Bryde's whale off South Africa. The offshore form is heavily scarred, has a peak of conception in autumn and is primarily planktivorous. The smaller inshore form has very little scarring, has a relatively unrestricted breeding season and is primarily piscivorous. These two forms also occur in the western North Pacific (Omura, 1977). As off South Africa, the offshore form appears to feed primarily on plankton and is heavily scarred, while the inshore form is primarily piscivorous and relatively free of scarring (Kawamura and Satake, 1976).

Limited evidence suggests that the inshore form may be present off Baja California (IWC, 1977) and our own data support this. Analysis of photographs as well as surface and subsurface observations of Bryde's whales in the Canal de Ballenas show an almost total absence of scarring. Bryde's whales in the Canal de Ballenas fed primarily on fish (Tershy and Breese, 1987). Calves of various sizes were seen at the same time throughout the year (Breese and Tershy, 1987).

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