

NEW ESTIMATE OF THE SOUTHEASTERN PACIFIC HUMPBACK WHALE STOCK OFF ECUADOR

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ABSTRACT

The winter migratory pathway for the Southeastern Pacific humpback whale stock (*Megaptera novaeangliae*) extends along the northwestern coast of South America, and possibly as far north as Costa Rica. A preliminary estimate of the size of the migratory population is reported here, using closed (Peterson) and open (Jolly-Seber) mark-recapture models. A database of 1,061 individual whales photo-identified off the coast of Ecuador (2°S, 81°W) between 1991 and 2004, was used. The best estimate with the Peterson model was 2,917 whales (C.I. 95% 1,751-4,859; CV 0.19), obtained in the period 2003-2004. Estimates with the Jolly-Seber model were more heterogeneous, even when data were pooled in periods of two years. However, an estimate of 2,881 whales (C.I. 95% 1,722-4,039), similar to results using the Peterson model, was obtained for the year 2004 (based on constant survival rate and time-specific capture probabilities). Although it is generally known that whale distribution is not homogeneous throughout the wintering area, our estimate is considered representative of the Southeastern Pacific migratory population because Ecuador is located in the southern part of the wintering area where whales are most likely to pass. A more extensive, collaborative effort including wintering areas further north will help to increase precision in abundance estimates.

INTRODUCTION

Humpback whales (*Megaptera novaeangliae*) migrate in the Southeast Pacific between their feeding grounds located west of the Antarctic peninsula (Stevick *et al.*, 2004) and south of Chile (Gibbons *et al.*, 2004) and their breeding grounds located along the coasts of Ecuador, Colombia, Panama and south of Costa Rica (Clarke, 1962; Florez-González, 1991; Scheidat *et al.*, 2000; Félix and Haase, 2001a; Rasmussen *et al.*, 2005).

First attempts to estimate the size of the Southeastern humpback whale stock at breeding grounds were made at the beginning of the 90's around Gorgona Island, Colombia, using mark-recapture models (Florez-González, 1991) and the coast of Ecuador using direct counts (Haase, 1990). New population estimates, although with wide confidence intervals, were obtained on the central coast of Ecuador by mid and end 90's years; for example, Scheidat *et al.* (2000) using the Petersen estimator modified by Chapman estimated in 405 (C.I. 95% 221-531) the number of whales that frequented the area of the Machaillia National Park, whereas Félix and Haase (2001b), using the Peterson model with Bailey modification, estimated in the same area in 1,920 (C.I. 95% 77-3,767) the size of the population presumed to belong to the Southeast Pacific. By mid 90's, another estimate at Gorgona Island, Colombia, resulted in 1,120-2,190 whales (Capella *et al.*, 1998). In 2003, Félix and Haase (2003) estimated in 2,470 (C.I. 95% 88-4,852) the population with the Petersen estimator and Castro *et al.* (2004), using the Jolly-Seber model for open populations, estimated in 2,662 (C.I. 95% 803-4,521) the size of the population off Ecuador.

Here we present a new estimate of the South East Pacific humpback whale stock carried out off Ecuador using mark-recapture models for both closed and open populations. A database three times larger than those previously used has reduced significantly the level of uncertainty.

THE STUDY SITES

The study sites are located on the central coast of Ecuador. The northern site is a triangular area of around 700km² formed by La Plata Island and two fishing villages, Puerto López and Puerto Cayo (1°26'S, 80°50'W). These last sites are located 22 km apart and La Plata Island is approximately 40km offshore. The second study site is Salinas, on the tip of the Santa Elena peninsula, 80km south of the former site (2°10'S, 81°05'W). The surveyed area in Salinas comprises around 150km² over a narrow platform surrounding the peninsula (see Figure right).



MATERIAL AND METHODS

Source of information

Photos of the ventral side of whales' flukes (see Katona, *et al.*, 1990) were obtained for individual identification during the breeding season (June-October) between 1991 and 2004 aboard whalewatching vessels, which regularly departed from three different ports: Puerto Lopez, Puerto Cayo and Salinas. Analyzed photographs are part of the catalogues maintained by the Fundación Ecuatoriana para el Estudio de Mamíferos Marinos (FEMM) and Pacific Whale Foundation-Ecuador, which contains multiple photographs of 1,061 different individuals.

Analysis of photographs

The digitalized catalogues were exchanged and analyzed separately by the other institution. Besides of identifying common individuals, each group separated the photographs considered unsuitable for comparison due to their poor quality (blurred, or too small to recognize a pattern) and/or inappropriate angle. By the end, both groups agreed in the number of whales in common and the photos considered suitable for the estimate. Photos showing only one lobe of the tail were also included to increase the size of the sample. Finally, photographs of 920 different individuals remained for the analysis.

Estimators

The population size was estimated using mark-recapture models for both closed (Peterson modified by Bailey) and open populations (Jolly-Seber model) (Seber, 1982). Program Jolly (Pollock *et al.*, 1990) was used for the open population modeling analysis.

RESULTS

Closed populations model

The more precise estimate, this is, the value with the narrowest confidence interval and the smallest coefficient of variability (CV), was obtained during the period 2003-2004 with a population size of 2,917 whales (C.I. 95% 1,751-4,859; CV=0.19) (see Table right).

Period	Population size	CV
2001-2002	2,093 (C.I. 95% 827-5,294)	0.44
2002-2003	3,320 (C.I. 95% 1,600-6,888)	0.31
2003-2004	2,917 (C.I. 95% 1,751-4,859)	0.19

Open population model

With the aim to improve the estimate, the number of samples was reduced pooling data in six sampling periods: 1991-1995, 1996-1997, 1998-1999, 2000-2001, 2002-2003, 2004 (alone). Program Jolly produced estimates with three different models: model B (constant survival, time-specific capture probability), model C (capture probability constant) and model D (survival and capture probability constant) (see Table below). Model B produced an estimate for 2004 similar to that obtained with the Peterson estimator for the last period (2003-2004), even with a narrower confidence interval.

Period	Model A	Model B	Model D
2000-2001	3,561 (C.I. 95% -1,806-8,928)	4,188 (C.I. 95% -1,582-9960)	873 (C.I. 95% 554-1,194)
2002-2003	1,743 (C.I. 95% 692-2,883)	1,944 (C.I. 95% 895-2,992)	3,690 (C.I. 95% 2,462-4,917)
2004		2,881 (C.I. 95% 1,722-4,039)	4,312 (C.I. 95% 2914-5,709)

DISCUSSION

An important increase of the research effort in 2004 allowed obtaining the most reliable estimate of the Southeastern Pacific humpback whale stock ever tried. However, the confidence intervals are still wide, requiring a major effort to reduce the current level of uncertainty. The estimate obtained confirms the increasing trend of this population noticed since 90's years (e.g. Capella *et al.*, 1998; Félix and Haase, 2001a; Castro, *et al.*, 2004).

An estimate based on the Petersen estimator introduce a positive bias in proportion to the turnover rate (recruitment rate and survivor up to the second sampling period (Seber, 1982; Hammond, 1986), parameters still unknown for this stock. Other sources of heterogeneity in the probability of capture biasing downward the estimate include individual behavior, site fidelity and migration timing (Hammond, 1986; Stevick *et al.*, 2003).

Estimates obtained with the Jolly-Seber method and models did not improve the estimate obtained with the Petersen estimator. Contrarily, estimations obtained had a higher heterogeneity and a significant lower value in the period when the Petersen estimator showed higher precision (2003-2004). In general, estimates obtained with models A and B (Jolly-Seber) were higher for the period 2001-2002 than those obtained with Peterson but were lower in 2003. The Jolly-Seber estimator requires a higher proportion of recaptures than was obtained in this study to obtain more reliable results. Despite this, there is noticeable similarity between the estimate obtained with model B in 2004 and the one obtained with the Petersen estimator for the period 2003-2004.

Another aspect for consideration of this estimate would be whether it is representative for the Southeastern Pacific population or just part of it. The available information on this population suggests that the study sites in Ecuador are located in the southern boundary of the breeding area, which would extend as from north of Peru until Panama and maybe further north (Florez *et al.*, 1998; Rasmussen *et al.*, 2005). As most humpback whales distributed in the central and northern parts of the breeding area probably passed by the surveyed sites, the estimate presented here is considered representative of the entire Southeastern Pacific stock.

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REFERENCES

- Capella, J., Florez-González, L., Falk, P. & Oels G.A. 1998. Population size of Southeastern Pacific humpback whale stock. Is it recovering? Pag. 23. World Marine Mammal Science Conference, México, 199 p. (Abstract).
- Castro, C., P. Forestell, G. Kaufman and M. Scheidat. 2004. Comportamiento, abundancia y residencia de las ballenas probadas *Megaptera novaeangliae* en una zona de reproducción en costas ecuatorianas. 11^o Reunión de Trabajo de Especialistas en Mamíferos Marinos de América del Sur, del 11 al 17 de agosto 2004, Quito, Ecuador. pp. 56-57 (Abstract).
- Clarke, R. 1962. Whale observation and whale marking off the coast of Chile in 1958 and from Ecuador and beyond the Galapagos Islands in 1959. *Wahington Tribune* 7:265-267.
- Félix, F. and B. Haase. 2001a. The humpback whale off the coast of Ecuador: population parameters and behavior. *Revista de Biología Marina y Oceanografía* Vol. 36(1):51-74.
- Félix, F. and B. Haase. 2001b. Towards an estimate of the Southeastern Pacific humpback whale stock. *Journal of Cetacean Research and Management*, Vol. 3(1):55-58.
- Félix, F. and B. Haase. 2003. Humpback whale research and education activities in Ecuador during 2003. Report to the Whale and Dolphin Society WDCS, England. *Quaypack*, December 2003. 27 pp. (Unpublished) (Available from the authors).
- Florez-González, L. 1991. Humpback whales *Megaptera novaeangliae* in the Gorgona Island, Colombian Pacific breeding waters: population and pod characteristics. *Memorias of the Queenstand Museum* 30(2): 291-295.
- Florez-González, J., Capella, J., Haase, B., Bravo, G.A., Félix, F. and Gerrodette, T. 1998. Changes in winter destinations and the northernmost record of southeastern Pacific humpback whales. *Marine Mammal Science* 14(1): 189-196.
- Gibbons, J., J. Capella & C. Valladares. 2003. Rediscovery of a humpback whale, *Megaptera novaeangliae*, feeding ground in the Straits of Magellan. *Chilean Journal of Cetacean Research and Management* 5: 203-208.
- Haase, B. 1989. Study of the humpback whale *Megaptera novaeangliae* in Ecuador, with an estimation of the eastern tropical Pacific stock boundaries. Progress Report to Whale and Dolphin Conservation Society, Bath, England. 11 p. (Unpublished). (Available from the author).
- Hammond, P.S. 1986. Estimating the size of naturally marked whale populations using capture-recapture techniques. *Rep. Int. Whal. Commn. (Special issue)* 9: 283-291.
- Katona, S., Barber, B., Brazer, C., Kraus, S., Perkins, J. and Whitehead, H. 1976. Identification of humpback whales by fluke photographs. *PP-33-34*, In: H.E. Winn and B.L. Olla (Eds.). *Behavior of Marine Animals* Vol. 4. Plenum Press.
- Pollock, K.H., J.D. Nichols, G. Browne, and J.E. Hines. 1990. Statistical Inference for Capture-Recapture Experiments. *Wildlife Monographs* 107. 379pp.
- Rasmussen, K., J. Calambokidis, G. Steiger, M. Saborio, J. Allen, G. Stone, L. Florez-González, and A. Aguayo. 2004. América Central es zona de reproducción para ballenas probadas de los hemisferios norte y sur. P. 29. Resúmenes 11^o Reunión de especialistas en Mamíferos Acuáticos de América del Sur y P^o Solomón. Septiembre 2004, Quito, Ecuador. (Abstract).
- Scheidat, M., Castro, C., Denlinger, J., Gonzalez, J. and Adelman, D. 2000. A breeding area for humpback whales (*Megaptera novaeangliae*) off Ecuador. *J. Cetac. Res. Management* 2(3):165-171.
- Seber, G. A. F. 1982. *The Estimation of Animal Abundance and Related Parameters*. 2nd Edition. Charles Griffin and Company Ltd., London. i+xvi+654 p.
- Stevick, P., Allen, J., Chapman, P., J. Friday, M., Kalonsa, S. K., Larsen, P., Liem, J., Mattia, D. K., Palacios, P., J. Sigurjonsson, J. Smith, T. D., Oen, N. and Hammond, P. S. 2003. North Atlantic humpback whale abundance and rate of increase four decades after protection from whaling. *Marine Ecology Progress Series* 258:263-273.
- Stevick, P., A. Aguayo, J. Allen, I. C. Avila, J. Capella, C. Castro, K. Chater, M. H. Engel, F. Félix, L. Florez-González, A. Freitas, B. Haase, M. Llano, L. Lodi, E. Muñoz, C. Otevarria, E. Secchi, M. Scheidat & S. Siciliano. 2004. A note on the migrations of individually identified humpback whales between the Antarctic Peninsula and South America. *Journal of Cetacean Research and Management* 6(2):109-113.