Towards an estimate of the Southeastern Pacific humpback whale stock

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ABSTRACT

Between 1991 and 1997 a photo-identification study of Southeastern Pacific humpback whales was carried out on the central coast of Ecuador (1°26'S, 80°50'W), South America. During this period, a total of 219 whales were identified and catalogued by the colouration pattern on the ventral side of their flukes. Naturally marked whales were used to estimate the population through the Petersen's mark-recapture method as modified by Bailey. With data from the final two seasons (1996-1997), the resultant estimate was 1,922 (95% CI = 77-3,767) whales. Pooling data from the first six years resulted in an estimate of 2,683 (95% CI = 397-4,969) whales. Sources of bias relate to violations of the assumptions of closure and equal catchability conditions. The low inter-yearly resighting rate and a high rate of new discoveries in the last season indicate that only a fraction of the population has so far been identified. Despite the broad confidence interval, these data provide an indication of the current number of whales.

KEYWORDS: HUMPBACK WHALES; MARK-RECAPTURE; PHOTO-ID; ABUNDANCE ESTIMATE; SOUTH AMERICA; PACIFIC OCEAN

INTRODUCTION

The humpback whale (*Megaptera novaeangliae*) was severely depleted as a result of intensive whaling in the 19th and 20th centuries (see review in IWC, 2001). There are now thought to be up to seven stocks of humpback whales in the Southern Hemisphere (IWC, 2001). One of these stocks migrates along the west coast of South America during the austral winter months towards its breeding grounds in the coastal waters of Ecuador and Colombia (Clarke, 1962; Dawbin, 1966; Chiriboga, 1972; Ramírez, 1988; Flórez, 1991; Félix and Haase, 1996; Félix and Haase, 1997a; Félix and Haase, 1998). Photo-identification studies have established that the breeding boundaries of this stock extend more than 1,400km from the coastal waters of northern Peru (4°30'S) to as far north as Panama (Flórez *et al.*, 1998) and perhaps Costa Rica (8°30'N; Acevedo and Smultea, 1995). A few humpback whales have also been recorded during the breeding season around the Galapagos Islands (01°30'S, 90°30'W), 1,000km west of Ecuador (Day, 1994; Merlen, 1995) and around Isla del Coco (5°33'N, 87°02'W; Acevedo and Smultea, 1995).

The first references to humpback whales in the Southeastern Pacific originated from the whaling vessels that operated along the west coast of South America during the 19th century. During this period, large numbers of humpbacks were taken along the coasts of Ecuador and Colombia between June and September (Townsend, 1935; Beneden, 1887, cited by Clarke, 1962). Whaling continued intensively along the western South American coast during the 20th century from land stations in Peru and Chile, where 2,281 humpback whales were processed between 1908 and 1975 (Clarke, 1980). Additionally, humpback whales were killed during three pelagic whaling campaigns: in 1914 and 1926 off the coasts of Ecuador and Colombia, and in 1954 off Ecuador, Peru and Chile (Clarke, 1962; Chiriboga, 1972). The most significant takes occurred in Antarctic waters, especially during the first half of the 20th century (Chapman, 1974).

The Southeastern Pacific humpback whale stock is one of the least known in the Southern Hemisphere and no reliable estimate of its present size exists (IWC, 2001). Recently, attempts have been made to assess the size of this stock on its breeding grounds: Haase (1990) estimated the stock to be between 994 and 1,698 animals based on direct and systematic observations from land and aboard fishing vessels in Ecuador; Flórez (1991) and Ojeda and Hurtado (1992), using different mark-recapture models, estimated the number of whales breeding at Gorgona Island, Colombia, at 170-450 and 127-645 individuals respectively. This paper presents an estimation of the Southeastern Pacific stock using data obtained from a photo-identification study carried out on the central coast of Ecuador between 1991 and 1997.

METHODS

Boat surveys to study humpback whales were carried out during the austral winter months of June-September between 1991-1997 on the central coast of Ecuador (1°26'S, 80°50'W). The study area covered approximately 800km^2 of sea, bounded by the coastal villages of Puerto López, Puerto Cayo and La Plata Island (Fig. 1). Surveys were regular but not systematic, as commercial whale watching vessels were usually used as the research platforms. Boats departed from Puerto López toward La Plata Island (42km) and from Puerto Cayo toward the Bajo de Cantagallo (19km), a shallow area located halfway between Puerto Cayo and La Plata Island.

Whales were photographed with 35mm cameras (200-500mm lenses) and 100-200 ISO slide and colour print films and individually identified from the unique pattern on the ventral side of the flukes (see Katona *et al.*, 1979; Hammond *et al.*, 1990), each whale was assigned a number. Photographs were stored in a catalogue curated at the Fundación Ecuatoriana para el Estudio de Mamíferos Marinos in Guayaquil, Ecuador.

For the purposes of this paper the term 'population' is used to refer humpback whales in the Southeastern Pacific. The population size was estimated using the Bailey-modified Peterson's mark-recapture method (Seber, 1982):

$$N_1 = n_1(n_2+1)/(m_2+1)$$

$$V_1 = n_1^2(n_2+1)(n_2-m_2)/(m_2+1)^2(m_2+2)$$

where:

N_1 = estimated number of whales in a closed population;
n_1 = number of whales in sample 1;

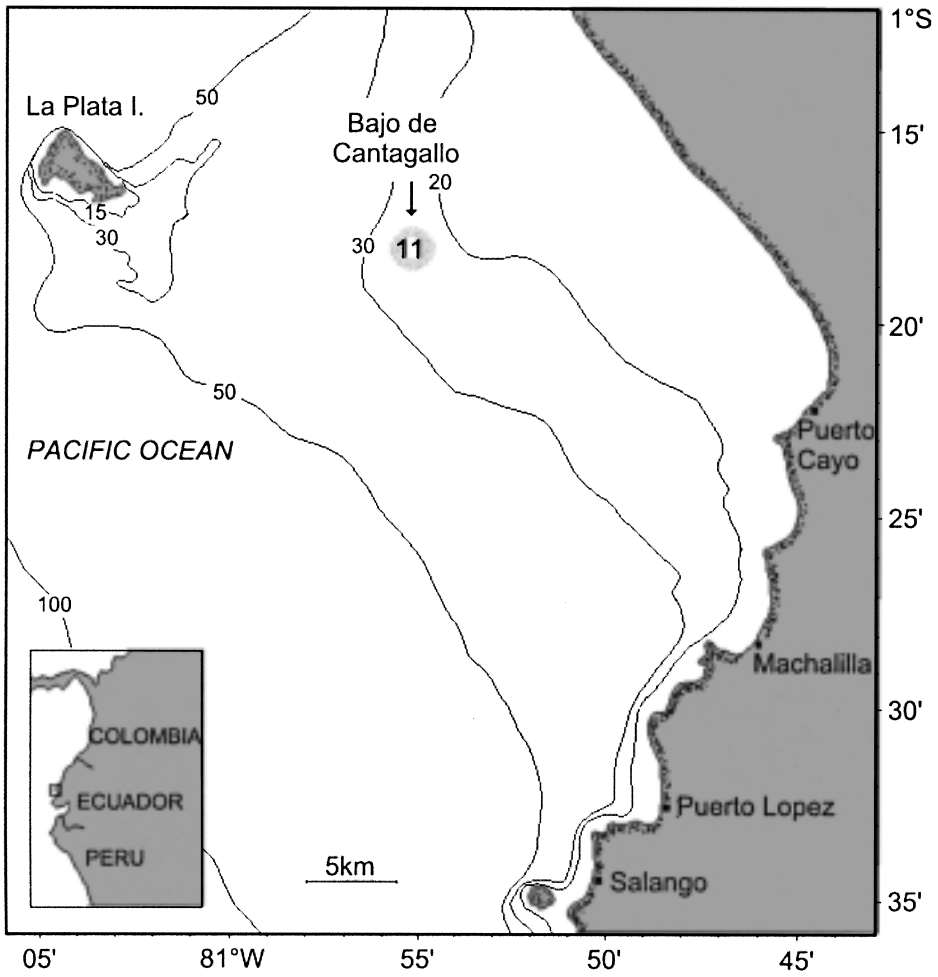

Fig. 1. The study area.

n_2 = number of whales in sample 2;
m_2 = number of marked whales found in sample 2;
V_1 = variance.

The conditions of the model are:

(1) the population is closed (N is constant);
(2) all animals have the same probability of being 'caught' in the first sample;
(3) marking does not affect the catchability of an animal;
(4) the second sample is a simple random sample, i.e. each of the possible samples has an equal chance of being chosen;
(5) animals do not lose their marks in the time between the two samples;
(6) all marks are reported on recovery in the second sample.

The Petersen model requires two samples, one at the beginning and the other when marks are recovered. In this paper, population size is estimated by:

(1) only considering data from the most recent two seasons, using data from 1996 as sample one and data from 1997 as sample two; and
(2) pooling all the identified whales between 1991 and 1996 to form sample one and those from the season 1997 to form sample two.

RESULTS

A total of 219 whales were identified by their natural markings (32% of the total sighted whales) in 127 surveys conducted during the study period. Table 1 shows the deployed effort and the number of whales sighted, identified and re-sighted in each year. During the first four years (1991-1994) surveys were largely opportunistic. They became more regular during the last three seasons (1995-1997). Fig. 2 shows the monthly effort during this last period (1995-1997) when 83% of the total effort occurred. Since commercial whalewatching boats were used as the research platform, effort was concentrated when the whales were more abundant (July-September). In 1995, more than 50% of the effort was made during the second half of the season (September), but during the last two seasons (1996 and 1997), effort peaked in August. In 1996, the effort was higher in September than in July, whereas in 1997 the opposite occurred.

Inter-yearly resightings ($n = 3$) were only obtained during the final season (1997): one whale having previously been identified in 1992 and two in 1996 (Table 1). The population in 1996 was estimated using method (1) to be 1,922 (95% CI = 77-3,367) whales, and with method (2) to be 2,683 (95% CI = 397-4,969) whales.

DISCUSSION

The abundance estimates obtained here are considerably higher than previous estimates made at the end of 1980s on the coast of Ecuador (Haase, 1990) and from photo-identification studies at Gorgona Island, Colombia, at about the same time (Flórez, 1991; Ojeda and Hurtado, 1992). The Gorgona Island study was focussed in a single nursing area where mothers and calves formed a high

Table 1
Effort deployed and results obtained on the coast of Ecuador during the study period 1991-1997.

	1991	1992	1993	1994	1995	1996	1997
No. trips	7	6	2	7	5	50	40
Navigation time (hours)	30	26			108	195	128
No. whales sighted	45	26			102	256	207
No. identified whales	9	13	1	14	31	79	72
No. resighted whales							3

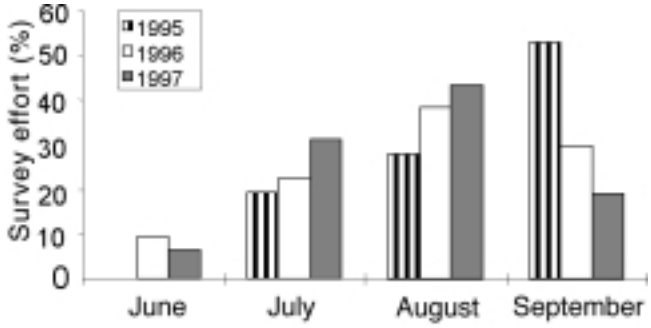

Fig. 2. Monthly effort distribution during the seasons 1995-1997. Data are presented as proportions of the total kilometres surveyed in each year.

proportion of the recorded animals - this does not make it an ideal site for estimating population size. By contrast, the proximity of the Ecuadorian coast to the southern breeding limit makes it a more appropriate site because most whales pass by the area, implying that it is both part of the migration corridor and a breeding zone. Therefore, it is possible to obtain a more representative sample of the population in the present study area as shown by the comparable results of both estimations made at Ecuador.

A recent estimate in our study area, using a similar methodology, has been provided by Scheidat *et al*. (2000). However, their highest estimate for the seasons 1998-1999 (405 whales, 95% CI 221-531, $n_1 = 28$, $n_2 = 27$, $m_2 = 1$) is based on only one resighting of a whale recorded during the four consecutive years of their study. We consider our estimate more reliable because it is based on a sample 2.74 times higher (seasons 1996-1997, $n_1 = 79$, $n_2 = 72$, $m_2 = 2$). The smaller the sample the greater the risk of introducing biases in the estimate. Formation of a unified catalogue would greatly improve the value of studies in this area.

Working with naturally marked animals fulfils many of the estimation model assumptions as discussed by many authors (e.g. Hammond, 1986; IWC, 1990). Hammond (1986) recommended the Bailey-modified estimator for similar studies and provided an extensive discussion of the possible effects of model assumption violations. Based on such considerations, we consider method (1) to be preferable given the assumption of a closed population. Thus, ideally, the interval between marking and recapture should be as short as possible provided that it is sufficient to enable random intermixing among individuals to occur. A major factor in any mark-recapture study is the question of heterogeneity in capture-recapture probability. With respect to the present study, it is well known from elsewhere (Dawbin, 1966) that different age/sex classes migrate at different times in the season. Thus, if effort is concentrated in only certain months of the migration period, some classes may be more frequently sampled than others or some individuals may never be available for sampling. This will result in downwardly biased estimates. Apart from 1995, when effort was concentrated later in the season than in other years, most survey effort was carried out during the months with the highest abundance of whales, when most of the age/sex classes were well represented.

Another potential source of capture heterogeneity is the observed age class segregation inside the study area (Félix and Haase, 1997b); the representation of certain classes may therefore be dependent on the levels of effort at specific sites. Additionally, as has been noted in other studies, certain whales were more difficult than others to photograph. In particular, mothers and calves usually did not raise their flukes as often as other classes; only 1 of 25 mothers (4%) and no calves were positively fluke-identified. In this particular case, the shallowness of the sites they frequented (80% female-calf pairs were found in water 20m deep or less (Félix and Haase, 1996; Félix and Haase, 1997b) would also have impeded fluke-up dives by these whales. A better understanding of the social structure (e.g. age class distribution, migration timing, type and length of period of individual associations) and behaviour would improve obtained estimates, as would sampling on the feeding grounds (Smith *et al.*, 1999).

Clearly a major factor in the precision of any estimate depends on the sample size. Seber (1982) examined the effect of sample size on accuracy for mark-recapture studies and the small number of recaptures here ($n = 3$) is well below the number recommended even for preliminary studies. This is reflected in the broad confidence intervals presented. However, both the high rate of new discoveries and the low rate of inter-yearly resightings suggest that the number of photo-identified whales off Ecuador ($n = 219$) represents only a fraction of the total population. Despite these problems, the estimate is shown here in the spirit of providing more information on abundance in the area. In our opinion, the information presented suggests that in common with several other stocks in the Southern Hemisphere (e.g. Paterson and Paterson, 1989; Bannister *et al.*, 1991; Findlay and Best, 1996), the Southeastern Pacific stock may now be recovering since protection was granted in the mid-1960s.

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