SEXUAL SIZE DIMORPHISM IN BLACK-BROWED ALBATROSS (*DIOMEDEA MELANOPHRIS*) INCIDENTALLY KILLED DURING LONGLINE OPERATIONS

PATRICIA GANDINI [1,2,4], ESTEBAN FRERE [1,2], M. FERNANDA GARCÍA [1] AND JUAN P. SECO PON [3]

[1] *Centro de Investigaciones de Puerto Deseado, Universidad Nacional de la Patagonia Austral. Avenida Prefectura s/n, CC 238, 9050 Puerto Deseado, Santa Cruz, Argentina.*
[2] *Wildlife Conservation Society. 2300 Southern Boulevard, Bronx, New York, NY 10460, USA.*
[3] *Avenida Colón 1906 1º K, 7600 Mar del Plata, Buenos Aires, Argentina.*
[4] *pagandini@yahoo.com.ar*

ABSTRACT.— Black-Browed Albatross (*Diomedea melanophris*) displays little sexual dimorphism and although males are usually larger than females, sexing birds by direct observation is difficult. We evaluated sexual size dimorphism in this species and provided a reliable method to predict the sex of measured birds. Discriminant Analysis of six morphometric measurements of adult birds indicated that only three variables (bill depth, head width and nape) were the most accurate variables to use in a discriminant function model, predicting sex with 87% of reliability.

KEY WORDS: *Argentina, Black-Browed Albatross, Discriminant Analysis, sexing, sexual size dimorphism.*

RESUMEN. DIMORFISMO SEXUAL DEL TAMAÑO CORPORAL EN ALBATROS CEJA NEGRA (*DIOMEDEA MELANOPHRIS*) CAPTURADOS INCIDENTALMENTE DURANTE LAS OPERACIONES DE PALANGRE.— El Albatros Ceja Negra (*Diomedea melanophris*) muestra un escaso dimorfismo sexual y aunque generalmente los machos son más grandes que las hembras el sexado por observación directa puede ser difícil. Se evaluó el dimorfismo sexual del tamaño corporal en esta especie con un método confiable para predecir el sexo a partir de mediciones de las aves. El Análisis Discriminante aplicado a seis caracteres morfométricos tomados en individuos adultos indicó que solo tres de las variables (ancho del pico, ancho de la cabeza y la nuca) son las más precisas para utilizar en una función discriminante, prediciendo el sexo con un 87% de exactitud.

PALABRAS CLAVE: *Albatros Ceja Negra, Análisis Discriminante, Argentina, dimorfismo sexual de tamaño corporal, sexado.*

Received 10 February 2009, accepted 20 August 2009

Sex ratio is an important parameter to consider in ecological and conservation seabirds studies (Weimerskirch and Jouventin 1987). Often simple ratios of male to female sizes are used as indices of sexual dimorphism (Fairbairn and Shine 1993); they could be also used to attempt to better understand the ecology of sexes of birds incidentally captured by fisheries. In the last decades the population tendency of several species of albatrosses and petrels in the Southern Ocean are declining, often linked to longlining operations (Croxall and Prince 1990, Brothers 1991, Cherel et al. 1996), primarily because thousands of birds are hooked accidentally when they swallow or are snagged on the baited hooks set by commercial longline crews (Brothers 1991, Tasker et al. 2000, Belda and Sanchez 2001, Gandini and Frere 2006).

Black-Browed Albatross (*Diomedea melanophris*) were re-categorized as endangered by IUCN in 2005, as inferred from a steep decline of 65% over three generations (BirdLife International 2008). Therefore, the proportion of sexes affected by commercial longline is crucial to determine the future of the species. Some of the hooked birds drown when they are caught mainly during setting and some others can be released alive when they caught during hauling. These birds are socially monogamous and form long-term pair bonds (Brooke 2004). During the breeding season, visual assessment of sexes of live seabirds can be inferred from sexual displays with certainty (Jouventin and Lequette 1990, Pickering and Berrow 2001). However, it may be an impossible task in other situations when no obvious differences in

Table 1. Morphometric measures (mean ± SD) of drowned males (n = 105) and females (n = 50) of Black-Browed Albatross (*Diomedea melanophris*) collected from longline fishery in waters off the Patagonian Shelf, Argentina. Results of Multivariate Analysis of Variance evaluating differences between sexes are shown.

Variable	Males	Females	F	P
Bill depth (mm)	28.53 ± 1.27	26.97 ± 1.20	53.33	<0.01
Head width (mm)	62.46 ± 3.22	58.52 ± 4.34	40.24	<0.01
Nape (mm)	76.26 ± 4.80	71.64 ± 4.20	33.94	<0.01
Nalospi (mm)	38.73 ± 1.65	36.97 ± 1.62	38.88	<0.01
Bill length (mm)	120.10 ± 3.07	118.09 ± 6.62	6.68	<0.01
Wing length (cm)	116.40 ± 11.06	112.93 ± 10.76	3.38	0.06

plumage or body size exist between the two sexes, as is the case of this species (Croxall 1991).

Nowadays is relatively easy to sex birds molecularly (Jodice et al. 2000, Quintana et al. 2003, Copello et al. 2006, Svagelj and Quintana 2007), but sometimes an immediate determination of sex at the field is still useful (e.g., when the sample is too big or it is impossible to transport samples from ship to laboratory). Here we report which body measurements can be used to determine the sex of living or dead individuals of Black-Browed Albatross based on morphometric analyses of birds incidentally caught by commercial fisheries.

METHODS

Samples of drowned birds (n = 155) were collected at four time intervals: October 2001, July–November 2003, January–March 2005, and October–December 2005 from longline fishery that operated between 43–48°S and 59–62°W in waters off the Patagonian Shelf, Argentina. The longline systems used there have been described by Gandini and Frere (2006) and Seco Pon et al. (2007). Bird measurements include: nalospi (distance from the tip of bill to the nostril), head width, bill depth (minimum depth at the mid length of the bill), nape, and bill length (exposed culmen). All measures were obtained to the nearest 0.01 mm using a digital vernier calliper (Hull 1996, González-Solís 2004). Additionally, wing length (carpal joint to tip of the longest primary) was measured on the right side of the body with a ruler to the nearest 1 mm. Body mass was discarded because measurements were performed on frozen individuals. All birds brought to the laboratory were sexed by dissection and the six morphometric measurements were taken when possible because some of the drowned birds were in poor condition and it was not possible to take all of them. All measurements were taken in adult albatrosses. To determinate the age of birds we used plumage pattern.

Multivariate Analysis of Variance was used to determine whether the overall external morphology varied with sex. We used Discriminant Analysis to combine the biometric data of birds of known sex using the statistical package STATISTICA. The performance of each variable was evaluated with Wilk's Lambda statistic, which decreases as discriminatory power increases. The combination of measurements that best discriminated between sexes was selected, and a discriminant function model was obtained from there. The cutting score for the discriminant function was calculated as the weighted average of the mean value of discriminant scores for each sex (Hair et al. 1995). We report here the percentage of individuals correctly identified for each sex and for all birds pooled.

RESULTS

Males were significantly larger than females in all body measurements except for wing length (Table 1). Stepwise Discriminant Analysis chose five variables from the six body measurements available and bill depth emerged as the single most accurate indicator of sex, correctly identifying 79% of all sampled individuals, followed by head width, nape, nalospi and bill length

Table 2. Accuracy of sexing Black-Browed Albatross (*Diomedea melanophris*) obtained by Discriminant Analysis using single morphometric measurements and combined functions D_1 and D_2 (see text). Wilk's Lambda statistic, *F* values and the percentage of individuals correctly identified for each sex are shown.

Variable	Wilk's Lambda	*F*	Males (%)	Females (%)
Bill depth	0.74	53.34	89	60
Head width	0.79	40.24	89	30
Nape	0.82	33.95	89	36
Nalospi	0.79	38.88	87	52
Bill length	0.96	6.68	100	8
Wing length	0.98	3.38	100	0
D_1	0.57	116.98	91	74
D_2	0.58	111.32	91	78

(Table 2). The resulting discriminant function was:

D_1 = 0.433 bill depth + 0.131 head width + + 0.086 nape + 0.117 nalospi + 0.029 bill length + - 34.656

where values of $D_1 > 0$ identified males and values of $D_1 < 0$ identified females. This function correctly identified the sex of 86% of the samples.

Because a discriminant function requiring five different measurements is of little practical value in field studies, the functions with the highest discriminatory power using fewer measurements were calculated. The discriminant function based on the linear combination of only three variables was:

D_2 = 0.529 bill depth + 0.142 head width + + 0.092 nape - 30.420

where values of $D_2 > 0$ identified males and values of $D_2 < 0$ identified females. This function correctly identified the sex of 87% of the samples.

DISCUSSION

Adults of Black-Browed Albatross analyzed showed significant differences in body measurements between sexes, with males bigger than females, in almost all measurements. The estimated Discriminant Analysis indicated that bill depth was the most useful character for distinguishing between sexes. Our results are in line with several studies (Conroy 1972, Croxall 1982, Fairbairn and Shine 1993, González-Solís 2004) and indicate that even though seabirds are externally similar regarding the sex this combination of external measurements still provides a useful tool for sexing birds.

The discriminat function D_2 explained greater percentages of classification (87%) using half of the variables in comparison with the D_1 function (86%) that uses all the variables. In addition, it is recommended that fewer variables be used to determine a bird's sex due to the difficulty of manipulating birds in the field. Therefore, the function with three of the most important external measures (head width, bill depth and nape) turned out to be the best way to discriminate between sexes of Black-Browed Albatross. While D_2 correctly classified 87% of all birds, it was not so reliable to classify females; the percentage of correct classifications for females was smaller than for males. This may be due to the original unbalance of the sample (105 males and 50 females).

Morphological differences are apparent for Black-Browed Albatross with the subspecies *Diomedea melanophris impavida* endemic to New Zealand (Marchant and Higgins 1990), but groups of birds breeding at other Sub-Antarctic sites are not clearly discriminated (Waugh et al. 1999). According to this, our Discriminant Analysis should be tested on biometric data of individuals of known provenance in order to determine the feasibility of our findings.

ACKNOWLEDGEMENTS

This research was funded by Universidad Nacional de la Patagonia Austral, Wildlife Conservation Society and CONICET. We thank to ARGENOVA S.A.

LITERATURE CITED

BELDA EJ AND SANCHEZ A (2001) Seabird mortality on longline fisheries in the western Mediterranean: factors affecting bycatch and proposed mitigation measures. *Biological Conservation* 98:357–363

BIRDLIFE INTERNATIONAL (2008) *Species factsheet: Thalassarche melanophrys*. BirdLife International, Cambridge (URL: http://www.birdlife.org/)

BROOKE M (2004) *Albatrosses and petrels across the world*. Oxford University Press, Oxford

BROTHERS N (1991) Albatross mortality and associated bait loss in Japanese longline fishery in the Southern Ocean. *Biological Conservation* 55:255–268

CHEREL Y, WEIMERSKIRCH H AND DUHAMEL G (1996) Interactions between longline vessels and seabirds in Kerguelen waters and a method to reduce seabird mortality. *Biological Conservation* 75:63–70

CONROY JW (1972) Ecological aspects of the biology of the giant petrel, *Macronectes giganteus*, in the maritime Antarctic. *British Antarctic Survey Report* 75:1–74

COPELLO S, QUINTANA F AND SOMOZA G (2006) Sex determination and sexual size dimorphism in Southern Giant-Petrels (*Macronectes giganteus*) from Patagonia, Argentina. *Emu* 106:141–146

CROXALL JP (1982) Sexual dimorphism in snow petrels *Pagodroma nivea*. *Notornis* 29:171–180

CROXALL JP (1991) Constraints in reproduction in albatrosses. Pp. 279–302 in: BELL BD, COSSEE RO, FLUX JEC, HEATHER BD, HITCHMOUGH RA, ROBERTSON CJR AND WILLIAMS MJ (eds) *Acta XX Congressus Internationalis Ornithologici*. New Zealand Ornithological Congress Trust Board, Wellington

CROXALL JP AND PRINCE PA (1990) Recoveries of Wandering Albatrosses *Diomedea exulans* ringed at South Georgia 1958–1986. *Ringing & Migration* 11:43–51

FAIRBAIRN J AND SHINE R (1993) Patterns of sexual size dimorphism in seabirds of the Southern Hemisphere. *Oikos* 68:139–145

GANDINI P AND FRERE E (2006) Spatial and temporal patterns in the bycatch of seabirds in the Argentinean longline fishery. *Fishery Bulletin* 104:482–485

GONZÁLEZ-SOLÍS J (2004) Sexual size dimorphism in northern giant petrels: ecological correlates and scaling. *Oikos* 105:247–254

HAIR JF JR, ANDERSON RE, TATHAM RL AND BLACK WC (1995) *Multivariate data analysis*. Fourth edition. Prentice Hall, Englewood Cliffs

HULL CL (1996) Morphometric indices for sexing adult Royal *Eudyptes schlegeli* and Rockhopper *E. chrysocome* penguins at Macquarie Island. *Marine Ornithology* 24:23–27

JODICE PGR, LANCTOT RB, GILL VA, ROBY DD AND HATCH A (2000) Sexing adult Blacklegged Kittiwakes by DNA, behavior, and morphology. *Waterbirds* 23:405–415

JOUVENTIN P AND LEQUETTE B (1990) The dance of the Wandering Albatross *Diomedea exulans*. *Emu* 90:123–131

MARCHANT S AND HIGGINS PJ (1990) *Handbook of Australian, New Zealand and Antarctic birds. Volume 1. Ratites to ducks*. Oxford University Press, Melbourne

PICKERING SPC AND BERROW SD (2001) Courtship behavior of the Wandering Albatross *Diomedea exulans* at Bird Island, South Georgia. *Marine Ornithology* 29:29–37

QUINTANA F, SOMOZA G, UHART M, CASSARÁ C, GANDINI P AND FRERE E (2003) Sex determination of adult Rock Shags by molecular sexing and morphometric parameters. *Journal of Field Ornithology* 74:370–375

SECO PON JP, GANDINI P AND FAVERO M (2007) Effect of longline configuration on seabird mortality in the Argentine semi-pelagic Kingclip *Genypterus blacodes* fishery. *Fisheries Research* 85:101–105

SVAGELJ WS AND QUINTANA F (2007) Sexual size dimorphism and sex determination by morphometric measurements in breeding Imperial shags (*Phalacrocorax atriceps*). *Waterbirds* 30:97–102

TASKER ML, CAMPHUYSEN CJ, COOPER J, GARTHE S, MONTEVECCHI WA AND BLABER SJM (2000) The impacts of fishing on marine birds. *ICES Journal of Marine Science* 57:531–547

WAUGH SM, PRINCE PA AND WEIMERSKIRCH H (1999) Geographical variation in morphometric of Black-browed and Grey-headed albatrosses from four sites. *Polar Biology* 22:189–194

WEIMERSKIRCH H AND JOUVENTIN P (1987) Population dynamics of the wandering albatross, *Diomedea exulans*, of the Crozet Islands: causes and consequences of the population decline. *Oikos* 49:315–322