REPORT OF THE 1996 GRAY WHALE STUDIES AT LAGUNA SAN IGNACIO, B.C.S., MEXICO.

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ABSTRACT

Laguna San Ignacio is located in the west coast of the Baja California Peninsula and it is one of the four main calving-breeding lagoons of the Eastern Pacific gray whale (*Eschrichtius robustus*) There is uncertainty concerning the potential effects of the whale-watching and the development of a proposed salt project on the gray whales, and on the lagoon ecosystem. The purpose of this report is to present the results of the 1996 gray whale winter season on abundance, density and distribution of the whales. Twenty complete censuses of the lagoon were done by boat to determine whale abundance and distribution from January 17 to March 27, 1996. The surveys were done using the lagoon division and the methodology described by Jones and Swartz (1984, 1986). The maximum combined count was 207 (115 solitary whales and 92 cows with calves). The peak numbers of both single whales and cow-calf pairs were at the same time in early March. There were 39% less whales in 1996 than the average during 1978-82 seasons. The density of the whales in the lagoon during the maximum combined count was: 8.6 whales/km2 in the lower zone, 3.8 whales/km2 in the middle zone and 1.3 whales/km2 in the upper zone. From 474 photoidentified whales, 257 were single whales, 186 cows with calves, and 31 undetermined; there were 51 recaptured whales, 43 of cows with calves and only 8 of solitary whales. Further photographic and tagging studies may help in developing turnover rates, which will allow the number of whales using a lagoon to be calculated based on visual surveys.

INTRODUCTION

Laguna San Ignacio is located in the west coast of the Baja California Peninsula and it is currently the only one of the four calving-breeding lagoons of the Eastern Pacific gray whale (*Eschrichtius robustus*) that remains mostly undeveloped and largely unaltered by human intervention (Dedina and Young, 1995). The lagoon lies within the Vizcaino Desert Biosphere Reserve, Mexico's largest refuge administrated by Secretaria de Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP) (Fig. 1). The lack of paved roads restricts the potential for development.

Laguna San Ignacio is a popular destination for recreational whale watching. During the 1994 whale season, five land-based camps, six touring boats based in San Diego, California, and one luxury cruise-liner based in Seattle, Washington conducted whale tours in Laguna San Ignacio (Dedina and Young, 1995). During the 1996 whale season 2969 tourist visited the lagoon generating an income of $51,000 US. (Sánchez, 1997).

A corporation that produces salt from the area around Laguna Ojo de Liebre, has plans to develop a salt production facility in the salt flats around the northern shoreline of Laguna San Ignacio. Salt evaporation and concentration would occur on approximately 20,000 has. of mudflats north of the northern arm of Laguna San Ignacio. Salt water would be pumped from

the interior of the lagoon at the northernmost tip of the lagoon. (Dedina and Young, 1995). There is uncertainty concerning the potential effects of whale-watching and the development of the proposed salt project on gray whales and the lagoon ecosystem.

Detailed studies of demography and phenology of gray whales were conducted during the winter occupation in Laguna San Ignacio from 1978 to 1985 (Jones and Swartz, 1984; Jones *et al.*, 1994; Swartz and Cummings, 1978; Swartz and Jones, 1980, 1981, 1983).

The purpose of our research is to know the current use of Laguna San Ignacio by the gray whales. Here, we report the results of the 1996 gray whale winter season on abundance, density and distribution of the whales.

METHODS

Boat Surveys (census)

Twenty complete censuses of the lagoon were done by boat in order to determine whale abundance and distribution from January 17 to March 27, 1996. The surveys were done using the lagoon division (Fig. 2) and the methodology described by Jones and Swartz (1984) so that the census of 1996 could be compared to the 1978-1982 and 1985 previous counts. No whale counts were done in 1983. Whale abundance during 1984 was not taken in account because there were only two counts and the abundance was significantly less than previous years, possibly due to acoustic experiments in the lagoon (Dahlheim *et al.* 1984; Dahlheim and Ljungblad, 1990; Jones *et al.* 1994).

Transects were conducted from 7 m boats powered by a outboard motors, travelling at an estimated speed of 11 km/hr. This speed insures that whales (which typically travel at 7 to 9 km/hr) do not move ahead of the survey boat and thus be counted more than once. Transects ran along an imaginary line drawn mid-lagoon from the breaker line at the lagoon entrance to Isla Garzas at the north end of the lagoon. Each transect required about 2.5 to 3.0 hr to complete. The maximum distance from the boat to the 2 m depth contour along shore was 2.5 km and the minimum was 0.8 km. Thus, waters inhabitable by whales and both shorelines were clearly visible at all times within the lagoon (it was assumed that essentially all animals within 2.5 km of the trackline were seen). Whales in the "North End" of the upper lagoon (north of the transect termination) were counted through binoculars from a 5 m bluff on the northern tip of Isla Garzas (Fig. 2). Surveys were aborted when sea conditions exceeded Beaufort 3 sea state (winds greater than 18 km/hr and occasional white caps).

Similar to Swartz and Jones (1981), we considered “cow-calf pairs” as a single unit and counts of these pairs are equivalent to calf counts. “Single whales” refer to nonparturient females, adult males, and inmatures.

Analysis Procedure

For the analysis of gray whale abundance during the 1996 winter season, separate comparisons were made for all whales, single whales and cow-calf pairs, taking in account the three zones in which the lagoon was divided. To compare the number of whales in the group classes mentioned above among years (1996 vs. 1978 to 1982 and 1985), only the respective high counts from the 1996 surveys were compared with those from previous years.

Photographic Identification

Gray whales possess individually unique pigmentation and markings that can be used to report the presence of specific individuals. When surveys for abundance and distribution were not being conducted, we dedicated effort to obtain photographs of individual whales.

Photographs from visible portions of the whales backs were taken with 35 mm cameras with 75-300 mm telephoto zoom lenses using T*max* black and white film of 400 ISO pushed to 1600 ISO (shutter speed of 1000th/sec.) (Darling, 1984). Any scars or other conspicuous natural markings were also photographed.

From the photographs, individuals were distinguished by comparing the natural markings around the dorsal region of the whale. The markings included pigmentation of the skin, mottling, scarring, and barnacles, which varied between individuals. These markings have provided a reliable means of identifying gray whales over long periods (Darling, 1984; Calambokidis *et al.* 1994).

The best photographs from the right and left sides of each whale (for each sighting) were selected from the negatives and custom printed (7 x 2.5 inch). Photographic prints were compared among them in order to know the residency time of individual whales. Each different whale was assigned a unique sequential identification number and added to our catalogue.

RESULTS

Abundance

Gray whale counts from 20 boat transects were used as an index of the abundance of whales within the lagoon during 9 weeks of effective fieldwork (from 17 January to 27 March). The maximum combined count was obtained in the first week of March and consisted of 207 whales (115 single whales and 92 cow-calf pairs). The peak numbers of both single whales and cow-calf pairs occurred at the same time in early March, and the single whales were the 56% of the total count (Table 1, Fig.3).

The abundance of whales in the lagoon considered by group class (single whales or cow-calf pairs), increased in a similar way for both groups during January and February. Nevertheless, during these two months, the number of single whales was greater than that of cow-calf pairs. After March 2, the decrease in single whales was faster than that of cow-calf pairs, and after this date the cow-calf pairs predominated than single whales. (Fig. 3).

Distribution

Whale counts were always greater from the lower zone towards the upper in the lagoon. During the whole season, 49% of the gray whale population was present in the lower zone, 32% in the middle and 19% in the upper zone.

Lower zone

At the maximum combined count, 57% of the total population (84 single whales and 33 cow-calf pairs) occupied this zone. The single whales were the principal occupants during the season. During the first counts, both group classes were found in similar numbers but by the end of January, the single whales differed from the cow-calf pairs and remained more or less stable until February 17. From this day on, the number of single whales increased and reached their peak of abundance on March 2. Their numbers began to decline while the number of cow-calf pairs, which had remained low but stable from January to February, also increased after February 17 and reached their maximum on March 16. This coincided with the almost null abundance of single whales (Fig. 4).

Middle zone

During the maximum combined count, this zone had 27% of the total population of whales (31 single whales and 25 cow-calf pairs). The number of single whales was similar to

that of cow-calf pairs. Not withstanding, there was a slight superiority in the number of single whales until the maximum. After this, they began to leave this zone and by March 16 there were no more registers. The cow-calf pairs increased in number accordingly with single whales, although their peak of abundance was not reached until March 9. After the maximum, their abundance declined abruptly but recovered slightly later (Fig. 5).

Upper zone

The 16% of the total population of whales was registered in this zone (6 single whales and 28 cow-calf pairs) at the maximum combined count. Both group classes presented different counts and the number of cow-calf pairs was always higher. There was no definite pattern in the abundance of cow-calf pairs cause it decreased and increased a number of times before it reached the maximum. On the other hand, the number of single whales was relatively constant during the season. Generally speaking, the abundance and numeric dominance of this group class was opposite to that documented in the lower zone; the cow-calf pairs prevailed during the season (Fig. 6).

Density

During the season, the density of whales in the lagoon was not equivalent for the three zones (H(2)=30.2, P=0.0000, a=0.05) (Fig. 7). On the maximum combined count, it was distributed in the following manner: 8.6 whales/km^2 in the lower zone, 3.8 whales/km^2 in the middle and 1.3 whales/km^2 in the upper zone. In this estimation the cow-calf pairs were counted as 2 individuals.

Before the maximum combined count, the lower zone was occupied primarily by single whales, but after this day, the single whales began to abandoned the lagoon leaving the cow-calf pairs. In the upper and middle zones, the cow-calf pairs were always dominant.

Analysing separately both group classes, it turned out that cow-calf pairs density was not the same in the lagoon ($H_{(2)}$=9.5, p=0.0088, α=0.05). Nevertheless, multiple comparisons showed that at least in January and February, it was equivalent for the three zones ($H_{(2)}$=1.52, p=0.4676; $H_{(2)}$=5.26, p=0.0719, α=0.05 respectively) (Fig. 7). Likewise, single whales density was not homogenous during the season ($H_{(2)}$=27.0, p=0.0000, α=0.05) (Fig. 12) yet the multiple comparison analysis revealed an equivalence for the three zones in March ($H_{(2)}$=5.23, p=0.0732).

Residency

A total of 1404 exposures were taken, from which 661 photographs were printed. Of this total 474 different animals were obtained, 228 of the right side and 246 of the left side. Only 91 whales had photographs from both sides.

Of the 474 identified whales, 257 were single whales, 186 cow-calf pairs, and 31 undetermined (individuals that for some reason could not be assigned to one of the previous group classes). There were 51 recaptured whales, 43 cow-calf pairs and only 8 single whales. This same tendency was noticed when we compared individuals photographed from different sides. There were 32 recaptures for the right side photographs, 26 cow-calf pairs and 6 single whales; and 19 for the left side photographs, 17 cow-calf pairs and 2 single whales (Table 2).

Different residence intervals were documented for cow-calf pairs and single whales. Cow-calf pairs stayed in the lagoon for a period of 1 to 39 days with an average of 16.7 ± 3.3 95% C.I. Unlike cow-calf pairs, single whales used the lagoon for 1 to 22 days with an average of 5.9 ± 2.1 95% C.I. (Fig. 9).

DISCUSSION

An important factor to consider when assessing any change in the abundance of gray whales in the lagoon, its the occupancy timetable for the whales that visit it during a typical winter (Jones *et al*., 1994). The highest counts from 1978 to 1985 range from 300 in 1978 to 407 in 1982 (Jones *et al.*, 1994). Based in these counts, they estimated an annual increment rate of a 7.3% for 1978 to 1982 (Jones and Swartz, 1986), and 4.5 % for 1978 to 1985 (Jones *et al*. 1994). The 1996 season maximum count of 207 whales shows an important decline of 48% in relation with 1985. This reduction is primarily attributable to lower counts of single whales, the 115 single whales counted in 1996 are 61% less than 1985. In contrast, the 92 cow-calf pairs from 1996 were 3% less than 1985 (Fig. 10).

The temporal distribution of whales during the 1978-1982 seasons was bimodal due to the pooling of observations from two whale group classes (single whales and cow-calf pairs). The larger mode for each year consisted of the highest count of single whales and the highest count of all whales (including single whales and cow-calf pairs), and both coincided.

Single whales averaged 70% and cow-calf pairs averaged 30% of the total count during the mean date of peak counts for the 5 years (February 15 ± SE 3.9 days). This was follow by a dip and then a second smaller peak in counts that consisted almost entirely of cow-calf pairs. Some of these cow-calf pairs arrived from other lagoons and used Laguna San Ignacio after the earlier departure of the single whales. The mean date for the highest counts of cow-calf pairs was March 19 ± SE 2.3 days (Jones and Swartz, 1984) (Fig. 10). In 1996, the maximum combined count occurred on March 2 and the single whales averaged 56% and cow-calf pairs 44%. We think that there were no cow-calf pairs coming from other lagoons using Laguna San Ignacio as a staging area, because we did not have a second peak that could suggest this (Fig. 10).

The distribution of whales this year followed a gradient of whales that ran south to north in the lagoon (Jones and Swartz, 1984). Whales were present predominantly in the lower zone, then in the middle and lastly in the upper zone of the lagoon. As mentioned, the abundance of whales was greatest in the lower zone during the previous years (Jones and Swartz, 1984) and also in 1996. This zone might be preferred by its oceanographic characteristics. It contains channels that are deeper than in other zones in the lagoon (20-27 m) (Swartz and Jones, 1981)

The abundance and distribution in the lagoon zones of gray whales during the maximum count in 1996 in relation with 1978-82 seasons is showed in the Table 3. The main differences are the decline of cow-calf pairs in the upper lagoon (-67 %), their increase in the middle and lower zones (+154 % and +106 % respectively) and the reduction of single whales in the three zones. Although the three zones showed a decrease in whale numbers, the upper lagoon is the zone with a most dramatic change (-70 %). There are similar results when we compare the density of the gray whales during the 1978-82 seasons with the 1996 season. The upper lagoon, the largest zone, had a decrement of 69% of the density of whales, while the other zones had minor changes (Table 4).

Based on these comparisons we can conclude that during the 1996 winter season, in the maximum combined counts, there were 39% less whales than during the 1978-82 seasons. The main changes were: a) Single whales were 49% less and this produces a change in the date of the maximum combined count from mid February to early march (at the same time than the maximum count of cow-calf pairs happened), b) There was no increase of cow-calf pairs after the departure of single whales in the first half of March, which suggests that they did not visit the lagoon during their northern migration, c) In the upper lagoon there were 70% less whales

perhaps due to oceanographic changes. For instance the bathymetry of this area, which could cause a different distribution of the whales in the lagoon and at the same time, less habitable space in the interior of the lagoon.

It is necessary to continue this kind of studies for a longer period, in order to know if the changes in abundance are the result of annual environmental factors. Like shifts in the formation of the Arctic ice sheet, extremely favourable or unfavourable weather in the summer range and along the migratory route during the previous years, long term changes in the lagoon like its bathymetry or human activities as whale-watching.

The photographic identification results revealed that the cow-calf pairs stay in the lagoon area close to three times more than single whales. This result supports what was established by Jones and Swartz (1984) and Harvey and Mate (1984), that the cow-calf pairs remain more time in the lagoon than single whales, because the cows use the lagoon as a parturition and nursing zone, while the single whales use it only as a mating zone.

The short residence time in the lagoon and daily movements for many of the tagged whales by Harvey and Mate (1984), suggest that there is a considerable turnover in the lagoon population. Estimates of whale abundance in Laguna San Ignacio fluctuated between consecutive daily counts (Swartz and Jones, 1980; this work). This implies that some whales may be continuously moving out the lagoon while others replace them. Estimates of the total number of whales using a particular lagoon, therefore, cannot be made simply from visual counts (Harvey and Mate, 1984). Further photographic and tagging studies may help in developing turnover rates, which will allow the number of whales using a lagoon to be calculated based on visual surveys.

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TABLES….

Table I. Census of gray whales in Laguna San Ignacio, B.C.S., during 1996 winter.

Census date		Zone						Total	
		Lower		Middle		Upper			
		Sing.	Cow-c p.	Sing.	Cow-c p.	Sing.	Cow-c p.	Sing.	Cow-c p.
17	Jan	5	3	13	0	4	0	22	3
18	Jan	8	3	6	7	1	2	15	12
19	Jan	7	4	6	2	7	6	20	12
31	Jan	18	7	30	10	4	15	52	32
1	Feb	37	8	26	15	1	13	64	36
2	Feb	36	10	14	12	6	32	56	54
4	Feb	55	8	21	14	4	10	80	32
5	Feb	49	3	19	13	8	21	76	37
7	Feb	50	8	25	17	18	29	93	54
10	Feb	39	5	24	7	8	13	71	25
13	Feb	54	10	28	21	3	31	85	62
17	Feb	48	10	25	17	1	15	74	42
24	Feb	65	19	32	27	7	22	104	68
2	Mar	84	33	25	31	6	28	115	92
3	Mar	66	23	39	25	7	46	112	94
9	Mar	32	35	10	38	2	10	44	83
10	Mar	28	44	15	27	1	12	44	83
16	Mar	1	46	0	3	0	3	1	52
21	Mar	3	34	0	14	0	2	3	50
27	Mar	0	35	0	14	0	2	0	51

Table II. Number of photographs and recaptures in Laguna San Ignacio, B.C.S. February –March 1996.

Group class	Left side		Right side		Total	
	Photos	Recaptures	Photos	Recaptures	Photos	Recaptures
Singles	146	2	111	6	257	8
Cow-calf pairs	87	17	99	26	186	43
Indeterminated	13	-	18	-	31	-
Total	246	19	228	32	474	51

Table III
Changes in abundance and distribution of gray whales from 1978-82 census with 1996 census. (Maximum combined counts)

Zone	Cow-calf pairs			Singles			All whales		
	$\bar{x}$ *(1978-82)*	$\bar{x}$ *(1996)*	*% variation*	$\bar{x}$ *(1978-82)*	$\bar{x}$ *(1996)*	*% variation*	$\bar{x}$*(1978-82)*	$\bar{x}$ *(1996)*	*% variation*
Lower	16	33	+106%	147.6	84	-43%	163.6	117	-28%
Medium	12.2	31	+154%	54	25	-54%	66.2	56	-15%
Upper	84.4	28	-67%	25.2	6	-76%	109.6	34	-70%
TOTAL	112.6	92	-18%	226.8	115	-49%	339.4	207	-39%

Table IV
Changes in density of gray whales from 1978-82 census with 1996 census. (Maximum combined counts)

Zone	$\bar{x}$ 1978-82 (whales/Km^2)	$\bar{x}$ 1996 (whales/Km^2)	% variation
Lower (17.5 Km^2)	10.3	8.6	-16%
Middle (22.9 Km^2)	3.4	3.8	+12%
Upper (46.6 Km^2)	4.2	1.3	-69%
TOTAL (87 Km^2)	5.2	3.4	-34.6%

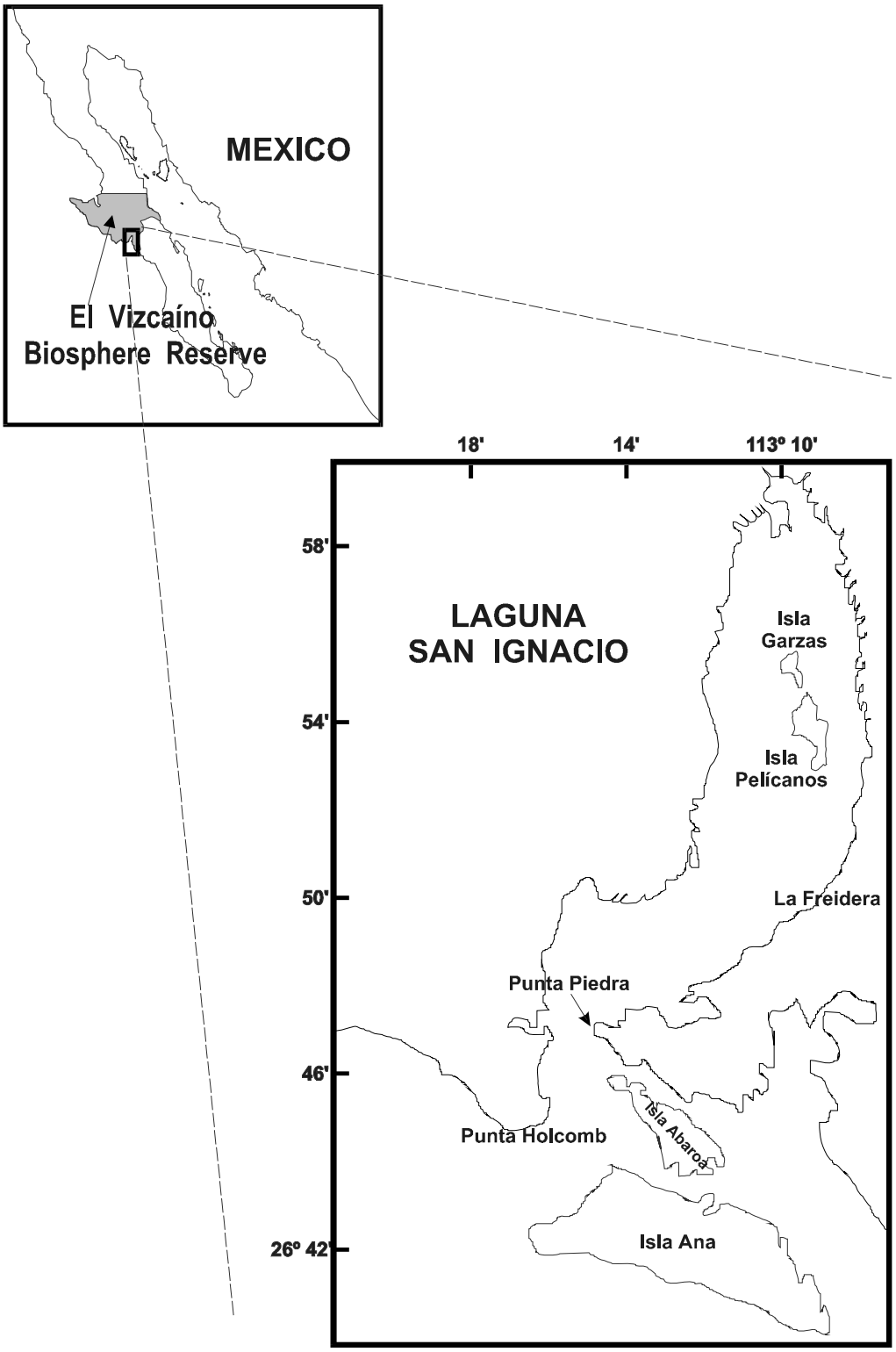


Figure 1. Study site.

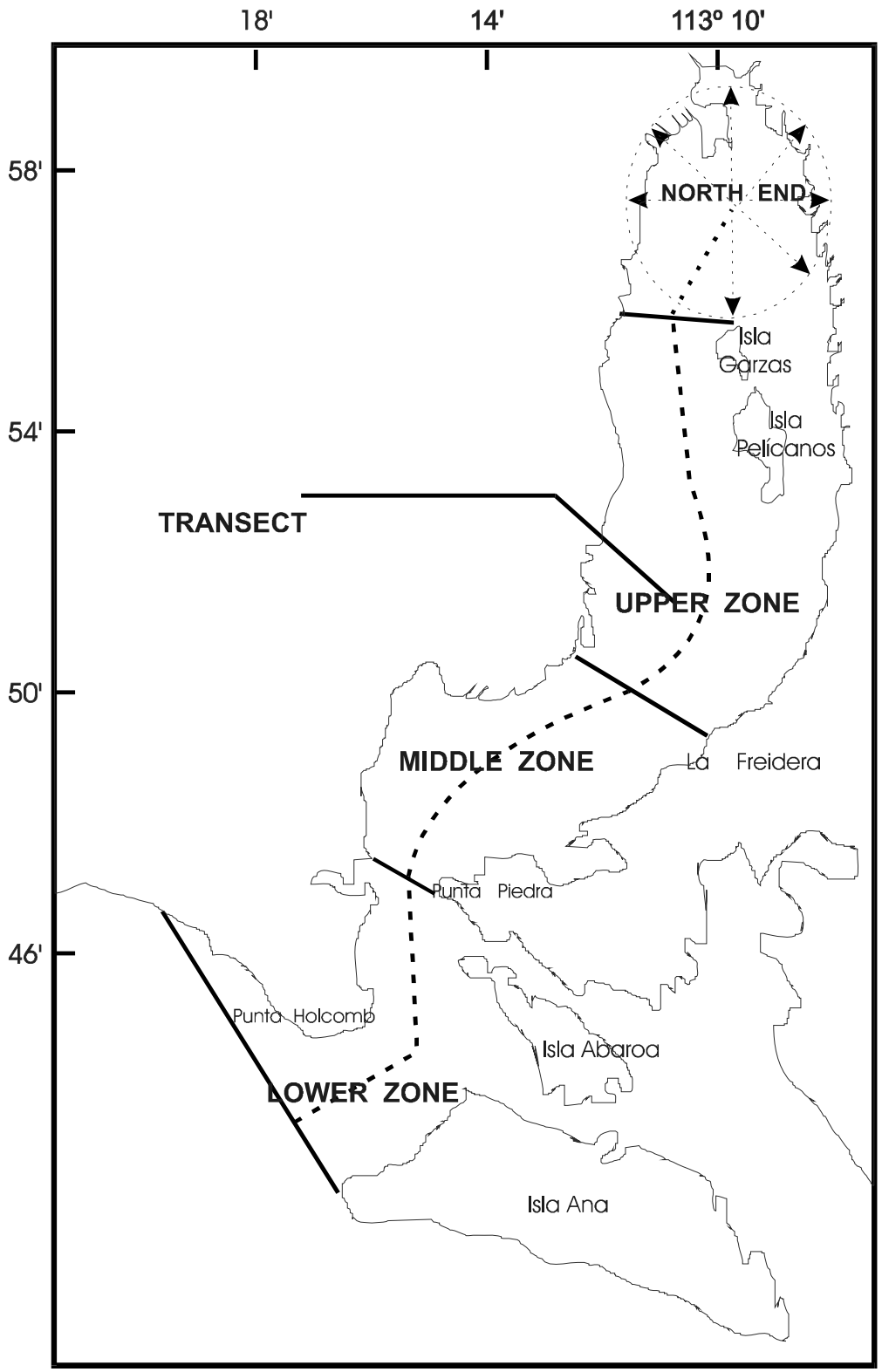


Figure 2. Transect for countings of gray whales in Laguna San Ignacio during 1996 winter.

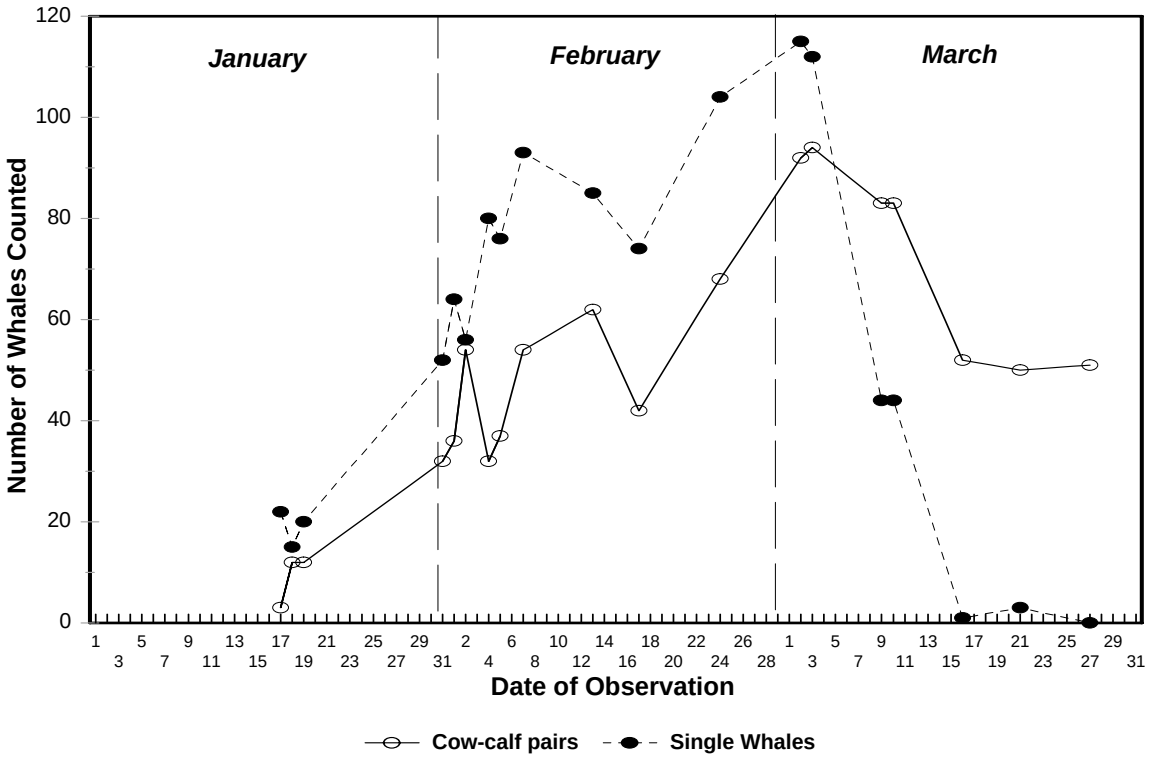


Figure 3. Number of single whales and cow-calf pairs counted in 20 vesel transects of Lagua San Ignacio during 1996 winter.

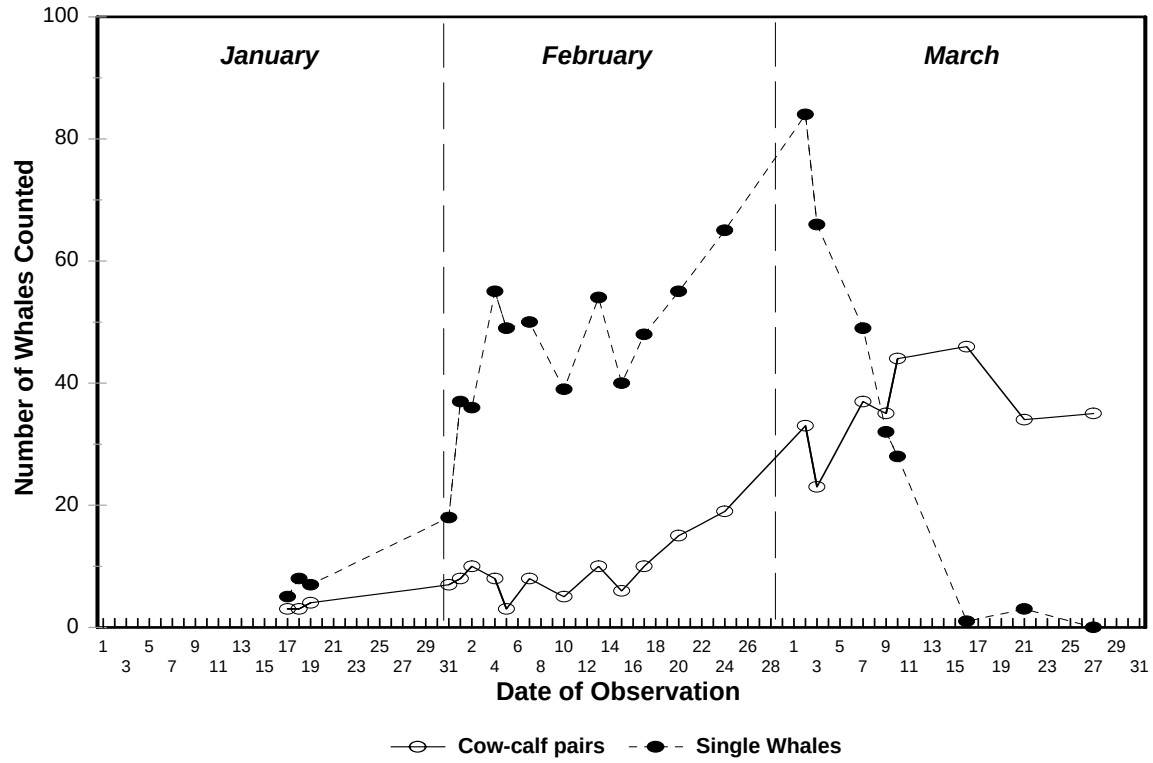


Figure 4. Number of single whales and cow-calf pairs counted in the Lower Zone of Laguna San Ignacio during 1996 winter.

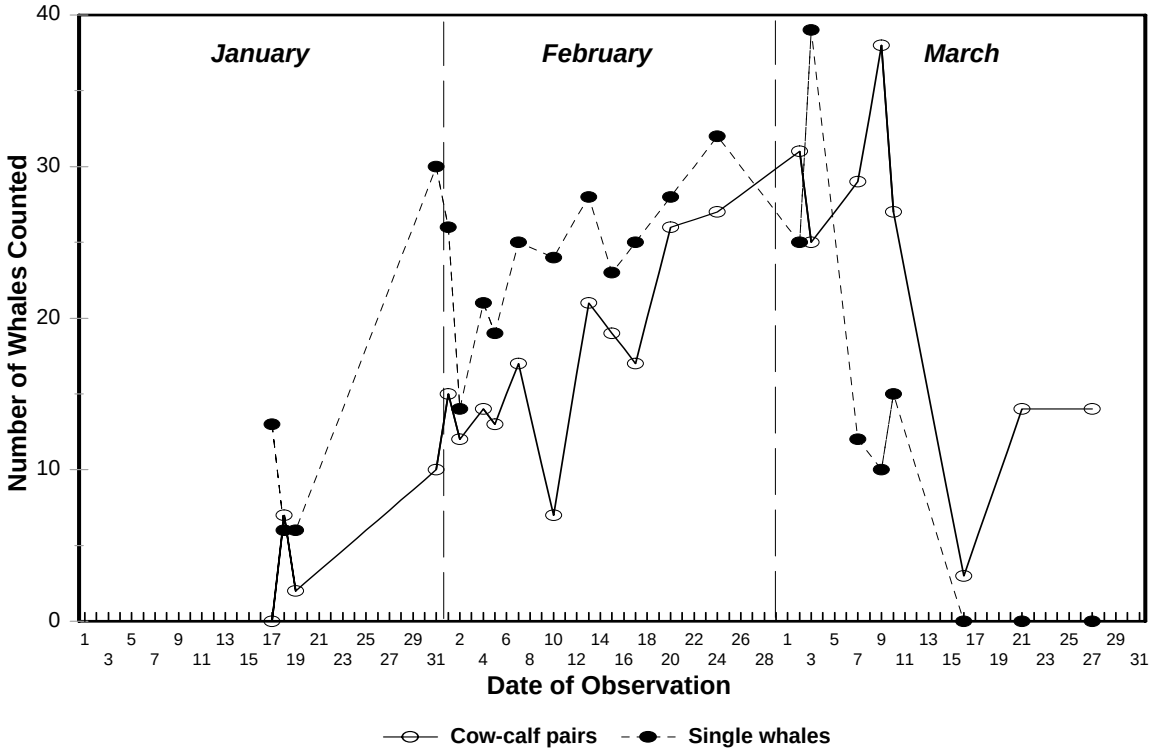


Figure 5. Number of single whales and cow-calf pairs counted in the Middle Zone of Laguna San Ignacio during 1996 winter.

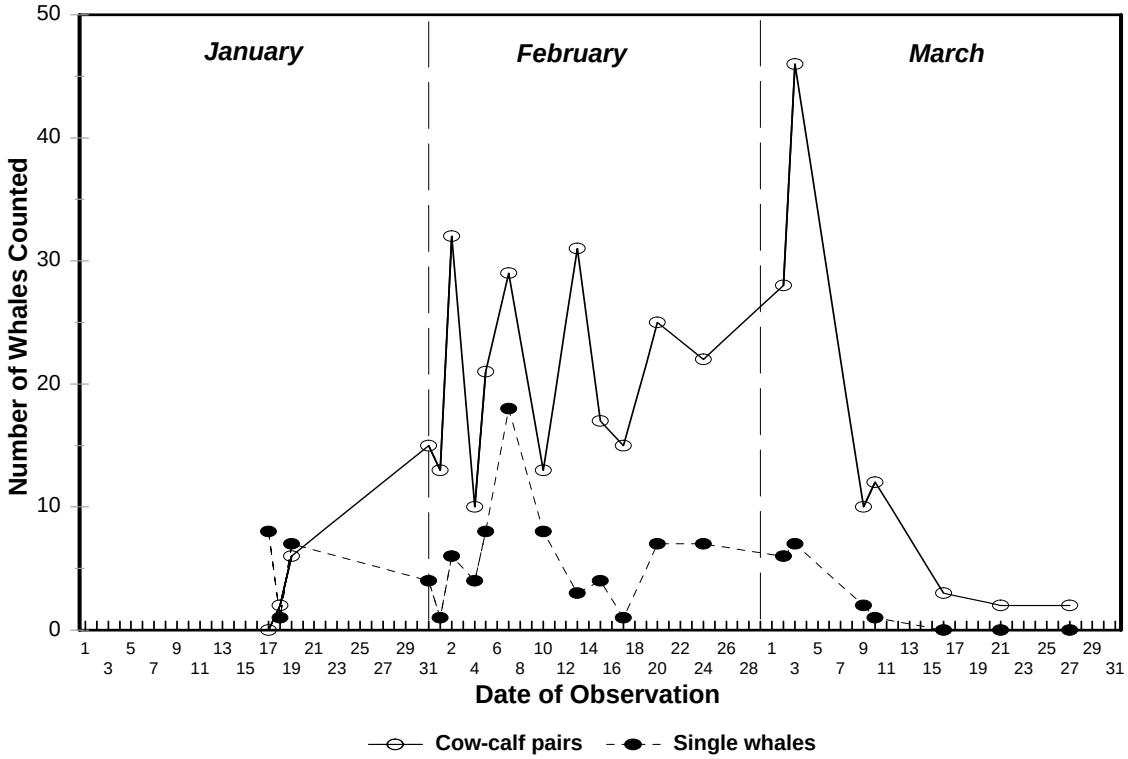


Figure 6. Number of single whales and cow-calf pairs counted in the Upper Zone of Laguna San Ignacio during 1996 winter.

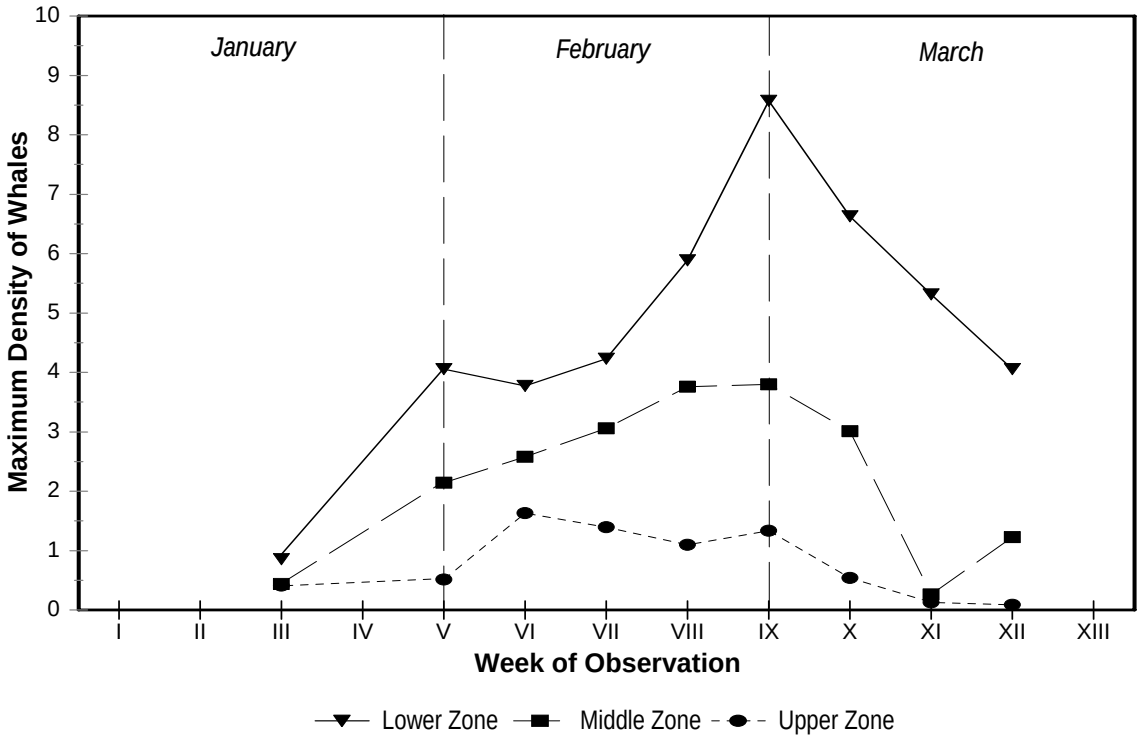
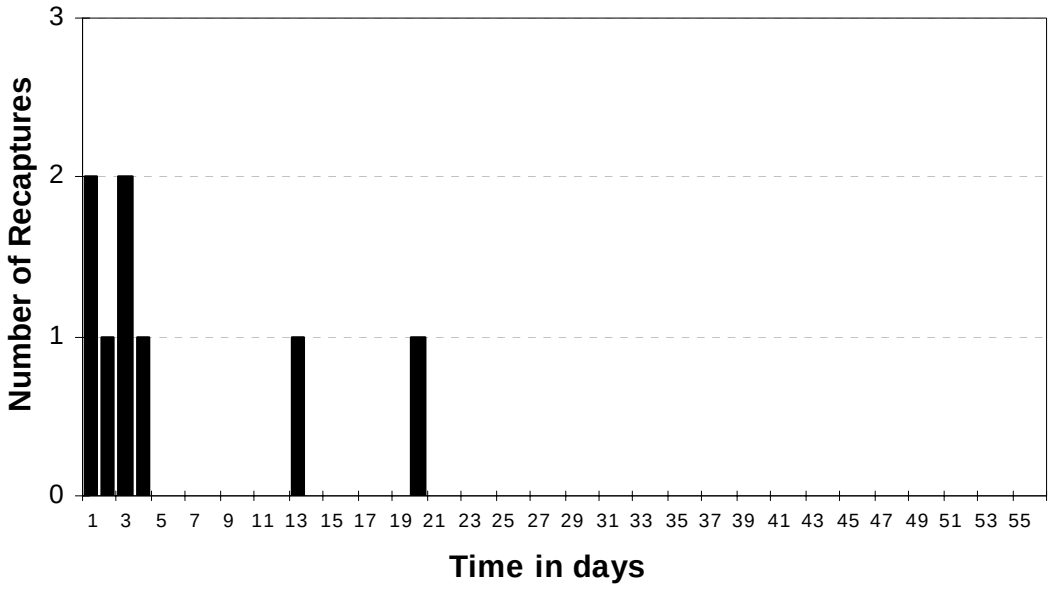
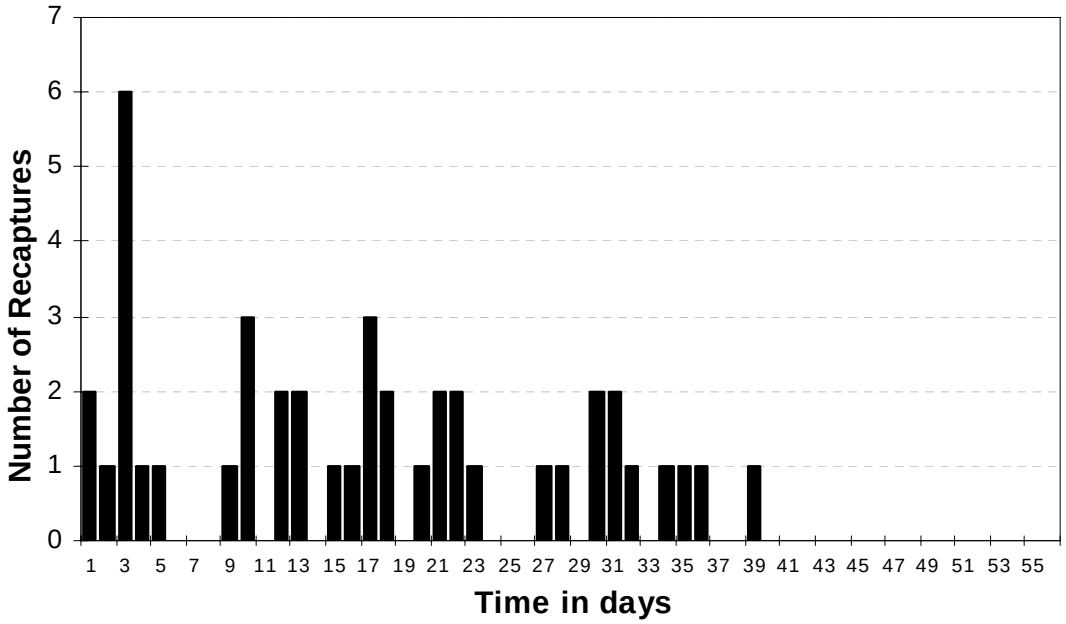


Figure 7. Density of gray whales in Laguna San Ignacio, from highest combined counts of each week for 1996 winter.



a. Single whales



b. Cow-calf pairs

Figure 8. Range of time between recaptures from single whales (a) and cow-calf pairs (b), in Laguna San Ignacio during 1996 winter.

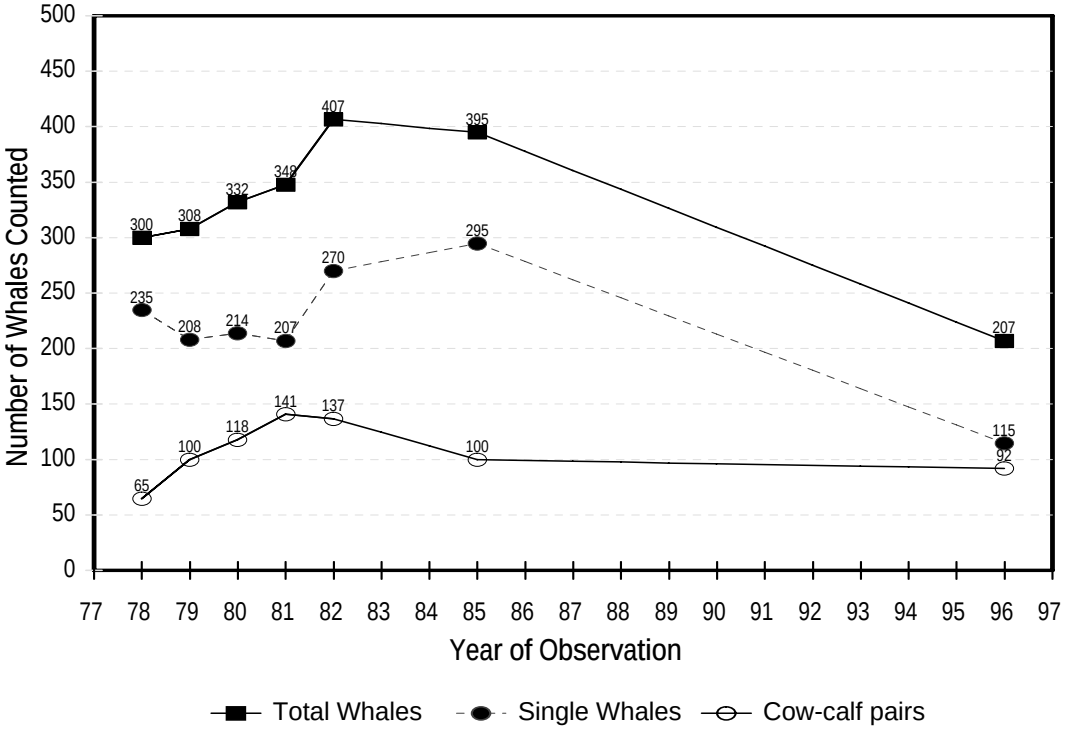


Figure 9. Annual maximum count of all whales except calves (Total Whales), single whales and cow-calf pairs for the years 1978 to 1982, 1985 and 1996 in Laguna San Ignacio, during the winter period of those years.

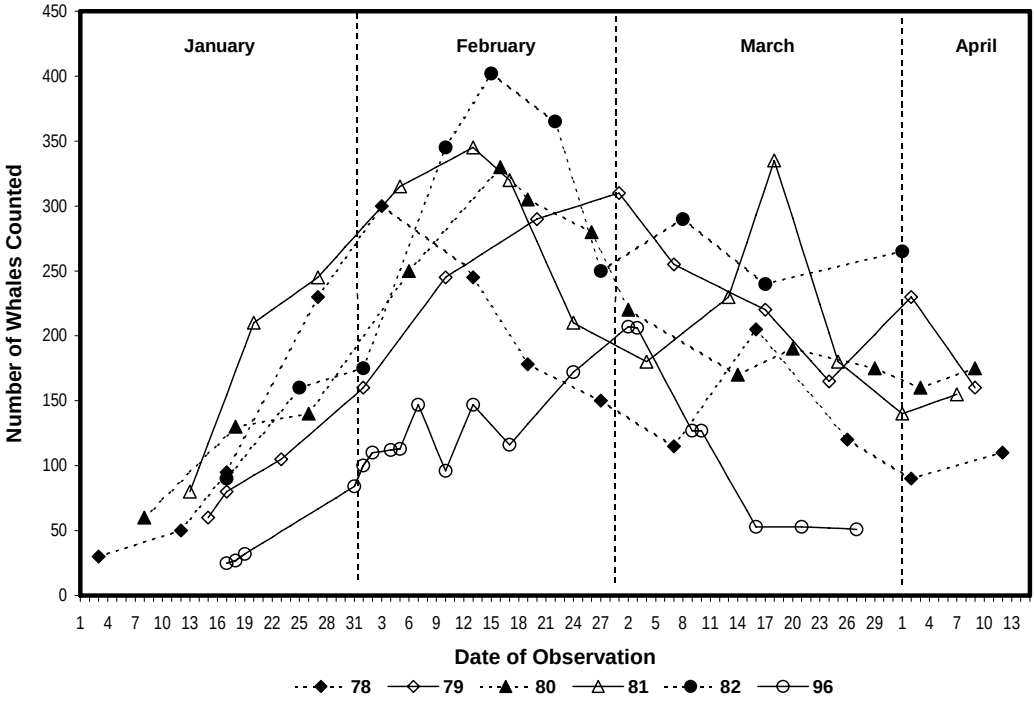


Figure 10. Number of whales (only adults), counted in 80 vessel transects of Laguna San Ignacio from 1978 to 1982 and 1996. (Modified from Swartz and Jones, 1996).