

**Aspects of the behaviour and ecology of grey whales, *Eschrichtius robustus*
off the central coast of mainland British Columbia**

BY

Deborah A. Randall

The University of British Columbia

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ABSTRACT

We studied grey whales (*Eschrichtius robustus*) off the central coast of mainland B.C. near Cape Caution from 1994-1999, with all observations between late June and early September each year. Individual identification of grey whales using photographs of natural markings enabled us to make repeated observations of the same individuals over six years of study. All whales identified in this study were considered summer residents. We identified a total of 78 animals over six summers. Of these, 56% (44 of 78) returned in more than one summer. Some individuals were identified in as many as four or five summers. Grey whale abundance (the number of individuals identified per day of survey effort) was highest in 1997 and lowest in 1998 and 1999. Intra-year abundance was highest in September in most years of observation. Individuals moved in and out of the study area each summer indicating that the range of most if not all animals extended outside our study area. Residency patterns were similar for all years from 1996 to 1999, however whales appeared to spend less time in the study area in 1998 than in other years. Within our study area whales varied in the degree of site fidelity they exhibited both within and between years. While the population as a whole fed along most of the coastline in 1996 and 1997, habitat utilization patterns changed in 1998 and 1999. In these years, whales were sighted most frequently in and around primary feeding sites while secondary and tertiary feeding sites experienced reduced use. Seasonal and annual variation in grey whale abundance, residency and habitat utilization most likely coincided with changes in food availability in the study area. Changes in grey whale feeding behaviour in 1998 and 1999 were probably at least in part due to decreased food availability in our study area as a result of the 1997-1998 El Niño event.

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INTRODUCTION

California grey whales (*Eschrichtius robustus*) migrate annually between winter breeding grounds off the coast of Baja California and summer feeding grounds in the Bering and Chukchi Seas (Pike 1962, Rice & Wolman 1971, Braham 1984, Clarke *et al.* 1989). Breeding and calving occurs in the warm, shallow, protected waters of lagoons along the Mexican coast from early January to the end of February (Pike 1962, Rice & Wolman 1971). The northward migration extends from mid-February to October with the peak abundance of grey whales off Alaska occurring from April to June (Rice & Wohman 1971, Braham 1984). The southward migration occurs from October through January (Pike 1962, Rice & Wolman 1971). Most individuals travel more than 18,000 kilometres to complete the migration from subtropical breeding waters to Arctic feeding grounds (Rice & Wolman 1971). Earlier observations of grey whales lingering along the coasts of California, Oregon, Washington and British Columbia suggested that some whales occupy summer feeding grounds south of Alaska rather than completing the full migration (Pike 1962, Pike & MacAskie 1969, Rice & Wolman 1971, Hatler & Darling 1974).

Recent observations in British Columbia have confirmed the existence of a summer resident population of grey whales along the west coast of Vancouver Island (Hatler & Darling 1974, Darling 1978, Darling 1984). Hatler and Darling (1974) found that grey whale occurrence along the outer coast of Vancouver Island was common during the summer months and some individuals appeared to remain in the area all year. Darling (1978, 1984) later identified individual whales returning to Vancouver Island over several years. From these observations, he estimated that a resident population of

35-50 grey whales occupies summer feeding grounds off the west coast of Vancouver Island from about April to December, between northern and southern migrations. Resident grey whales range from Victoria to Cape Scott, apparently moving among feeding sites (Darling 1978, 1984).

Grey whales exploit several prey types off Vancouver Island. These include both benthic species such as amphipods (*Ampelisca* spp.) and ghost shrimp (*Callinassa californiensis*), and planktonic species such as mysids (*Holemsimysis sculpta*, *Neomysis rayii*, *Acanthomysis* spp.) and crab larvae (*Cancer magister* megalops) (Hatler & Darling 1974, Murison *et al.* 1984, Darling *et al.* 1998). Darling *et al.* (1998) found that there is year-to-year variability in both the feeding locations and prey types exploited by grey whales off Vancouver Island.

Previous studies have also documented the presence of grey whales along the B.C. mainland coast northeast of Vancouver Island (Darling 1974, 1984, Darling *et al.* 1998). However, grey whale abundance, distribution and habitat utilization in this area remain poorly understood. We observed grey whales off the central coast of mainland B.C. near Cape Caution, just north of Vancouver Island, from 1994 to 1999. Individual identification of grey whales using photographs of natural markings enabled us to make repeated observations of the same individuals over six years of study. Grey whales bear unique patterns of black and white pigmentation on their flanks and flukes making them relatively easy to identify. Photo-identification has been used previously to identify individual grey whales (Hatler & Darling 1974, Darling 1978, 1984, Calambokidis *et al.* 1994) and similar techniques have been used to identify other cetacean species including humpback whales, *Megaptera novaeangliae* (Katona *et al.* 1979, 1980), killer whales,

Orcinus orca (Bigg 1982), blue whales, *Balaenoptera musculus* (Sears 1984, Sears *et al.* 1987), and minke whales, *B. acutorostrata* (Dorsey 1983).

The objectives of this study were: (1) to estimate grey whale abundance off the central coast of mainland B.C. from 1994 to 1999, (2) to determine the spatial and temporal distribution of grey whales and (3) to describe habitat use patterns of the population.

The data from this study may further be used in conjunction with other grey whale studies to determine the movements of grey whales over their entire summer range. Darling (1984) speculated that the animals off the west coast of Vancouver Island form part of a larger northwest population. He speculated that at least 100 animals occupy the British Columbia-Washington-Oregon area during the summer. The results of this study will describe the ecology and behaviour of grey whales ranging onto the central mainland coast of B.C. and improve our understanding of the feeding ecology and movement of grey whales over their entire Pacific Northwest summer range.

METHODS

Study Area and Grey Whale Surveys

This study operated northeast of Vancouver Island in the area extending from Port Hardy to Bella Bella, B.C. All surveys for grey whales focused on the central coast of mainland B.C. extending approximately 50 kilometres from Shelter Bay to Rivers Inlet (centred on Cape Caution at 51.16 N, 127.79 W, Fig. 1). This part of the B.C. coast is characterized by rocky shores and cliffs as well as sandy bays. Nearshore kelp (*Nereocystis luetkeana*) beds are common on reefs along the coastline.

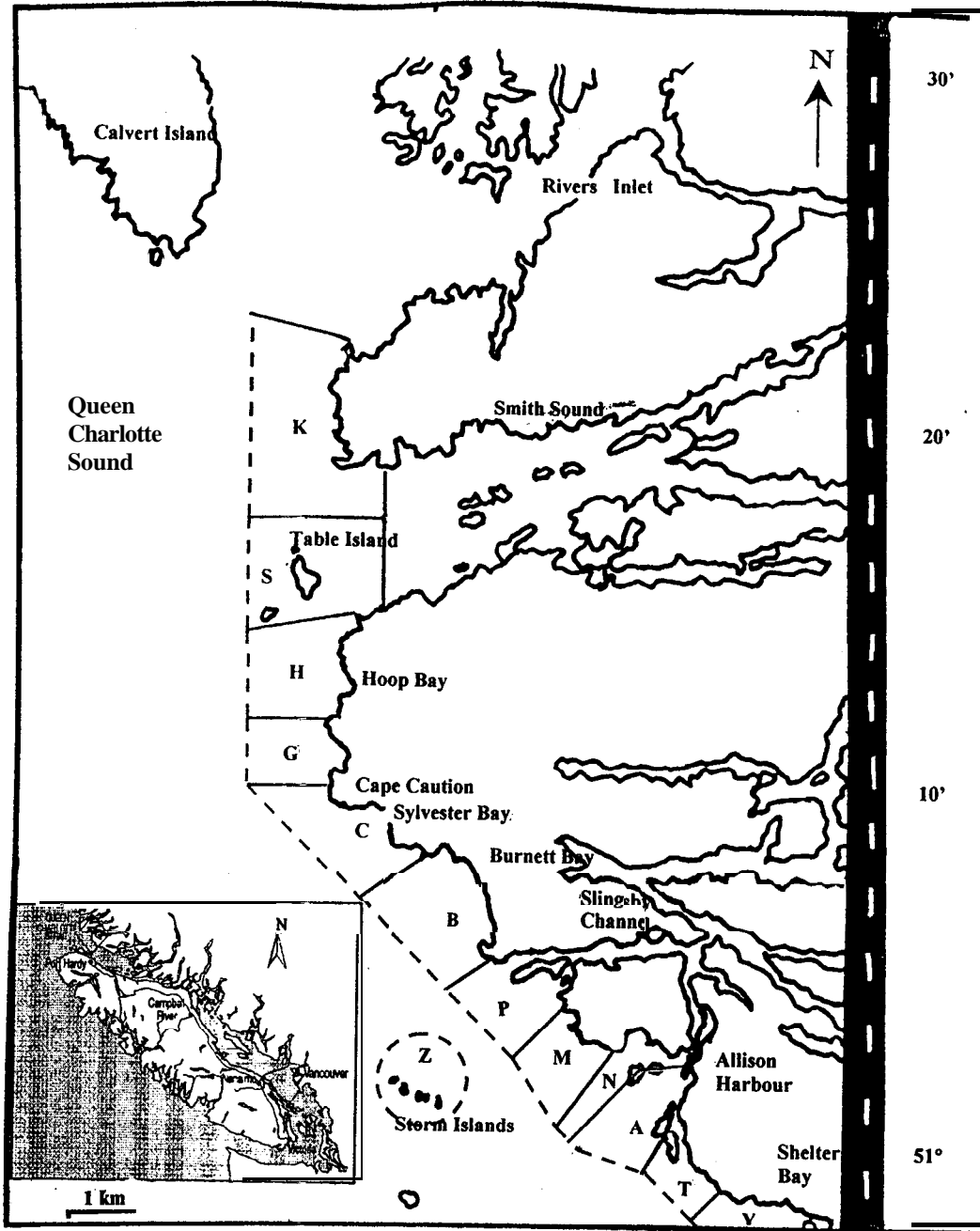


Figure 1. Map of study area and zone boundaries.

All data in this study were collected during the months of June to September from 1994 to 1999. Surveys were conducted by observation crews of 2-8 people aboard several vessels (Table I). All surveys were conducted during daylight hours (0630 - 2100). Most surveys were within 2 km of shore since this is where the majority of grey whales were observed (Darling 1984). However, our surveys extended more than 2 km from the mainland in some areas to include islands and reefs where whales were regularly observed (Fig. 1). Shore sightings from our camp were also recorded.

The survey area was divided subjectively into 13 zones (Fig. 1). Zones were determined such that a whale present within a particular zone could be seen from all points within that zone. Dividing the study area into zones simplified our subsequent analysis of survey effort along the coastline. We attempted to allocate equal survey time to all zones from Shelter Bay to Rivers Inlet within each year of observation to ensure an accurate description of grey whale distribution and habitat use. We also attempted to equalize survey effort in all zones between years to ensure an accurate description of grey whale abundance over the six years of study. Table II summarizes survey effort from 1994 to 1999. Total survey effort was low in 1994 and 1995 compared to the following years of study. Additionally, in 1994, surveys were conducted only in the southern part of the study area (Shelter Bay to Burnett Bay), and in 1995, survey effort was highly concentrated in this same area. To eliminate any biases in the data resulting from unequal survey effort, we excluded data from 1994 and 1995 in some of our analyses.

From 1996 to 1999, we designed our survey effort to monitor the presence or absence of individuals within the entire study area over the course of each summer observation period and over each year of study (Fig. 2). Effort within zones was

Table I. Boats used to survey for grey whales (X= used)

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---------------------------------------|------|------|------|------|------|------|
| MV Lagtime ,5.3 m motorboat | x | x | x | x | | X |
| SV Feel Free, 17.0 m sailboat | | X | | | | |
| SV Dagon, 13.0 m sailboat | | | x | x | x | |
| MV Etta Pace, 6.0 m motorboat | | | | | X | |
| MV Seabreeze, 11.6 m ex-forestry boat | | | | | | X |
| FV Star Dust, 12.6 m ex-gilnetter | | | | | | X |
| MV Theodore, 8.0 m crew boat | | | | | | X |

Table II. Survey effort for grey whales off the central coast of mainland, B.C., 1994-1999.

| | <u>1994</u> | 1995 | 1996 | <u>1997</u> | <u>1998</u> | <u>1999</u> |
|---|-----------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
| Period of observation | July 24- Sept. 10 | July 9- Sept. 2 | June 16- Sept. 7 | June 29- Sept. 13 | June 2 1- Sept. 12 | June 26- Sept. 10 |
| Number of weeks of observation | 7 | 7 | 12 | 11 | 12 | 11 |
| Number of days of observation | 11 | 37 | 58 | 64 | 57 | 70 |
| Number of hours of observation | 38 | 226 | 366 | 468 | 307 | 358 |
| Mean (\pm SE) hrs. of observation per week | <u>5 \pm 2</u> | <u>26 \pm 5</u> | <u>36 \pm 3</u> | <u>40 \pm 4</u> | <u>25 \pm 3</u> | <u>33 \pm 2</u> |

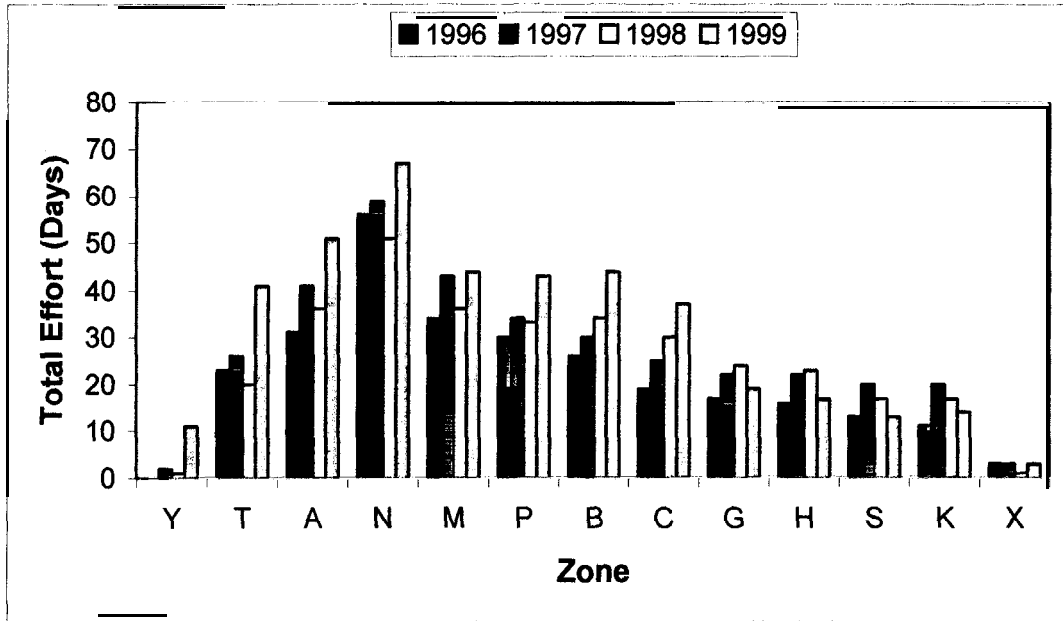


Figure 2. Survey effort per zone, 1996- 1999. Values represent the number of days we surveyed for grey whales in each zone. Figure 1 shows zone boundaries.

unequal, with the greatest effort in zone N, the location of our camp. Effort decreased in the northernmost and southernmost zones, and zone X (encompassing the offshore Storm Islands, Fig. 1). All zones were surveyed on at least one day of each week, with the exception of zone X, the Storm Islands, and zone Y, Shelter Bay. Shelter Bay was not included in our weekly surveys until 1999, and the Storm Islands were surveyed only occasionally in all four years.

We assumed that individuals not photographed within a given year were not present in the study area that summer. We could not say for certain whether a whale was present in the study area for all days between the first and last sighting in each summer. If whales left the study area for a period of time and then returned, using the number of days between first and last sightings would have overestimated individual occupancy time. To alleviate this bias, we used weekly intervals to measure individual occupancy time from 1996 to 1999. In these years, we surveyed the entire coastline within the study area each week by making one complete survey from the southernmost portion of the study area to the northernmost portion of the study area in one day and the reverse survey route in another day of that week. On all other days in each week we surveyed only specific portions of the study area in a given day. Using this survey method we assumed that if a whale was present in the study area it would be sighted in a given week of surveys. We then used the number of weeks that an individual was sighted in one summer as our measure of occupancy time. Occupancy time will only be overestimated using this method if whales were not present in the study area for the entire week in which they were sighted.

Individual Identification

Photo-identification was based on photographs taken using SLR cameras with SO-300mm zoom lenses and Kodak 3200 ASA black and white film. Individual whales were recognized by the light and dark skin patterns on their right and left flanks (sides) and the ventral surface of their tail flukes. Natural markings were usually white or grey on a dark background. For each whale sighted, we attempted to obtain photographs of both flanks and the ventral tail surface. All photographs of flanks were taken when whales surfaced to breathe. Tail fluke pictures were obtained when whales “fluked” (displayed the tail above the surface of the water at the onset of a deep dive). Visual identification of each whale was made in the field and later double-checked using the photographs to ensure that a correct identification had been made.

We developed the negatives of the photographs and scanned them using a Hewlett-Packard Photosmart scanner and software developed in our lab for grey whale photo identification. We established a digital photographic-catalog of all grey whales sighted in the survey area over the six years, catalogued by year to establish a record of repeated sightings. A hard copy of this catalogue was carried on all surveys in 1999 to aid in immediate visual identification of individuals in the field. Some whales had more obvious markings than others but all individuals were identifiable by photographs; Figure 3 shows the different patterns of natural markings on the right sides of three whales identified in this study

Grey whales are born with their markings and appear to maintain them throughout their lives (Rice & Wolman 1971, Darling 1984). Darling (1978, 1984) found that some grey whale markings did change or disappear over time, but most were permanent. In

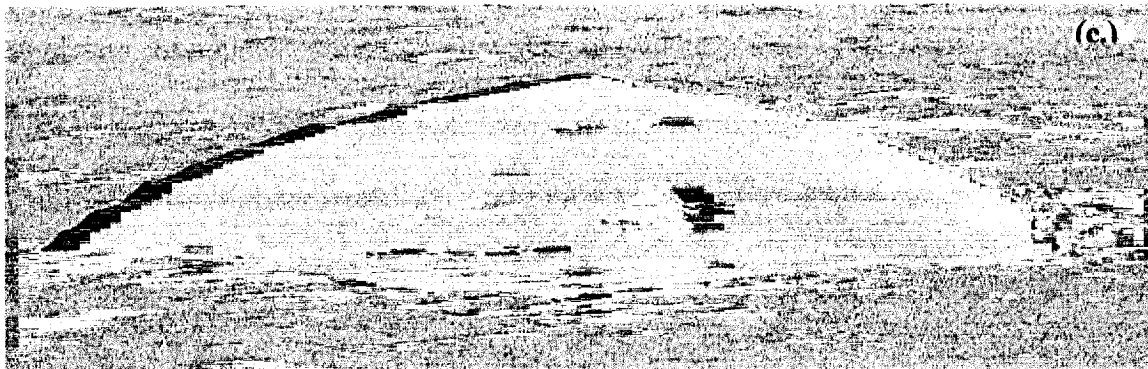
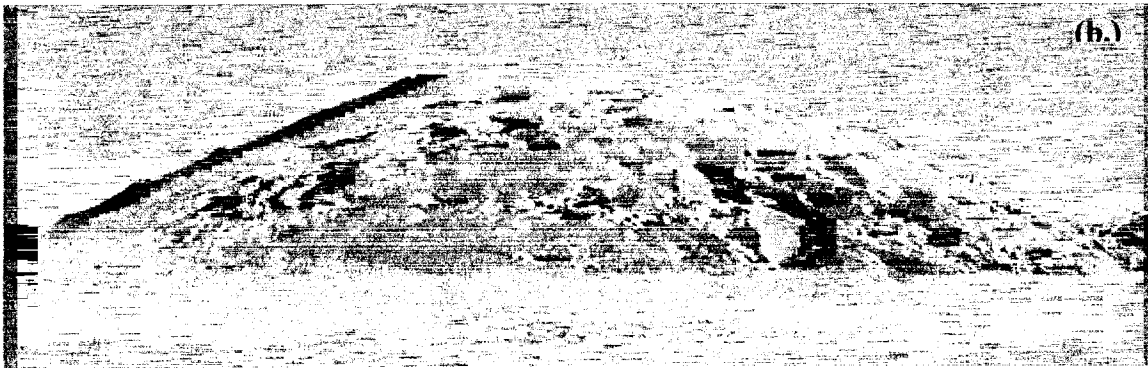
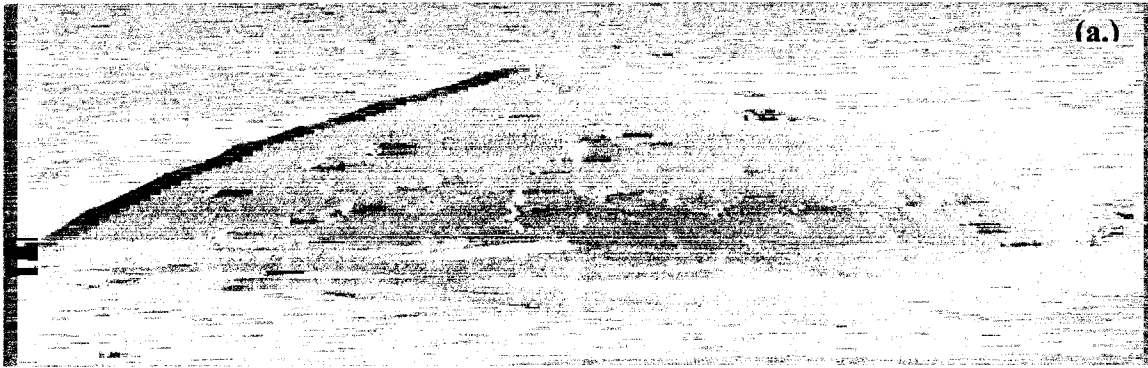


Figure 3. Examples of skin patterns used to identify individual grey whales: (a) whale G052 in 1994, (b) whale G014 in 1996, and (c) whale G012 in 1999 (all right sides).

most cases, we used several details in the skin pattern to identify animals, so small changes in a few natural markings did not affect identification. Notice that the patterns on the left side of whale G051 changed very little from 1994 to 1999 and are easily identifiable in both years (Fig. 4).

Grey whales also have scars, barnacle (*Cryptolepus rhachianceti*) patches and cyamids (*C. scammoni*, *C. ceti*, *C. kessleri*). Barnacles are most often found in clusters on the most anterior part of the back and dorsal aspect of the rostrum while cyamids cluster around barnacles and wounds (Rice & Wolman 1971). Scars were sometimes used for identification, as in the case of whale G017 (Fig. 5), while barnacles and cyamids were never used for identification since they are hard to distinguish in photographs. Scars were always used in conjunction with other skin patterns for identification.

Abundance

We did not use a mark-recapture model to estimate abundance since the population did not meet the assumption of homogeneity of capture (Hammond 1986) as a result of inherent differences in the behaviours of individuals and their degree of site fidelity. Yearly relative abundance was taken to be the number/of grey whales identified per day of survey effort. Days of effort were used instead of hours of effort since hours of effort tended to depend on the abundance of whales; more hours per day were spent photographing and observing whales when there were more whales in the study area.

Distribution and Habitat Use

For each grey whale sighting, we also recorded the animal's location in order to

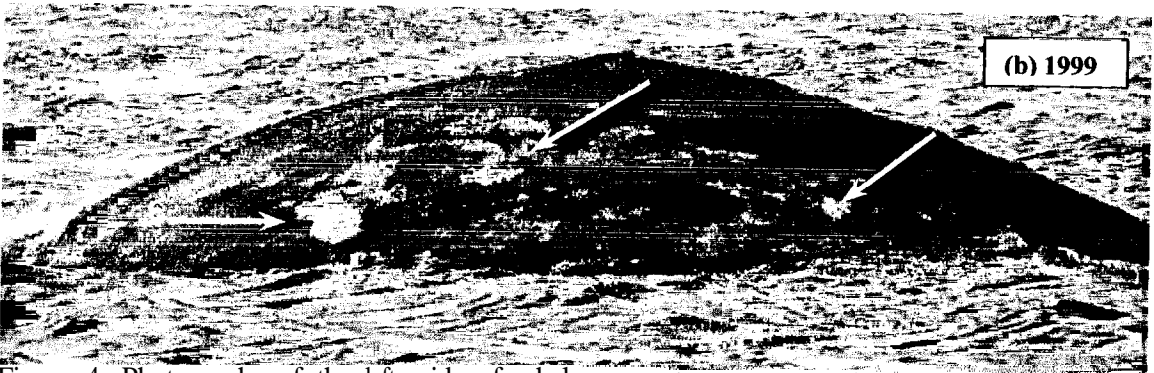
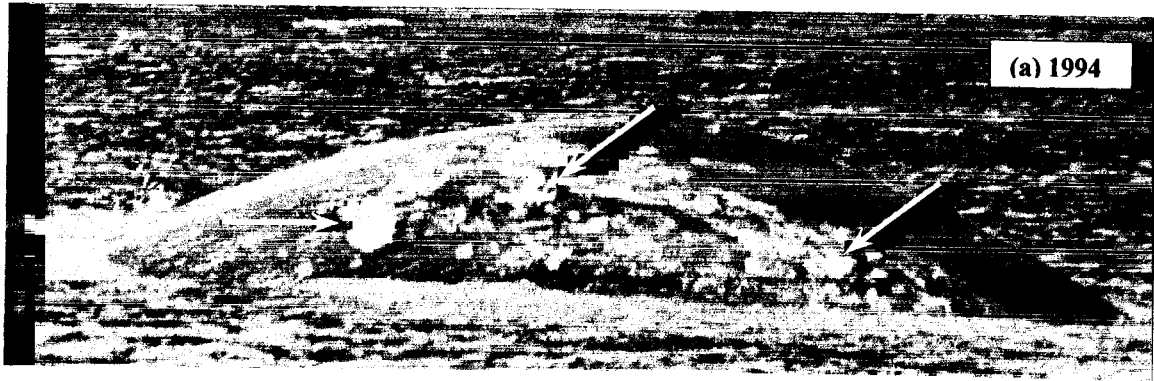


Figure 4. Photographs of the left side of whale G051 in (a) 1994 and (b) 1999. Arrows indicate three common reference points.

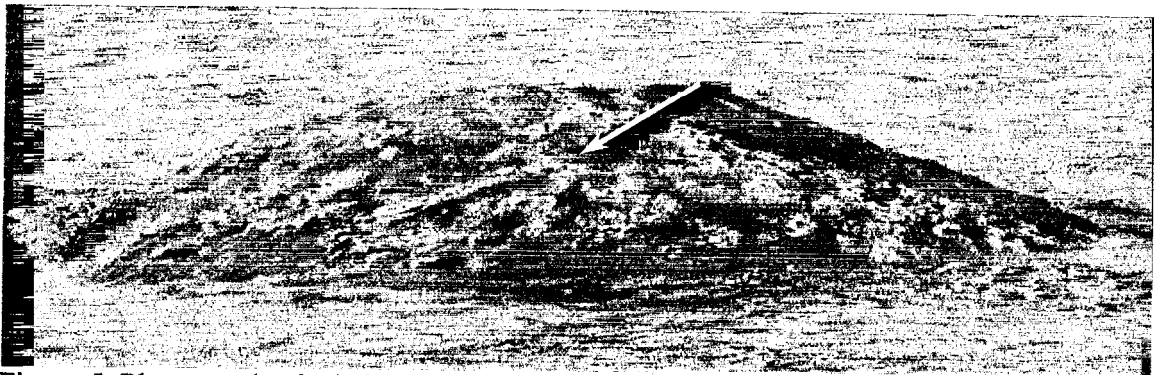


Figure 5. Photograph of whale G017 in 1999. Arrow indicates the scar on the left side used for identification.

determine the distribution and habitat use patterns of the population. The location of each whale was recorded as the distance and direction from a nearby landmark (island, point, bay etc.). We later estimated GPS coordinates for all sightings of all whales from 1996 to 1999 by plotting the location relative to nearby landmarks onto digital maps using Fugawi Navigation software (Northport Systems, Inc., Toronto). These coordinates were plotted along a linear transect from Shelter Bay to Rivers Inlet, centred on Cape Caution. The transect ran due north and southeast of Cape Caution: positive values for whale locations indicated positions due north of Cape Caution, while negative values indicated positions southeast of Cape Caution (Fig. 1).

Home range size was calculated as the greatest distance between sightings for each individual along this transect. Only those individuals sighted more than once in a given year were included in our analysis of home range size. The distribution of all grey whale sightings in each year was determined using the number of sightings at each location along this transect. The number of sightings was corrected for effort by dividing by the number of days of effort spent surveying at each location.

Statistical Analyses

We used JMP IN Start Statistics software (Sall & Lehman 1996) for all statistical analyses in this study. Non-parametric tests were applied since the data did not meet the assumptions of normality and equal variances. P- values of 0.05 were used to determine statistical significance. Descriptive statistics are expressed as means (\pm SE) in this paper.

RESULTS

Individual Identification

We identified 78 different grey whales in the study area from 1994- 1999 using photographs of their natural markings. Figure 6 shows the cumulative discovery rate of grey whales from 1994 to 1999. Most individuals were identified by 1997, and the number of new individuals identified each year was lower in 1998 and 1999 than in all other years (Fig. 6, Table III). We obtained pictures of both flanks of all individuals identified in 1994. In 1995, we photographed only the right flank of 3 individuals, and only the left flank of 1 individual. Thus, we may have double-counted 1 individual in 1995. From 1996 to 1999, we photographed only the left flank of 7 individuals, and only the right flank of 2 individuals. Thus, we may have double-counted 2 individuals in these four years, one in 1998 and one in 1999. From this we concluded that a minimum of 75 whales ranged onto the central coast of mainland B.C. from 1994 to 1999.

The largest number of whales identified in one summer was 51 in 1997 (Table III). The low number of whales identified in 1994 reflects our survey effort for that summer (Tables II and III). Fewer whales were sighted in 1998 and 1999 than in the previous 3 years despite higher survey effort in 1999. The number of new whales identified in one summer was highest in 1995 (25 individuals) and lowest in 1998 (3 individuals) (Fig. 6, Table III).

Of the 78 grey whales we identified between 1994 and 1999, 34 individuals were sighted in only one summer (Tables III and IV) and 44 individuals were sighted in more than one summer (Table V). None of the 44 animals that were sighted in multiple years were sighted in all 6 summers. Nine individuals were sighted in 5 years, 10 individuals

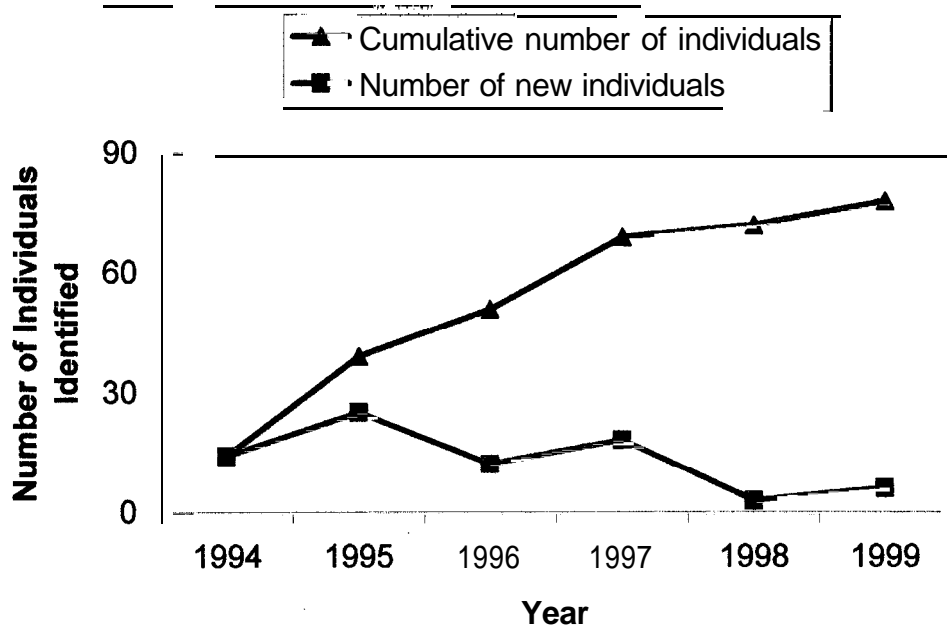


Figure 6. Discovery rate of grey whales off the central coast of mainland B.C. Total identified individuals and new individuals shown separately.

Table III. Grey whale identification off the central coast of mainland B.C., 1994 - 1999

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|------|------|------|------|------|------|
| Number of whales identified in this year | 14 | 32 | 33 | 51 | 27 | 22 |
| Number of new whales identified | 14 | 25 | 12 | 18 | 3 | 6 |
| Number of whales seen in only this year | 2 | 7 | 6 | 10 | 3 | 6 |
| Number identified per unit effort (days of observation) | 1.27 | 0.86 | 0.57 | 0.80 | 0.47 | 0.31 |
| Number of new whales identified per unit effort (days of observation) | 1.27 | 0.66 | 0.57 | 0.32 | 0.05 | 0.09 |

Table IV. Grey whales identified in only one year off the central coast of mainland B.C., 1994-1 999. Values represent the number of days each whale was sighted each year.

| Whale ID | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|----------|------|------|------|------|------|------|
| G002 | 2 | | | | | |
| G053 | 1 | | | | | |
| G018 | | 1 | | | | |
| G019 | | 1 | | | | |
| G025 | | 1 | | | | |
| G027 | | 1 | | | | |
| G034 | | 1 | | | | |
| G035 | | 1 | | | | |
| G044 | | | 5 | | | |
| G045 | | | 3 | | | |
| G047 | | | 1 | | | |
| G048 | | | 4 | | | |
| G050 | | | 3 | | | |
| G056 | | | 1 | | | |
| G020 | | | | 3 | | |
| G023 | | | | 3 | | |
| G058 | | | | 3 | | |
| G059 | | | | 3 | | |
| G060 | | | | 4 | | |
| G062 | | | | 2 | | |
| G065 | | | | 1 | | |
| G066 | | | | 1 | | |
| G068 | | | | 1 | | |
| G069 | | | | 1 | | |
| G072 | | | | | 2 | |
| G073 | | | | | 1 | |
| G075 | | | | | 1 | |
| G077 | | | | | | 1 |
| G078 | | | | | | 2 |
| G079 | | | | | | 3 |
| G080 | | | | | | 2 |
| G081 | | | | | | 2 |
| G082 | | | | | | 1 |
| Total | 2 | 7 | 6 | 10 | 3 | 6 |

Table V. Grey whales identified in more than one year off the central coast of mainland B.C., 1994- 1999. Values represent the number of days each whale was sighted each year.

| Whale ID | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|----------|------|------|------|------|------|------|
| G001 | 1 | 1 | 1 | 16 | 4 | |
| G004 | 2 | 4 | 16 | 14 | 2 | |
| G011 | 1 | 10 | 9 | 14 | 2 | |
| G005 | 3 | 14 | 20 | 21 | | 17 |
| G006 | 1 | 3 | 15 | 15 | | 12 |
| G007 | 1 | 2 | 4 | 2 | | 9 |
| G051 | 2 | 4 | 8 | 15 | | 4 |
| G038 | 1 | | 9 | 16 | 2 | |
| G042 | 1 | | 7 | 17 | 5 | |
| G037 | 1 | | 9 | 18 | | |
| G003 | 6 | | 1 | 8 | | |
| G052 | 1 | | | | 9 | |
| G014 | | 1 | 34 | 7 | 14 | 33 |
| G017 | | 1 | 5 | 9 | 4 | 20 |
| G009 | | 1 | 7 | 8 | 11 | |
| G033 | | 1 | 2 | 17 | 1 | |
| G049 | | 1 | 2 | 2 | | 3 |
| G010 | | 2 | 1 | 1 | | |
| G015 | | 3 | 10 | 13 | | |
| G032 | | 2 | 3 | 4 | | |
| G030 | | 1 | 9 | 2 | | |
| G012 | | 5 | 3 | | 2 | 13 |
| G031 | | 1 | | 13 | 3 | 3 |
| G022 | | 1 | | 1 | 1 | |
| G008 | | 11 | | 9 | | |
| G026 | | 1 | | 2 | | |
| G021 | | 1 | | 8 | | |
| G024 | | 2 | | 5 | | |
| G057 | | 1 | | 2 | | |
| G016 | | 1 | | | 1 | |
| G040 | | | 8 | 13 | 17 | 10 |
| G041 | | | 4 | 7 | 4 | 11 |
| G054 | | | 1 | 27 | 4 | 2 |
| G046 | | | 1 | 14 | 1 | |
| G039 | | | 3 | 2 | 1 | |
| G036 | | | 14 | 3 | | |
| G067 | | | | 1 | 1 | 2 |
| G043 | | | | 9 | 9 | |
| G061 | | | | 5 | 2 | |
| G063 | | | | 2 | 1 | |
| G064 | | | | 4 | 1 | |
| G028 | | | | 13 | | 2 |
| G029 | | | | 3 | | 1 |
| G055 | | | | 4 | | 1 |
| Total | 12 | 25 | 27 | 41 | 24 | 16 |

were sighted in 4 years, 10 individuals were sighted in 3 years, and 15 individuals were sighted in 2 years. Of the whales returning in more than one summer, 21 individuals were not seen in 1 intervening summer, 1 individual was not seen in 2 intervening summers, and 1 individual was not sighted for 3 intervening summers (Table V).

Figure 7 shows the discovery rate of grey whales each summer (1996- 1999). The discovery rate was highest at the beginning of each study period (June - July) and then leveled off, suggesting that most individuals in the study area had been identified by the beginning of August. A few new individuals were identified at the end of August and beginning of September each year. We were unable to account for whales ranging into the study area before the third week of June or after the second week of September (ie. outside our observation period). Thus, our results most likely underestimate the actual number of whales that used our study area as part of their summer range.

Abundance

Grey whale abundance increased from 1996 to 1997 and decreased from 1997 to 1999 (Fig. 8). Grey whale abundance was lowest in 1998 and 1999. Our preliminary surveys for grey whales in 1994 and 1995 did not cover the entire study area, so data from these years were excluded from this analysis.

Grey whale abundance generally increased from June to September (1996- 1999 averaged, Table VI). The wide range in abundance at the beginning of September (0.6 - 8.7 whales identified per day) over the four years led to a large standard error in mean abundance for this period (Table VI). Despite this variation, whale abundance was highest at the beginning of September in three (1996, 1997, 1999) out of the four years (Table VI); grey whale abundance decreased in September.

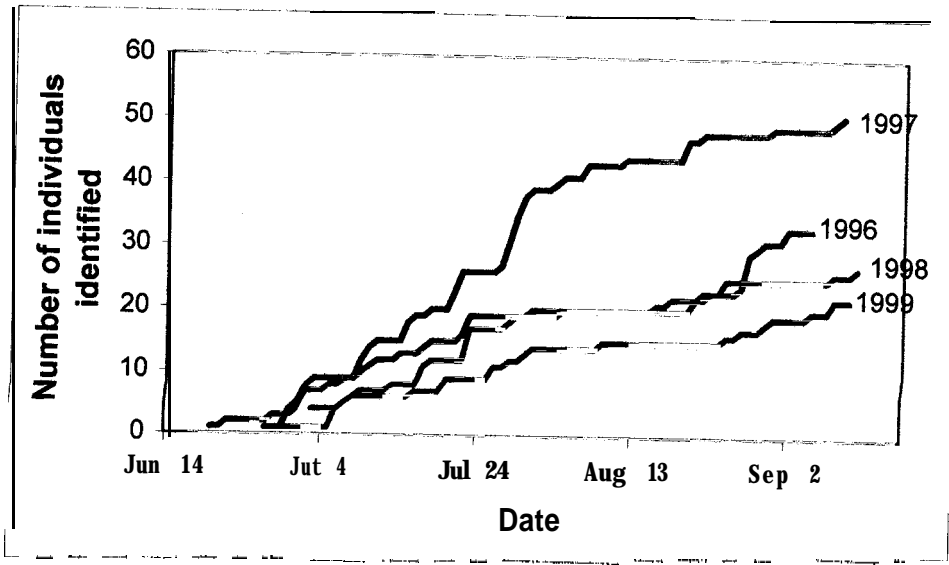


Figure 7. Discovery rates of grey whales off the central coast of mainland B.C. each summer of observation, 1996- 1999. 1994 and 1995 were excluded because of uneven sampling in those years.

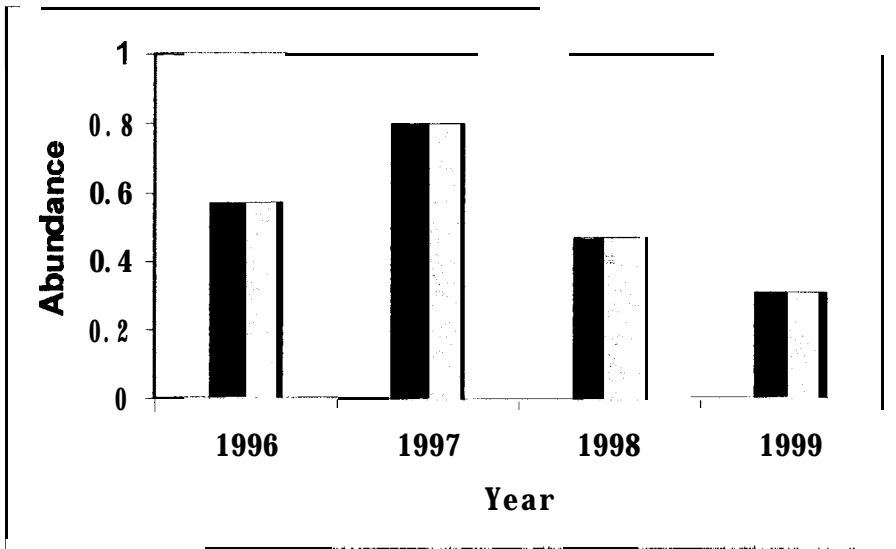


Figure 8. Abundance of grey whales off the central coast of mainland B.C., 1996 - 1999. Values represent the number of whales identified per day of survey effort.

Table VI. Grey whale abundance per half month off the central coast of mainland B.C., 1996-1999. Abundance is the number of whales identified per day of survey effort.

| | 1996 | 1997 | 1998 | 1999 | Average |
|-------------------------|-------------|-------------|-------------|-------------|----------------|
| June 15-30 | 1.0 | 2.0 | 0.0 | 0.3 | 0.8 +/- 0.5 |
| July 1 - 15 | 1.1 | 1.4 | 1.0 | 0.4 | 1.0 +/- 0.2 |
| July 16 - 31 | 1.1 | 2.6 | 1.0 | 0.6 | 1.3 +/- 0.4 |
| August 1 - 15 | 0.6 | 2.3 | 1.0 | 0.8 | 1.2 +/- 0.4 |
| August 16-31 | 1.6 | 1.9 | 1.3 | 0.9 | 1.4 +/- 0.2 |
| September 1 - 15 | 8.7 | 3.1 | 0.6 | 1.5 | 3.5 +/- 1.8 |

Residency

Grey whales were sighted in the study area in all months we conducted surveys (June - September). Individuals were identified as early as June 22 (G014, 1996) and as late as September 11 (G014, 1998). Since we made no observations before June or after September in any year, we do not know if whales were in the study area from April to May or from October to December as suggested by Darling (1984) for Vancouver Island grey whales. The longest duration between first and last sightings for any individual in one summer was 76 days: in 1996, GO 14 was first sighted on June 22 and last sighted on September 5 (GO14 was sighted 34 times in 1996, Table V). At the other extreme, several individuals were sighted on only one day in a given summer. This demonstrates that there was a high degree of individual variation in the amount of time whales occupied the study area during the summer.

Figures 9-12 summarize all grey whale sightings by week from 1996 to 1999. Some individuals were sighted in the study area in all weeks of observation (e.g. G014 was present for 12 consecutive weeks in 1996 and 11 consecutive weeks in 1999; GO54 was present for 11 consecutive weeks in 1997). Most individuals were absent from the study area for one or more weeks during the summer. An 'absence' refers to a period of time that a whale was not present in the study area between first and last sightings, suggesting that an individual left the study area and returned. Some individuals left and returned on more than one occasion (e.g. in 1997, GO37 left the study area and returned on three separate occasions after absences of one, one and two weeks respectively).

The amount of time individuals were absent from the study area varied from one to five weeks, not necessarily consecutive (Table VII). The longest absence from the study area was five consecutive weeks (GO4 1 was identified on July 9, 1996, departed for

| GWID | June 16 - June 22 | June 23 - June 29 | June 30 - July 6 | July 7 - July 13 | July 14 - July 20 | July 21 - July 27 | July 28 - Aug 3 | Aug 4 - Aug 10 | Aug 11 - Aug 17 | Aug 18 - Aug 24 | Aug 25 - Aug 31 | Sept 1 - Sept 7 | Total |
|------|----------------------|----------------------|---------------------|---------------------|----------------------|----------------------|--------------------|-------------------|--------------------|--------------------|--------------------|--------------------|-------|
| G001 | | | | | 1 | | | | | | | | 1 |
| G003 | | | | 1 | | | | | | | | | 1 |
| G004 | | | | | | | 4 | 2 | 5 | 3 | 1 | 1 | 16 |
| G005 | | | 5 | 4 | 3 | 1 | 4 | 1 | | 1 | | 1 | 20 |
| G006 | | | | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 3 | 1 | 15 |
| G007 | | | | | | | | | | 2 | 1 | 1 | 4 |
| G009 | | | | | 1 | 1 | | | | 2 | 1 | 1 | 7 |
| G010 | | | | | | | | | | | | 1 | 1 |
| G011 | | | | | | 2 | 1 | | 2 | 1 | 2 | 1 | 9 |
| G012 | | | | | | | | | | | 1 | 2 | 3 |
| G014 | 1 | 1 | 4 | 2 | 5 | 3 | 2 | 3 | 6 | 3 | 2 | 2 | 34 |
| G015 | | | | 1 | | 1 | | | 2 | | 4 | 1 | 10 |
| G017 | | | | | | | | | 1 | 1 | 2 | 2 | 5 |
| G030 | | | | 1 | | | 1 | | 1 | 1 | 3 | 2 | 9 |
| G032 | | | | | | | 1 | | | | 1 | | 3 |
| G033 | | | | | | | | | | | 1 | 1 | 2 |
| G036 | | | | | 3 | 2 | 1 | 1 | 1 | 2 | 3 | 1 | 14 |
| G031 | | | | | | | 1 | | | 1 | 4 | 1 | 9 |
| G030 | 1 | 1 | 1 | | | | 2 | | | 1 | 2 | | 9 |
| G039 | | 2 | 1 | | | | | | | | | | 3 |
| G040 | | | | | | 1 | 1 | | | | 1 | 2 | 6 |
| G041 | | | | | | | | | | 1 | 2 | 2 | 4 |
| G042 | | | | | | | | | | 2 | 1 | 1 | 7 |
| G044 | | | | | | 2 | | | | 1 | 2 | 2 | 5 |
| G045 | | | | | | | | | | 1 | 3 | 1 | 3 |
| G046 | | | | | | | | | | | 1 | 2 | 3 |
| G047 | | | | | | | | | | | | 1 | 1 |
| G040 | | | | | | | | | | | | 1 | 1 |
| G049 | | | | | | | | | | 2 | | 2 | 4 |
| G050 | | | | | | | | | | 1 | | 1 | 2 |
| G051 | | | | | | | | | | 2 | | 1 | 3 |
| G051 | | | | | | | | | | 1 | 2 | 2 | 8 |
| G064 | | | 2 | | | | | 1 | | | | | 3 |
| G056 | | | | | | | | | | | | 1 | 1 |

Figure 9. Summary of grey whale sightings by week, 1996. Numbers indicate the number of days each individual was sighted each week.

| GWID | June 29 - July 5 | July 6 - July 12 | July 13 - July 19 | July 20 - July 26 | July 27 - Aug 2 | Aug 3 - Aug 9 | Aug 10 - Aug 16 | Aug 17 - Aug 23 | Aug 24 - Aug 30 | Aug 31 - Sept 6 | Sept 7 - Sept 13 | Total |
|------|---------------------|---------------------|----------------------|----------------------|--------------------|------------------|--------------------|--------------------|--------------------|--------------------|---------------------|-------|
| G001 | | | | | 6 | 2 | | 3 | 2 | | 2 | 16 |
| G003 | | | | 4 | | 3 | 2 | 1 | | 1 | | 8 |
| G004 | | | | | 1 | 2 | 3 | 3 | 3 | 2 | | 14 |
| G005 | | 1 | 3 | 3 | 2 | 2 | 4 | 4 | 1 | 1 | | 21 |
| G006 | | | 1 | 4 | 3 | 4 | 1 | 1 | | 1 | | 15 |
| G007 | | 1 | 1 | | | | 1 | | | | | 2 |
| G009 | | | | 1 | 1 | 2 | | 1 | | 1 | 2 | 8 |
| G010 | | | | | | | | | | 1 | | 1 |
| G011 | | | | | | 3 | 4 | 1 | 3 | | 1 | 14 |
| G014 | | | | | | | 3 | 2 | 1 | | 1 | 7 |
| G015 | | | | 1 | 2 | 3 | 4 | 2 | 1 | | | 13 |
| G017 | | | | | | 1 | 1 | 1 | 3 | | | 9 |
| G020 | | 2 | | | | 1 | | | | | | 3 |
| G021 | | | | | 1 | 1 | | 2 | 2 | 1 | 1 | 8 |
| G022 | | 1 | | | | | | | | | | 1 |
| G023 | | | | 2 | 1 | | | | | | | 3 |
| G024 | 1 | 1 | | 1 | 1 | | 1 | | | | | 5 |
| G026 | | | | | 2 | | | | | | | 2 |
| G023 | | 1 | | 1 | 3 | 2 | | 2 | 3 | 1 | | 13 |
| G029 | | | | | 2 | 1 | | | | | | 3 |
| G030 | | | | | | | | 1 | | 1 | | 2 |
| G031 | | | | 1 | 4 | 2 | 1 | 4 | 1 | | | 13 |
| G032 | | | | | | 1 | | | | | 2 | 4 |
| G033 | | | | | 5 | 2 | 2 | 4 | 2 | 2 | | 17 |
| G036 | | | 3 | | | | | | | | | 3 |
| G-37 | 2 | | 1 | | | 7 | 1 | | 4 | 2 | 1 | 18 |
| G-38 | 2 | | | 3 | 3 | | 1 | 1 | 3 | 1 | 2 | 16 |
| G039 | | | | | 2 | | | | | | | 2 |
| G040 | 1 | 1 | 1 | 3 | 1 | 1 | | 1 | 2 | 1 | 1 | 13 |
| G041 | | 1 | 1 | | 1 | 1 | | | 1 | 1 | 1 | 7 |
| G042 | | | 2 | 1 | 3 | 3 | | 2 | 3 | 1 | 2 | 17 |
| G-43 | | | | | 1 | | | 2 | 4 | 1 | 1 | 9 |
| G-46 | | 1 | 4 | 2 | | | | 3 | 2 | 2 | | 14 |
| G049 | | | | | 2 | | | | | | | 2 |
| G051 | 2 | | 3 | 1 | 1 | 3 | 1 | 3 | | 1 | | 15 |
| G054 | 3 | 2 | 3 | 4 | 4 | 4 | 1 | 2 | 2 | 1 | 1 | 27 |
| G055 | | | | | 4 | | | | | | | 4 |
| G057 | 2 | | | | | | | | | | | 2 |
| G058 | 3 | | | | | | | | | | | 3 |
| G059 | | 1 | 1 | 1 | | | | | | 1 | 1 | 3 |
| G060 | | | | | 1 | 1 | | | | | | 4 |
| G061 | | | | | 3 | | 2 | | | 1 | 1 | 5 |
| G062 | | | | | | 1 | 1 | | | | | 2 |
| G063 | | | | | | | | 2 | | | | 2 |
| G064 | | | | | | | | 1 | 2 | 1 | | 4 |
| G065 | | | | | | | | | | | 1 | 1 |
| G066 | | | | 1 | | | | | | | | 1 |
| G087 | | | | | | 1 | | | | | | 1 |
| G068 | | | | | | | | | | | | 1 |
| G069 | | | | | | | | 1 | | | | 1 |

Figure 10. Summary of grey whale sightings by week, 1997. Numbers indicate the number of days each individual was sighted each week.

| GWID | June 21 - June 27 | June 28 - July 4 | July 5 - July 11 | July 12 - July 18 | July 19 - July 25 | July 26 - Aug 1 | Aug 2 - Aug 8 | Aug 9 - Aug 15 | Aug 16 - Aug 22 | Aug 23 - Aug 29 | Aug 30 - Sept 5 | Sept 6 - Sept 12 | Total |
|------|----------------------|---------------------|---------------------|----------------------|----------------------|--------------------|------------------|-------------------|--------------------|--------------------|--------------------|---------------------|-------|
| G001 | | | 1 | | | | 1 | | 2 | | | | 4 |
| G004 | | | | | | | | | 2 | | | | 2 |
| G009 | | | | 1 | 1 | 2 | 3 | | 2 | 2 | | | 11 |
| G011 | | | | | | | | 1 | 1 | | | | 2 |
| G012 | | | | | 1 | | | | 1 | | | | 2 |
| G014 | | 1 | 1 | 1 | 1 | 1 | 3 | | | | | | 14 |
| G016 | 1 | | | | | | | | | 3 | 1 | 3 | 8 |
| G017 | | | | | | 1 | 2 | | | | | | 4 |
| G022 | | | | | | | | | 1 | | | | 1 |
| G031 | | | | 2 | | | | | 1 | | | | 3 |
| G033 | | | | | | | | | | | 1 | | 1 |
| G038 | 1 | | | | | | | | 1 | | | | 2 |
| G039 | | | | 1 | | | | | | | | | 1 |
| G040 | 1 | | | 1 | | | | | | | | | 2 |
| G041 | | | | | | 5 | 3 | | 3 | 2 | 1 | 1 | 17 |
| G042 | | | | | 1 | | | | 1 | 2 | | | 4 |
| G043 | | | | | | 2 | 1 | | | | 1 | | 5 |
| G046 | | | | | | 3 | 1 | 1 | 2 | 2 | | | 9 |
| G052 | | | 1 | 3 | 1 | 2 | 2 | | | | | | 9 |
| G054 | | | | | 1 | 3 | | | | | | | 4 |
| G061 | | | | | | 2 | | | | | | | 2 |
| G063 | 1 | | | | | | | | | | | | 1 |
| G064 | | | | | | | 1 | | | | | | 1 |
| G067 | | | | | | | | | | 1 | | | 1 |
| G072 | | | | 2 | | | | | | | | | 2 |
| G073 | | | | | | | | | | | | 1 | 1 |
| G075 | | | | | | | | | | 1 | | | 1 |

Figure 11. Summary of grey whale sightings by week, 1998. Numbers indicate the number of days each individual was sighted each week.

| GWID | June 28 - July 2 | July 3 - July 9 | July 10 - July 16 | July 17 - July 23 | July 24 - July 30 | July 31 - Aug 6 | Aug 7 - Aug 13 | Aug 14 - Aug 20 | Aug 21 - Aug 27 | Aug 28 - Sept 3 | Sept 4 - Sept 10 | Total |
|------|---------------------|--------------------|----------------------|----------------------|----------------------|--------------------|-------------------|--------------------|--------------------|--------------------|---------------------|-------|
| G005 | | 1 | | 2 | 3 | 4 | | 2 | 2 | 1 | 2 | 17 |
| G006 | | | | | | | 3 | 2 | 1 | 3 | 3 | 12 |
| G007 | | | | 2 | 2 | | 3 | 1 | | | 1 | 9 |
| G012 | | | | | | | | | 2 | 2 | 4 | 13 |
| G014 | 3 | 4 | 3 | 2 | 2 | 2 | 3 | 1 | 4 | 6 | 3 | 33 |
| G017 | | | 1 | 3 | | 2 | 2 | 2 | 2 | 3 | 5 | 20 |
| G028 | | | | | | | | | | 1 | 1 | 2 |
| G029 | | | | | | | | | | 1 | | 1 |
| G031 | 1 | | | | | 2 | | | | | | 3 |
| G040 | | | | 1 | 2 | 3 | 2 | 2 | | | | 10 |
| G041 | | | | | | 4 | 2 | 2 | 2 | | 1 | 11 |
| G049 | | | | | | | | | | | 3 | 3 |
| G051 | | | | | | | | | 1 | 2 | | 4 |
| G054 | | | | | 1 | 1 | | | | | 1 | 2 |
| G055 | | 1 | | | | | | | | | | 1 |
| G067 | | | | | 1 | 1 | | | | | | 2 |
| G077 | | | | | | | | | | | 1 | 1 |
| G078 | | | | | | | | | | | 2 | 2 |
| G079 | | | | 1 | 2 | | | | | | | 3 |
| G080 | 1 | 1 | | | | | | | | | | 2 |
| G081 | | | | | 2 | | | | | | | 2 |
| G082 | | | | | | | | | 1 | | | 1 |

Figure 12. Summary of grey whale sightings by week, 1999. Numbers indicate the number of days each individual was sighted each week.

Table VII. Grey whale absences from the study area, 1996- 1999. The numbers in parentheses represent the percentage of all whales identified that year that were absent for the given number of weeks.

| | 1996 | 1997 | 1998 | 1999 |
|---------------------------------------|----------|----------|---------|---------|
| Number of weeks of observation | 12 | 11 | 12 | 11 |
| Number absent for 1 week | 1 (3%) | 8 (16%) | 2 (7%) | 2 (9%) |
| Number absent for 2 weeks | 1 (3%) | 7 (14%) | 2 (7%) | 2 (9%) |
| Number absent for 3 weeks | 5 (15%) | 5 (10%) | 3 (11%) | 3 (14%) |
| Number absent for 4 weeks | 2 (6%) | 2 (4%) | 1 (4%) | 0 (0%) |
| Number absent for 5 weeks | 5 (15%) | 0 (0%) | 0 (0%) | 0 (0%) |
| Total | 14 (42%) | 22 (44%) | 8 (29%) | 7 (32%) |

five weeks and was re-sighted on August 21, 1996). The percentage of whales leaving the study area and returning was lowest in 1998 (29%, Table VII), *i.e.* most individuals did not return after leaving the study area. Whether or not they returned after we ended our observations for the year is unknown. In 1998, none of the whales identified were present in the study area in every observation week.

We used the number of weeks that an individual was sighted in one summer as a measure of residency time. There was no difference in residency time among years (1996-1999, Kruskal - Wallis Rank Sums, $\chi^2 = 6.84$, $df=3$, $P = 0.08$; Fig. 13). Residency time was lowest in 1998 (2.5 \pm 0.5 weeks, Fig. 13) and the percentage of individuals sighted in only one week was highest in 1998 (48%, Table VIII). From 1996 to 1999, mean residency time for all whales sighted off the central coast of mainland B.C. in one summer was 4.6 \pm 0.2 weeks.

Identifying patterns of residency proved difficult in this study due to large individual variation in the amount of time animals occupied our study area (Figs. 9-12). Some individuals were sighted throughout the observation period suggesting that they may spend the entire summer off the central coast of mainland B.C. Some individuals were sighted for several weeks and other individuals were sighted in only one week. Some individuals occupied our study area for several consecutive weeks but did not return after leaving the study area. Other individuals left and returned to the study area on more than one occasion in one summer. Most individuals also showed year-to-year variation in their residency patterns (Figs. 9-12). For example, whale GO54 was sighted in one week in 1996, 11 weeks in 1997, and 2 weeks in both 1998 and 1999. Whale GO36 as

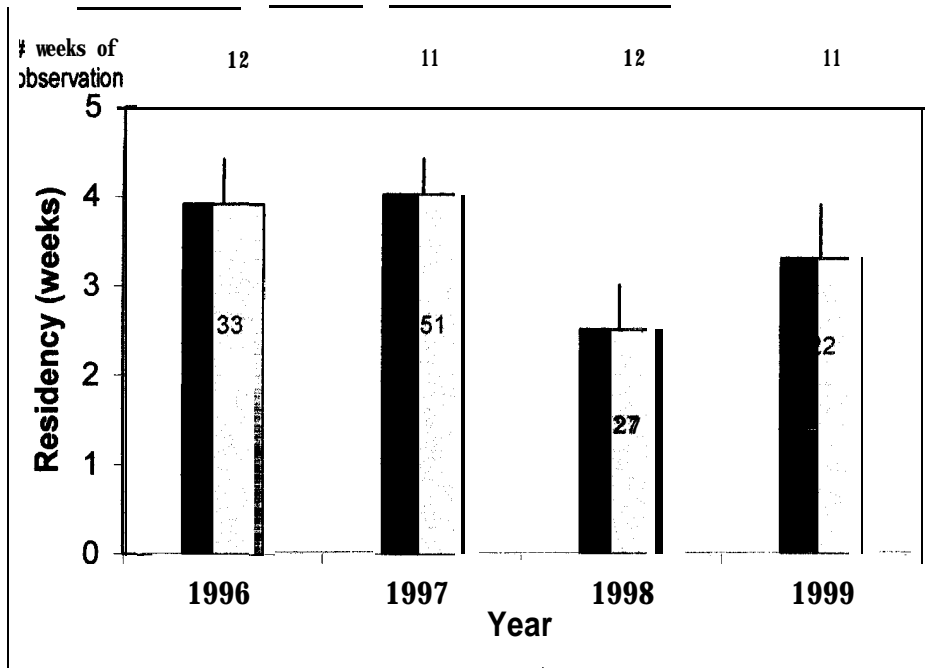


Figure 13. Residency time of grey whales off the central coast of mainland B.C., 1996 – 1999. Bars represent the mean number of weeks (\pm SE) individuals were sighted in the study area during each summer. Numbers on bars indicate sample sizes.

Table VIII. Grey whales sighted in only 1 week
off the central coast of mainland B.C., 1996-1999

| | 1996 | 1997 | 1998 | 1999 |
|--|------|------|------|------|
| Number of whales identified | 33 | 51 | 27 | 22 |
| Number of whales sighted only 1 week | 7 | 15 | 13 | 7 |
| Percentage of whales sighted only 1 week | 21 % | 29 % | 48 % | 32 % |

sighted in 8 weeks in 1996, but sighted in only 1 week in 1997, and never sighted in 1998 or 1999.

Distribution and Habitat Use

Grey whales were sighted from Shelter Bay (50.967 N, 127.447 W) to the southernmost entrance of Rivers Inlet (51.377 N, 127.790 W) over the six years of study. The locations of all sightings for each whale (1996- 1999) were plotted along a linear transect from Shelter Bay to Rivers Inlet, centred on Cape Caution. Figure 14 shows the frequency of sightings per day of survey effort along the coastline encompassed by our study area. Grey whale sightings were distributed along most portions of the coastline in 1996 and 1997 (Fig. 14a,b). In these years, there were few locations within the study area at which grey whales were not sighted. Whales were most frequently sighted around Allison Harbour (zones T, A, N in Fig.1) and north of Cape Caution in 1996 (north of zone C in Fig. 1). In 1997, whales were most frequently sighted around Allison Harbour, with the remaining sightings being fairly evenly distributed along the rest of the coastline. In 1998 and 1999 the frequency of sightings per day of effort was lower along the entire coastline (Fig. 14c,d). In these years, there appeared to be three areas used most often by grey whales: the area around Allison Harbour; the area from Slingsby Channel to Hoop Bay (zones P, B, C, G, and H in Fig 1, including Burnett Bay, Sylvester Bay, Cape Caution, and Blunden Bay); and the area around Table Island (zone S in Fig.1). This trend was especially evident in the habitat utilization patterns of grey whales in 1998 (Fig. 14c). Whales were most frequently sighted in and around Burnett Bay (zone B in

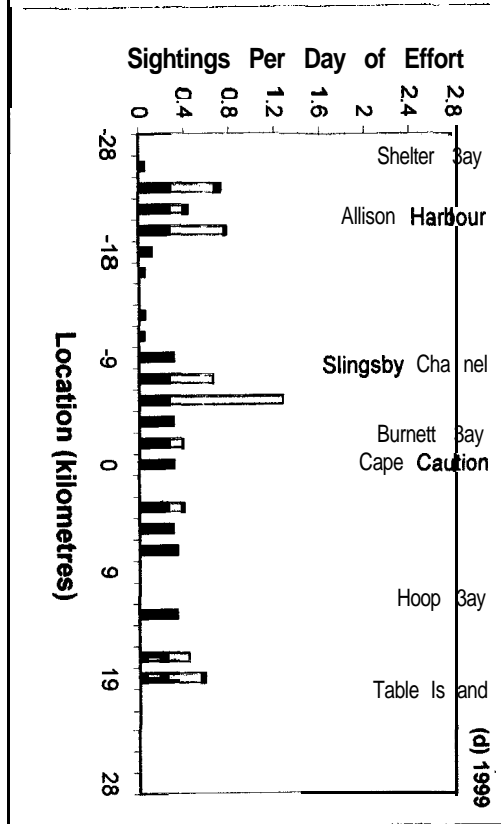
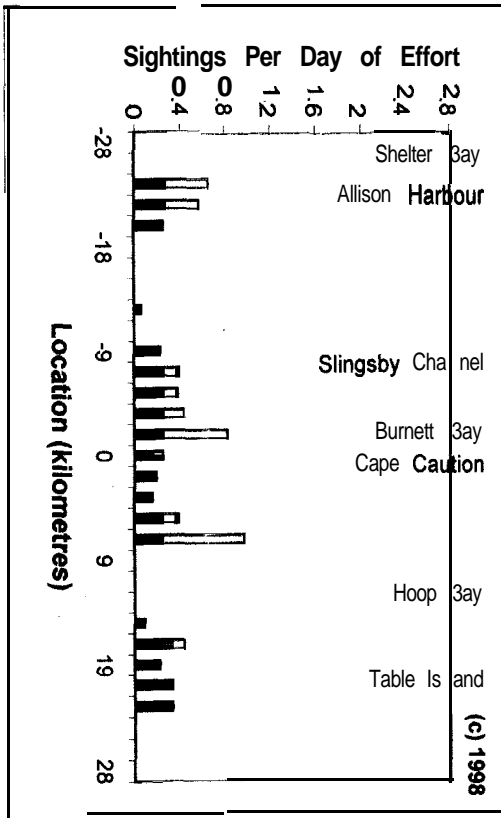
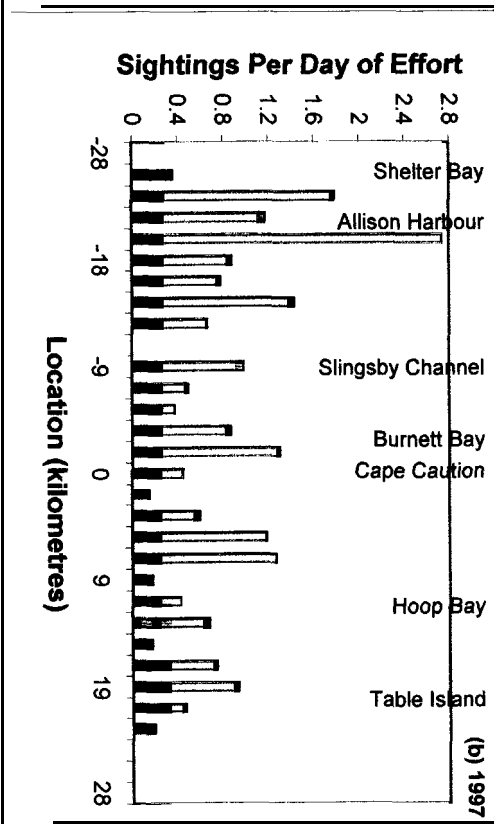
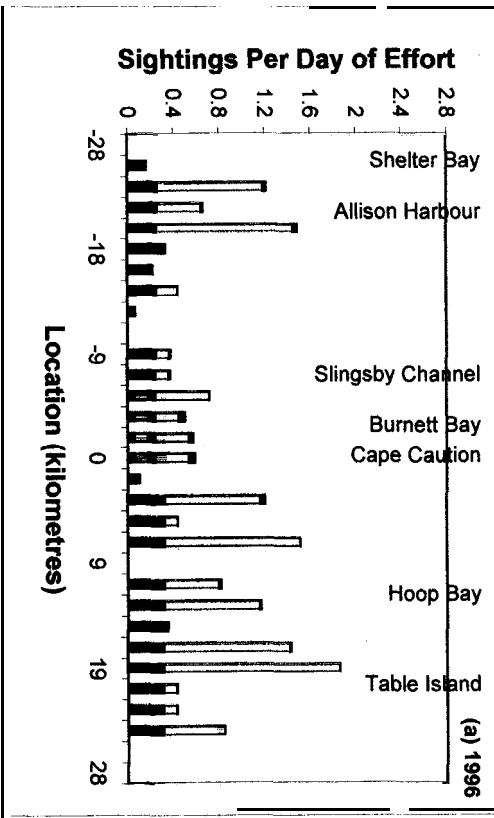


Figure 14. Frequency of all grey whale sightings along a linear transect centred on Cape Caution (1996-1999). Values represent the total number of sightings at each location divided by the number of days spent surveying at each location to correct for effort. The locations of certain landmarks are also indicated for reference.

Fig. 1) in 1999 (Fig. 14d). Whales were also frequently sighted near Allison Harbour in 1999, and less frequently sighted near Table Island (Fig. 14d).

The locations at which grey whales were most frequently sighted likely represent primary feeding sites. Those areas where whales were sighted less frequently were identified as secondary and tertiary feeding sites. Whales usually fed in and around nearshore kelp beds, primarily on mysids. Systematic sampling of kelp beds in our study area by researchers in our team using SCUBA gear revealed the presence of mysid aggregations (L. Stelle, Dept. of Organismic Biology, Ecology and Evolution, University of California, pers.comm.). On August 9, 1999, we observed three whales bottom feeding in shallow water close to shore in Burnett Bay where no kelp was visible. Underwater examination by SCUBA divers revealed large excavations typical of grey whales feeding on benthic prey (Nerini 1984, Oliver *et al.* 1984). This was our only confirmed observation of grey whales bottom-feeding in our study area during the course of our observations.

We estimated home range size as the greatest distance between sightings in one summer for each individual. Home range size was calculated for all individuals sighted more than once in a summer. Home range size did not vary between years (1996-1999; Kruskal-Wallis Bank Sums, $\chi^2 = 1.74$, $df = 3$, $P = 0.63$; Fig. 15). Mean home range size from 1996 to 1999 was 20.2 ± 1.4 kilometres. These values represent home range size only within our study area, and by no means represent the full range of grey whales beyond our study area.

Grey whales showed various degrees of mobility within the study area. We subjectively divided home range size into three classes: 0-10, 10-25 and 25-50

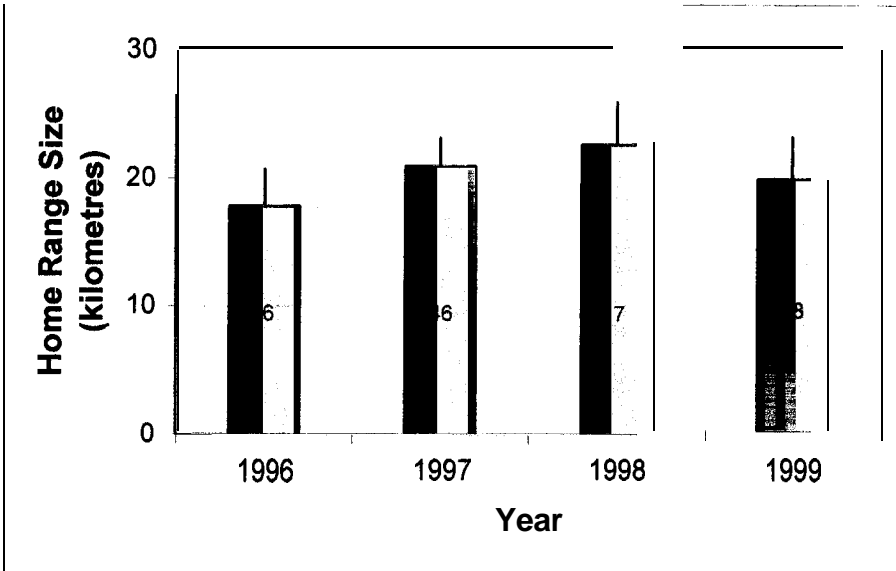


Figure 15. Home range size of grey whales off the central coast of mainland B.C., 1996 - 1999. Bars represent means (\pm SE). Home range size was estimated as the greatest distance between sightings along a linear transect centred on Cape Caution for each whale. Numbers on bars indicate sample sizes (the number of whales sighted at least twice that year).

kilometres. In 1996, 1997 and 1999 there were similar percentages of grey whales in each class and individuals were fairly evenly divided among the three classes (Fig. 16). In 1998, a higher percentage of whales had larger home ranges than in the other three years (Fig. 16). Most whales did not range throughout the entire study area in a summer (the distance from Shelter Bay to Rivers Inlet is approximately 50 kilometres).

Individuals also varied in the areas over which they ranged. In all years, there were individuals that restricted their movements to locations north of Cape Caution, individuals that restricted their movements to locations south of Cape Caution, and individuals that ranged both north and south of Cape Caution (Tables IX and X). In 1996 and 1998, the percentage of whales ranging only to the north or only to the south of Cape Caution were similar. In 1997 and 1999, a smaller percentage of whales ranged to the north than to the south of Cape Caution (Table X).

Individuals did not necessarily range over the same areas in all years they were identified. Twelve individuals (34% of all individuals sighted in more than one summer from 1996 to 1999) ranged over the same area in all years they were sighted (Table IX). Three of these individuals always ranged to the north of Cape Caution, 2 individuals always ranged to the south of Cape Caution and 7 individuals always ranged both to the north and south of Cape Caution. Five individuals (14% of all individuals sighted in more than one summer from 1996 to 1999) ranged to the north of Cape Caution in one summer and ranged to the south of Cape Caution in a later summer or vice versa (Table IX). In three of these cases, the animals also ranged to the north and south of Cape Caution in one summer.

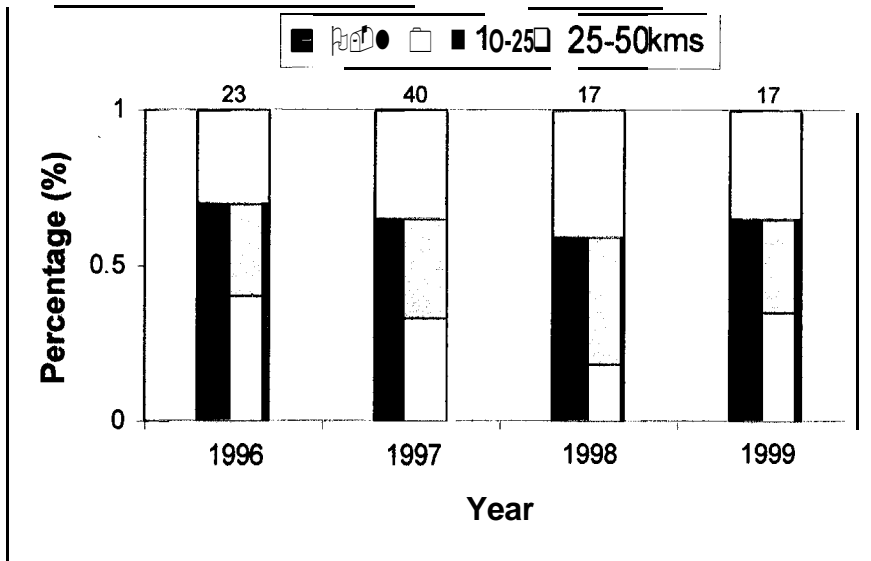


Figure 16. Home range size of grey whales off the central coast of mainland B.C., 1996-1999. Values represent the percentage of grey whales sighted more than once in a summer with home ranges of 0-10, 10-25, and 25-50 kilometres. Numbers above bars indicate sample sizes.

Table IX. Home ranges of grey whales, 1996-1999. S= south of Cape Caution, N= north of Cape Caution, B= both north and south of Cape Caution. Light grey shading indicates whales that ranged in the same location each year. Dark grey shading indicates whales that ranged north of Cape Caution one year and south of Cape Caution a later year or *vice versa*.

| GWID | 1996 | 1997 | 1998 | 1999 |
|------|------|------|------|------|
| G001 | S | b | b | |
| G003 | S | B | | |
| G004 | S | S | B | |
| G005 | B | S | | B |
| G006 | B | S | | S |
| G007 | N | N | | B |
| G008 | | S | | |
| G009 | B | B | B | |
| G010 | S | S | | |
| G011 | B | S | S | |
| G012 | N | | B | S |
| G014 | S | S | B | S |
| G015 | S | B | | |
| G016 | | | N | |
| G017 | N | B | B | B |
| G020 | | S | | |
| G021 | | B | | |
| G022 | | N | N | |
| G023 | | S | | |
| G024 | | B | | |
| G026 | | N | | |
| G028 | | B | | S |
| G029 | | S | | S |
| G030 | B | B | | |
| G031 | | B | B | B |
| G032 | N | N | | |
| G033 | B | S | N | |
| G036 | B | | | |
| G037 | B | | | |
| G038 | B | | S | |
| G039 | S | | N | |
| G040 | B | B | B | B |
| G041 | B | B | B | B |
| G042 | N | B | B | |
| G043 | | B | B | |
| G044 | B | | | |
| G045 | N | | | |
| G046 | N | B | S | |
| G047 | N | | | |
| G048 | N | | | |
| G049 | | N | | S |
| G051 | | B | | B |
| G052 | | | B | |
| G054 | | B | S | B |
| G055 | | B | | S |
| G057 | | B | | |
| G058 | | S | | |
| G059 | | N | | |
| G060 | | B | | |
| G061 | | B | S | |
| G062 | | S | | |
| G063 | | N | N | |
| G064 | | B | S | |
| G065 | | S | | |
| G066 | | N | | |
| G067 | | S | S | B |
| G068 | | S | | |
| G069 | | S | | |
| G072 | | | B | |
| G073 | | | N | |
| G075 | | | N | |
| G077 | | | | N |
| G078 | | | | N |
| G079 | | | | S |
| G080 | | | | S |
| G081 | | | | S |
| G082 | | | | S |

Table X. Home ranges of grey whales off the central coast of mainland B.C., 1996-1999. Numbers in parentheses indicate the percentage of all whales sighted that year that ranged over the given areas.

| | 1996 | 1997 | 1998 | 1999 |
|---------------------------------|----------|----------|----------|----------|
| North of Cape Caution | 9 (33%) | 8 (17%) | 7 (26%) | 2 (9%) |
| North and South of Cape Caution | 11 (41%) | 21 (46%) | 13 (48%) | 9 (41%) |
| South of Cape Caution | 7 (26%) | 17 (37%) | 7 (26%) | 11 (50%) |

DISCUSSION

Individual Identification

In agreement with Darling (1978), we concluded that grey whales present along the central coast of mainland B.C. between late June and early September were summer residents. It is unlikely that any of the whales we identified were migrating to Alaska for the summer; northerly migration past Vancouver Island begins in February, peaks in late March, and ends by late May or early June (Rice & Wolman 1971, Darling 1978, 1984). Similarly, animals identified from June to early September were present too early to be southward migrants; these pass Vancouver Island beginning in late September, peaking at the end of December and ending in January (Pike 1962, Pike & MacAskie 1969, Hatler & Darling 1974, Darling 1978, 1984).

Descriptions of the grey whale migration route along the B.C. coast may provide further evidence that the individuals sighted in our study area were probably not migrant animals, Grey whales cross the Straits of Juan de Fuca from the Washington coast and follow the west coast of Vancouver Island to Cape Scott (Pike 1962). From Cape Scott migrating whales are next sighted along the Queen Charlotte Islands, approximately 300 kilometres north of our study area (Pike 1962, Pike & MacAskie 1969, Hatler & Darling 1974). Therefore, it appears that migrant animals continue due north after reaching Cape Scott rather than turning east towards the B.C. mainland at the southernmost tip of Queen Charlotte Sound (our study area). Alternatively, the described migration route may reflect lack of effort at finding whales along this part of the coast during months of northern and southern passage off B.C., so whales may enter our study area unobserved during the migration periods.

Our results show that 56 % (44 of 78) of the individuals identified from 1994 to 1999 returned to the study area in more than one summer. Some individuals were identified in as many as four and five years. Individuals not identified in a summer, but identified in a subsequent summer, probably spent that summer feeding in other areas along the northwest coast. Individuals not sighted in a subsequent summer may have died or emigrated to another area. Darling (1984) proposed that the resident whales off Vancouver Island form part of a larger northwest coast population. He estimated that there are at least 100 whales in the British Columbia-Washington-Oregon area. Confirmed sightings of grey whales off the coasts of Washington (Pike 1962, Rice & Wolman 1971, Darling 1979, Calambokidis *et al.* 1994) and Oregon (Pike 1962, Rice & Wolman 1971) during summer months further support this notion. Our data indicates some permanence to the population occupying the central coast of mainland B.C. in the summer; exchange with other areas of the northwest coast probably explains the periods of absence that some whales exhibited.

Each year a few new individuals were identified at the end of August and the beginning of September. These were probably individuals arriving from other parts of their summer range rather than individuals passing on their southward migration. Grey whales probably ranged into the study area at this time to exploit the greater abundance of prey following the mysid reproductive period in mid-August (L. Stelle, pers. comm., see the next Discussion section on abundance). Darling (1978) reported that several grey whales that were sighted off Vancouver Island early in the summer (May-June) departed and then returned in August and September. We don't know if whales identified towards

the end of our study period ranged onto the central mainland coast prior to our presence in the study area.

Abundance

Grey whale abundance off the central coast of mainland B.C. varied from year to year; abundance was relatively high in 1997 and relatively low in 1998 and 1999 (excluding data from 1994 and 1995 due to incomplete survey effort in those years, see Methods).

Grey whales summering off the B.C. coast are most likely moving among feeding sites (Darling 1978, 1984). Whales in our study area fed mostly in and around nearshore kelp beds, primarily if not exclusively on mysids (L. Stelle, pers.comm.). Murison et al. (1984) also determined that grey whales summering off the west coast of Vancouver Island fed on mysid swarms in kelp beds. Yearly variability in zooplankton biomass might account for the observed variability in grey whale abundance in our study area. In years when plankton abundance was low in our study area, grey whales most likely fed in other parts of their summer range where plankton was more abundant or where other prey types could be exploited.

The 1997- 1998 El Nino Southern Oscillation (ENSO) event severely affected the nutrient content of oceanic waters off British Columbia and in the Gulf of Alaska. In 1998, nitrate concentration was severely depleted in all regions of the Gulf of Alaska including Queen Charlotte Sound (a late El Nino impact; F.A. Whitney, Institute of Ocean Sciences, pers. comm.). Primary production is about 40% less in nitrate-depleted oceanic waters than in those that are nitrate-rich (Whitney *et al.* 1998). Since mysids

consume phytoplankton, reduced productivity in Queen Charlotte Sound during El Nino might have reduced mysid abundance off the central coast of B.C. This may account for the lower abundance of grey whales feeding in our study area in 1998 and 1999.

Opportunistic sampling of mysid swarms in our study area revealed that there were fewer mysids in 1998 than in 1999; mysid swarms were smaller and generally less dense (L. Stelle pers.comm.). There are no data on the mysid population prior to 1998, so we cannot compare mysid abundance during the El Nino event to abundance in earlier years. While mysid abundance was higher in 1999 than in 1998, grey whale abundance was lower in 1999 than in 1998. Mysid abundance in 1999 may have still been significantly lower than normal, thus continuing to make foraging in our study area energetically unfavourable for grey whales. Alternatively, there may have been fewer whales returning in 1999 due simply to lack of feeding success the previous year. If mysid abundance reached normal levels in 1999, and should it remain relatively high, grey whale abundance is likely to increase in the next few years.

It would be interesting to know whether the decrease in grey whale abundance 1998 and 1999 was a direct result of changes in nutrient supply during the El Nino event or whether we were observing a broader trend that will continue. While the El Nino event had an acute effect on the nutrient content of B.C.'s coastal waters, certain chronic oceanic trends have also been observed. F.A Whitney (pers.comm.) has documented a warming trend in oceanic waters off Vancouver Island of approximately 0.01 C per year over the past five decades. Increased temperature in coastal waters reduces the depth of winter mixing and shallower mixing coincides with lower nitrate levels (Whitney *et al.* 1998). A shallowing trend in the depth of the mixed layer has been recorded over the

same period (F.A. Whitney, pers. comm.). Zooplankton biomass has also been decreasing along the coast of Vancouver Island over the past five years, not just during the 1998 ENSO event (D. Mackas, Institute of Ocean Sciences, pers. comm.). Changes in grey whale abundance over the next few years will help us determine if we were observing temporary or long-term changes in the feeding ecology of grey whales in our study area.

Grey whale abundance was lowest at the beginning of our observation period (late June) and highest at the end of our observation period (early September). The abundance of whales coincided with food availability over the summer. In 1999, mysid abundance in our study area was lowest in early July and highest from mid-August to early September (L. Stelle, pers. comm.). Mysid abundance was highest when there were large, very dense swarms of small juveniles following a peak in reproductive activity in mid- August (L. Stelle, pers. comm.). Data on mysid abundance were collected over the entire observation period in 1999 only, however similar patterns in abundance probably existed in 1996 and 1997 (the other summers in which grey whale abundance increased in September).

In 1998 by contrast, grey whale abundance decreased at the beginning of September. Fewer grey whales returned to the study area after leaving to forage in other parts of their summer range in 1998 than in other years (see the next Discussion section on residency). This may be due to decreased prey abundance in our study area in 1998 as a result of El Nino. Higher foraging efficiency in other areas might have encouraged whales to remain in areas where prey abundance was high rather than to return to our study area later in the summer.

It is also possible that grey whale abundance increased at the beginning of September because individuals were able to exploit new prey types (1998 excluded). We observed three grey whales bottom feeding in Burnett Bay on August 9, 1999. Darling *et al.* (1998) found that the number of bottom-feeding whales increased in mid-August and later off the west coast of Vancouver Island. Since we made only one confirmed observation of grey whales bottom-feeding we do not have sufficient data to make any definite conclusions about a seasonal shift in benthic feeding in our study area.

Residency

Quantifying the exact duration of residency of individuals in the study area in a given summer would have necessitated surveying the entire study area each day. We were limited practically to approximating residency to the nearest week, and could confidently assume that a whale was absent from the study area if it was not sighted in one week of surveys. Residency time was similar for all years from 1996 to 1999, however our data suggested that whales spent less time in the study area in 1998 than in other years. Whales that left the study area were less likely to return to the study area at a later date in 1998. This may have been due to decreased food availability as a result of the 1997- 1998 El Nino event and its impacts on productivity in these waters (discussed above).

In a given year, whales sighted in all weeks of observation may have spent the entire summer within our study area. Darling (1978) found that some whales spent up to several months in their study area off the west coast of Vancouver Island. Similar to Darling's (1978) findings, most individuals were absent from our study area for one or

more weeks over the course of the summer. Individuals that were not observed for one or more weeks had most likely travelled to other parts of their summer range. In addition to the west coast of Vancouver Island, resident grey whales have been *sighted at the* northern tip of Vancouver Island at Cape Scott (Darling 1978, 1984) and north of our study area at Calvert Island (Pike 1962, Pike & MacAskie 1969, Darling 1978, 1984, Darling *et al.* 1998). We saw one whale on the northeast coast of Vancouver Island near Port Hardy in 1998. Whales have also been seen at the Storm Islands (present study), but we surveyed there only infrequently. Darling (1984) found that whales travelled among feeding sites at least 80 km apart in one summer. Calvert Island, Port Hardy, and Cape Scott are approximately 30, 40, and 75 kilometres from Cape Caution respectively. The Storm Islands are located within our study area, approximately 7 kilometres offshore. Therefore, it seems feasible that individuals travelled between these feeding sites over the course of a summer. Ongoing collaboration with other grey whale researchers in the Pacific Northeast will improve our understanding of grey whale movements between different areas of their summer range.

Individuals varied in the amount of time they occupied our study area in a given year. Most individuals also showed year-to-year variation in their residency time. We don't know what factors determine residency patterns of individual whales but food availability and the carrying capacity of the environment are likely to be important. Research on prey dynamics and the relationship between grey whales and their prey may help us understand the ecological factors determining the residency patterns of grey whales in our study area. Competition and other social interactions may also play a role by excluding some individuals from the study area at certain times. Describing social

behaviour in marine species that can be observed only sporadically and only at the surface, can be extremely difficult. Radio tags designed to record underwater swimming patterns may be a first step towards observing grey whale social interactions below the surface.

Distribution and Habitat Use

Grey whales were sighted along the entire coastline from Shelter Bay to Rivers Inlet from 1996 to 1999. Individuals moved in and out of the study area over the summer indicating that the range of most if not all animals extended outside our study area. For this reason, the maximum home range size is unknown. Individual differences in the number and duration of absences from the study area are consistent with differences in maximum home range size. Individuals that were absent from the study more frequently and/or for longer periods probably ranged more extensively than individuals that were present in the study area for most of the summer.

Grey whales also varied in their degree of mobility within our study area. Some whales had relatively extensive home ranges (25-50 kilometres) while others had much smaller ranges (0- 10 kilometres). Some whales had intermediate home range sizes within our study area (10-25 kilometres). This demonstrates individual variation in the degree of site fidelity. Whales that ranged over larger distances exhibited less site fidelity than whales that ranged over very small distances. Most whales did not range over the entire study area in a summer. While our results suggest site fidelity among grey whales, we were unable to quantify the degree of site fidelity. A more detailed analysis of grey whale ranges might show that whales have preferred bays or reefs within the study area.

Individuals that returned to the study in more than one summer did not necessarily have the same range each year. Some whales ranged over the same areas of the study area in all years in which they were identified but most individuals varied in range in different years. Thus, grey whales appear to vary in the degree of site fidelity they exhibited both within and between years.

The grey whale population as a whole exhibited some year-to-year variation in its use of particular feeding sites. Grey whales were sighted most frequently around Allison Harbour and in areas north of Cape Caution in 1996. In 1997, whales were most frequently sighted around Allison Harbour with slightly fewer sightings near Table Island. The locations at which grey whales were most frequently sighted probably represented primary feeding sites. Other locations where grey whales were sighted less frequently probably represented secondary and tertiary feeding sites. Changes in feeding sites in different years were probably due to changes in prey availability in particular areas. Since grey whales seemed to be feeding primarily on mysids in our study area, these changes are most likely due to mysid population dynamics. Future research should examine the dynamics of mysid populations and should identify factors that determine mysid abundance and distribution.

The overall number of sightings per day of effort was severely reduced throughout the study area in 1998 and 1999, a direct result of lower whale abundance in those years. In 1998 and 1999, the distribution of sightings was also concentrated in primary feeding sites while secondary and tertiary feeding sites experienced reduced use. This coincides with the findings of Darling et al. (1998) that certain feeding sites off Vancouver Island experienced extended periods of non-use by whales. The area in and

around Burnett Bay remained a primary feeding site in 1998 and 1999, as did the area around Allison Harbour and Table Island.

In 1998 and 1999, it appeared that grey whales limited their feeding activity to particular areas rather than reducing their foraging activity evenly over the entire coastline. This change in habitat use patterns in 1998 and 1999 may be a result of reduced zooplankton biomass, as suggested by the data showing nitrate depletion in these waters during the 1998 ENSO event (F.A. Whitney pers.comm., see discussion above). Even if plankton abundance were reduced in these years, the habitat utilization of grey whales could reflect (a) a reduced abundance of good feeding sites, (b) a behavioural response to severely lower food availability, (c) some other factor, or (d) a combination of factors. We did not measure plankton abundance, so we know neither overall abundance nor how food was distributed within the study area over our years of study. Future research should examine the variables affecting feeding behaviour in grey whales, the dynamics of prey populations, and the interaction between these factors.

Implications for Conservation and Management of Grey Whales

Grey whales were hunted almost to extinction in the late 1800's and early 1900's (Gilmore 1955). The 1937 International Agreement for the Regulation of Whaling forbade the killing of grey whales in the United States, Canada and Mexico. The 1947 International Convention for the Regulation of Whaling was ratified by the governments of 17 nations including Canada, Japan, Mexico, the Soviet Union, and the United States. This convention also forbade the killing of grey whales, except by aborigines or a government on behalf of aborigines, and only when the meat was to be used for

consumption. International protection allowed grey whale numbers to recover successfully and the International Whaling Commission (IWC) reclassified the California grey whale, moving it from protected to sustained-management status. The population was estimated to be between 15,000 and 20,000 as of 1980 (Reilly 1984).

Appropriate conservation and management policies need to be developed to ensure that grey whales continue to thrive throughout their range. British Columbia must address the needs of both migrating and resident whales when establishing policies to preserve grey whale habitat and protect grey whales using its coastal waters. Industrial activities, fishing, commercial whale watching, and private boating should not obstruct the progress of migrating whales and should not interfere with the foraging behaviour of resident whales. Plans for coastal development need to ensure that the feeding habitat of grey whales is protected. Also, now that the grey whale has been removed from the endangered species list, pressures to re-open the commercial hunt are growing from native groups along the coasts of Washington (Makah) and Vancouver Island (Nuu-chah-nulth). A better understanding of grey whale population dynamics is necessary before deciding whether whaling can be sustainable in British Columbia.

The government of British Columbia is currently developing a Land and Coastal Resource Management Plan (LCRMP) for its central coast. Figure 17 shows the Central Coast LCRMP plan area encompassing our study area. The plan identifies how B.C.'s resources will be managed such that growth and economic development are promoted while social and environmental needs are met. The Central Coast is the first LCRMP in the province to deal with the use and management of both coastal and land resources.

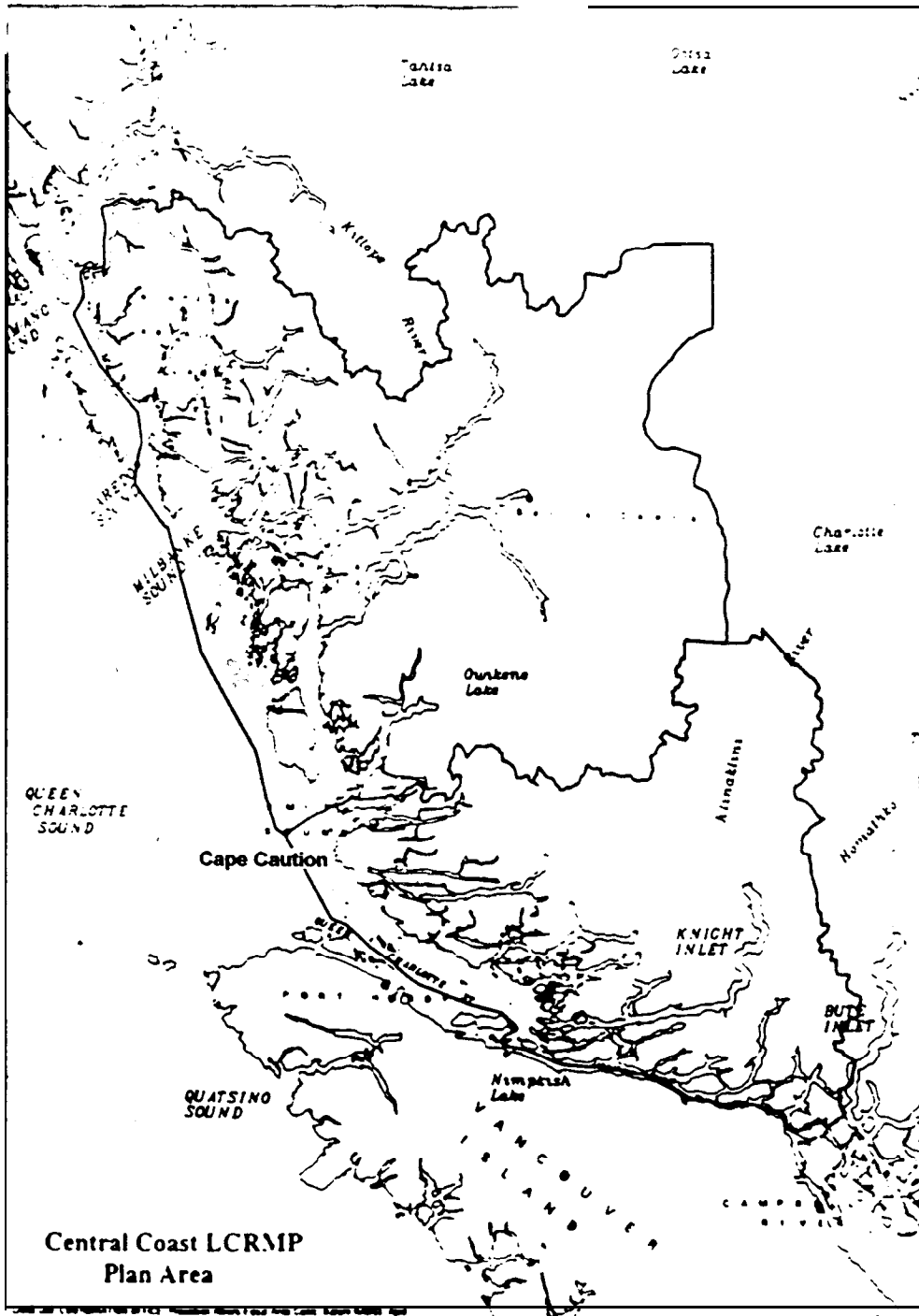


Figure 17. Map of the Central Coast LCRMP plan area.

There is currently a proposal to have most of the Queen Charlotte Sound declared a Marine Protected Area. The health of the nearshore marine ecosystem needs to be considered in the management plan such that grey whale feeding habitat is properly managed. Strategies might include protecting kelp beds to ensure grey whale prey conservation; mysids serve as the primary food source for a diverse group of species other than grey whales, and as a secondary food source for a number of additional species. Conservation and management of the mysid populations would tend to ensure the overall health and stability of the marine ecosystem.

The impact of the growing eco-tourism industry should also be taken into account when establishing conservation and management priorities for grey whales along the central coast. There is no direct evidence that commercial whale-watching is having a deleterious impact on whales but as the number of whale watching vessels increases, the behaviour of grey whales may be affected. Regulations need to be established and properly enforced to prevent whale-watching boats from interfering with the normal behaviour of migrating and/or feeding whales along the central coast.

Developing and implementing conservation and management strategies requires extensive knowledge of the behaviour and ecology of grey whales. The long-term research conducted by Coastal Ecosystems Research Foundation (present study) and other grey whale researchers forms an integral part of grey whale conservation. Further research related to grey whale movements in the northeast Pacific and the ecology of grey whales and their prey is a necessary first step towards the comprehensive management of this species and other components of British Columbia's marine communities.

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