SC/A17/NP/18

Abundance and Recovery Rates in Humpback whales (Megaptera novaeangliae) in the Mexican Pacific (1986-2006)

S. Martinez-Aguilar, J. Urban R., and J. Barlow,

INTERNATIONAL WHALING COMMISSION

Abundance and Recovery Rates in Humpback whales (*Megaptera novaeangliae*) in the Mexican Pacific (1986-2006)

S. Martínez-Aguilar, [1], J. Urbán R.[1], and J. Barlow,[2]

[1].- *Universidad Autónoma de Baja California Sur, Ap. Post 19-B, La Paz, Baja California Sur 23081, México*

[2].- *NOAA Southwest Fisheries Science Center, 3333 N. Torrey Pines Court, La Jolla, California 92037, USA.*

INTRODUCTION

During the last two centuries commercial whaling for humpback whales (*Megaptera novaeangliae*) decreased the North Pacific stocks to near extinction. In 1965 the International Whaling Commission banned commercial whaling, when there were only around 1200 and 1400 whales in the North Pacific, since then, many countries have been conducting research to estimate the humpback whales abundance and recovery rates.

Through photo-ID at the beginning of the 80's, the North Pacific population was estimated between 1000 and 2000 individuals (Darling y Morowitz, 1986; Baker y Herman, 1987). Using data between 1990 and 1993; Calambokidis, *et al*., estimated the population between 6000 and 8000 individuals (Calambokidis *et al.*, 2001). The most recent estimation for the North Pacific between 2004 and 2006 realized by the project SPLASH (Structure of Populations, Levels of Abundance and Status of Humpbacks), using Chapman-Petersen Model for closed populations, was of 21,808 individuals (CV=0.04) Barlow *et al.*, (2011) and for the Mexican Pacific, Urbán *et al*., (1999) using the Jolly-Seber method, estimated the Mexican Pacific coastal population of humpback whales in 1813 individuals (95% CI: 918-2, 505) for the year 1992 and of 914 animals (95% CI: 590-1, 193) for the Revillagigedo Stock in 1991.

In Mexico, humpback whales, are distributed mainly in three areas: The south part of the Baja California Peninsula (PBC), Mexican Pacific Coast (CPM) and at the Revillagigedo Archipelago (AR) (Rice, 1978; Urbán y Aguayo, 1987).

METHODS

Field work was conducted in Revillagigedo islands-Colima and in the Mexican Pacific Coast (Banderas Bay, Marías islands and Isabel island- Jalisco and Nayarit) from 1986 until 2006 and in the South part of the Baja California Peninsula from 1987 until 2006 (Figure 1).

Different ship vessels were used (small boat, and ships), and there were not predetermined navigation patterns. Whales were photo-ID by the white and black coloration and by other marks in the ventral surface of the flukes (Katona and Whitehead, 1981).

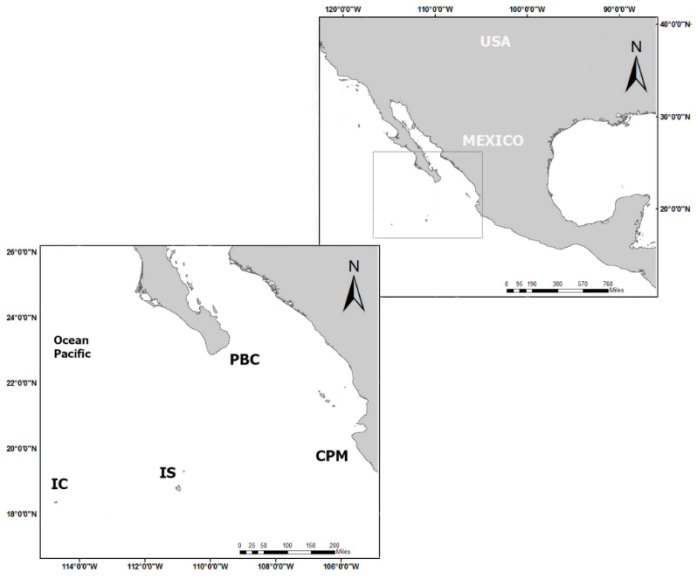

Figure 1. Localities where photo-ID work was conducted: (PBC) Baja California Peninsula, (CPM) Mexican Pacific Coast, including Isabel island and Banderas Bay in Jalisco-Nayarit; (IC) Clarión island and (IS) Socorro island, this last two are part of the Revillagigedo Archipelago.

Fluke photographs were classified using the ventral pigmentation of the flukes (Glockner and Venus, 1983). The best ones from each region were put together in photo-ID catalogs and this were matched between each other digitally at least twice with the program ACDSee 2.5, there were eight different catalogs matched from different institutes: Universidad Autónoma de Baja California Sur (UABCS), Universidad Nacional Autónoma de México (UNAM), Humbolt State University (HSU) y Cornell University (CU). There were a total of 7191 photo-identified from adult whales. Those photos that were not optimum (Poorly focused, bad position, light exposure, etc.) were not compared in order to be sure of the results.

For the absolute abundance estimations, we analyzed each congregation zone as independent units according to Urbán *et al*., (2000), proposed subdivision. For the data analysis we used *Anne Chao* Mth Model (1987). The analysis was made in the R program 2.12.0 (http://www.R-project.org/) and in the RMark 6. We used two sets of data with four years each (1987-1990 and 2003-2006), we obtained two estimations because of this, one at the beginning and one at the end.

The estimations obtained with Chao's Mth model (1987) were used to estimate the recovery rate of the population for each congregation, and the obtained values were analyzed according to an exponential growth model ($Y = \beta_0 e^{\beta 1 x}$). In order to know the annual recovery rate β_1, we used the $\beta 1$ =LN (Y / β_0) / x formula.

RESULTS

We had 7191 photographs of humpback whales flukes. When we matched these photographs, we obtained 4244 different individuals; 1277 for the Baja California Peninsula (PBC); 1800 for the Mexican Pacific Coast (CPM) and 1672 for the Revillagigedo Archipelago (AR). This number of photo-identifications does not match the sum because of the recaptures between the congregation zones.

Also for the absolute abundance estimation, we put together the photo identifications from Baja California Peninsula and the Mexican Pacific Coast, and eliminated the recaptures between them; we obtained 2805 individuals for this Coastal Stock, and we also put the three zones together for the Mexican Pacific Stock. This was in order to analyze them as congregation units and evaluate how the recovery rate modifies annually in this way.

In the groups of data obtained (1987 to 1990 and 2003 to 2006), final abundance estimations with 95% Confidence Intervals are: Baja California Peninsula with 6820 individuals, Mexican Pacific Coast with 4149 individuals, Revillagigedo Archipelago with 2,352 individuals, Coastal Stock with 7051 individuals and 8168 individuals for the whole Mexican Pacific Stock (Table1).

Table 1. Abundance estimations for the two data sets obtained with Mth Chao's model.

Congregation	Estimation 1987-1990	CI 95%	Estimation 2003-2006	CI 95%
Baja California Peninsula	1262	624-2757	6820	4650-10181
Mexican Pacific Coast	1642	1121-2499	4149	3475-5012
Revillagigedo Archipelago	571	465-729	2352	2030-2762
Coastal Stock	1742	1304-2401	7031	6048-8236
Mexican Pacific Stock	1964	1612-2448	8168	7357-9112

Once we obtained the estimation for each of the five congregations, we analyzed the growth rates with the exponential growth formula, obtaining the following results (Table 2):

Table 2. Annual recovery rate estimation of each of the congregations.

Congregation	Estimation 1987 - 1990		Estimation 2003 - 2006		# years	Annual Increase (%)
	(N)	IC 95%	(N)	IC 95%		
Baja California Peninsula	1262	624-2757	6820	4650-10181	16	**10.5**
Mexican Pacific Coast	1642	1121-2499	4149	3475-5012	16	**5.7**
Revillagigedo Archipelago	571	465-729	2352	2030-2762	16	**8.8**
Coastal Stock	1742	1304-2401	7031	6048-8236	16	**8.7**
Mexican Pacific Stock	1964	1612-2448	8168	7357-9112	16	**8.9**

DISCUSSION

The abundance estimation in the Baja California Peninsula N=6820, was the largest obtained, this could be because, it's not only an aggregation zone, but it is also in the migratory path of the whales from the Coastal Mexican Pacific and from the Revillagigedo Archipelago whales, this can be seen in the 31% percent of the photographed whales in the Peninsula, have also been photographed in one of the other two congregations, which could create an over estimation in the Peninsula abundance.

The abundance estimation in the Revillagigedo Archipelago N=2352 is similar to the one obtained with the Hilborn´s model during the SPLASH project (2003-2006), which was of 2600 individuals (Calambokidis *et al.*, 2008). The estimation seems correct, since in this study there was a more homogenous space-time effort and because we found the majority of the animals congregated within a small sample area, the recapture rate of the individuals was the largest of the congregation zones.

The Mexican Pacific Coast N=4149, one of the main bias in the recapture probability is because of the animal distribution, they can be distributed in more than 2000 km along the coast, and our sampling zone was of 200 linear km (between the Marías islands, Isabel island and Banderas Bay) which is the main aggregation zone in the coast, thus the animals that are distributed north of the Marías islands or south of the Banderas bay have less recapture probability, besides the sampling efforts were not the same in the zone. In order to reduce the bias in the Baja California

Peninsula and the Mexican Pacific Coast, we estimated the abundance of the two congregations in what we named the Coastal stock, thus we eliminate the error of identifying those animals that belong to the CPM and not to the PBC, besides the recapture number increases, giving an estimation of 7031 animals.

Finally, by putting together and analyzing every photo identification from the three congregation zones, we estimated the abundance for all of the Mexican Pacific Stock N=8128; this estimation is slightly bigger than the one obtained during SPLASH (2003-2006), which was of 6000-7000 individuals (Calambokidis *et al.*, 2008).

With the results obtained with Chao's Mth model, we estimated that the recovery rates or annual growth for the winter aggregation zones are: Baja California Peninsula 10.5%, Mexican Pacific Coast 5.7%, Revillagigedo Archipelago 8.8%, Coastal Stock 8.7% and for the whole Mexican Pacific Stock 8.9%, which is why we can say that the recovery rate in general is between 8.7 and 8.9 %, considering that the recovery rate of the PCB could be biased by an overestimation of abundance because of the animals that are migrating through the area.

The annual recovery rate obtained for the Mexican Pacific is a little higher than the annual recovery rate obtained for the US West Coast, estimated between 1988-1989 to 1997 Mizroch *et al*., (2004); it is also higher than the annual recovery rate of 8.1 % obtained for the North Pacific, during SPLASH project 2003-2006 (Barlow et al., 2011). And higher also than the 6.9 % obtained by Calambokidis *et al*., 2008 for the Mexican Pacific.

It's important to consider that of the 21808 humpback whales estimated in the North Pacific (Barlow *et al*,.2011); 8168 have been estimated for the Mexican Pacific, being a little more than 37% of the North Pacific population, which reflects the importance of these aggregation zones for the population.

ACKNOWLEDGMENTS

This work was realized under the permits from the Secretary of Environment Natural Resources and Fisheries (SEMARNAT), Natural Protected National Areas Commission (CONANP), Government Secretariat and Secretariat of Navy of Mexico and was realized with support from the projects "Cambio ambiental, dinámica de los hábitos de la ballena jorobada y conformación de la mastofauna marina en la boca del Golfo de California y las Islas Revillagigedo" (CONACyT 38605-V), "Habitos reproductivos e historia poblacional reciente de las ballenas jorobadas (Megaptera novaeangliae) en el Pacífico Mexicano (CONACyT 400302-5-3725PN).

We would like to thank WWF-Telcel alliance, the SPLASH project (Structure of Populations, Levels of Abundance and Status of Humpbacks), WDCS and CONACyT (218125 scholarship), for the economic funds to realize this project.

To the South West Fisheries Service Center for allowing us to process the data analysis in the institute. To Jeff Lake and Eleonora Romero for their support in the data analysis. To the UNAM Marine Mammal laboratory, Mexico ECOTOURS and Jeff Jacobsen, Salvatore Serchio and Danielle Cholewiak and everyone that collected data for the last 20 years.

REFERENCES

Baker C.S. y Herman L.M., 1987. Alternate population estimates of humpback whales (*Megaptera novaeangliae*) in Hawaiian waters. Can. J. Zool. 65:2, 818-21.

Barlow J., Calambokidis J., Falcone E., Baker S.C., Burdin A. M., Clapham P. J., Ford J. K. B., Gabriele C.M., Leduc R., Matttila D. K. Quiin T.J., Rojas-Bracho L., Straley J. M., Taylor B. L., Urbán R. J., Wade P., Weller D., Witteveen B. H., Yamaguchi M., 2011. Humpback whale abundance in the North Pacific estimated by photographic capture-recapture with bias correction from simulation studies. Marine Mammals Science DOI 10.1111-j 1748-7692.

Calambokidis, J., Steigner, H. G., Stranley, J. M., Herman, M. L., Cerchio, S., Salden, R. D., Urbán, R. J., Jacobsen, K. J., Ziegesar, O., Balcomb, C. K., Gabriele, M. C., Dahleim, E. M., Uchinda, S., Ellis., G., Miyamura, Y., Ladrón de Guevara P, P., Yamaguchi, M., Fumihiko, S., Mizroch, S., Schlender, L., Ramussen, K., Barlow, J. y Quiin II, J. T. 2001. Movements and population structure of humpback whales in the North pacific, Marine Mammal Science, 17 (4): 769-794.

Calambokidis J. ., Falcone E., Quiin T.J., Burdin A. M., Clapham P. J., Ford J. K. B., Gabriele C.M., Leduc R., Matttila D. K., Rojas-Bracho L., Straley J. M., Taylor B. L., Urbán R. J., Weller D., Witteveen., Yamaguchi M., Bendlin A., Camacho D., Flynn K., Havron A., Huggins J., Maloney N., B. H., Wade P., Barlow J., Baker S.C., 2008. SPLASH: Structure of populations, levels of abundance and status of hump back whales in the North Pacific. (Final Report for contract AB133F-03-RP-00078) 40 p.

Chao A., 1987 estimating the population size for capture-recapture data with unequal catchability. Biometrics, Vol. 43; 783-789.

Darling, J.D. y Morowitz.1986. Census of "Hawaiian" humpback whales (*Megaptera novaeangliae*) by individual identification. Can. J. Zool., 64: 105-111.

Katona, S. K. y Whitehead, H. P., 1981. Identifying humpback whales using their natural markings. Polar Records, Vol. 20, No. 128: 439 – 444.

Mizroch, S. A., L. M. Herman, J. M. Straley, D. A. Glockner-Ferrari, C. Jurasz, J. Darling, S. Cerchio, C. M. Gabriele, D. R. Salden and O. von Ziegesar. 2004. Estimating the adult survival rate of central North Pacific humpback whales (*Megaptera novaeangliae*). Journal of Mammalogy 85:963–972.

Rice, D. W., 1978. The Humpback Whale in the North Pacific: Distribution, Exploitation, and Numbers. NMFS, EUA: 170 a 195 En. W. E. Schevil (ed.) The Whale Problem. Harvard University Press.

Urbán, R. J. y A. Aguayo L. 1987. Spatial and seasonal distribution of the humpback whale, *Megaptera novaeangliae*, in the Mexican Pacific. Marine Mammal Science 3 (4):333-344.

Urbán, R. J., Alvárez F. C., Salinas Z. M., Jacobsen J., Balcomb K.C., Jaramillo L., Ladrón de Guevara P. P., y Aguayo L. A., 1999. Population size of Humpback Whale, *Megaptera novaeangliae*, in waters off Pacific Coast of Mexico. Fish. Bull. 97: 1017 – 1024

Urbán, R. J., Alvarez C.F., Salinas Z. M., Jacobsen J., Balcomb K.C., Ladrón de Guevara P. P y Aguayo A.L. 2000. Migratory destinations of humpback whales wintering in the Mexican Pacific., J. Cetacean Res, 2(2): 101 – 110.