

MORPHOLOGY OF THE RECENTLY RE-CLASSIFIED TASMAN MASKED BOOBY *SULA DACTYLATRA TASMANI* BREEDING ON THE KERMADEC ISLANDS

STEFANIE M.H. ISMAR¹, KAREN BAIRD^{2,3}, SELINA PATEL¹, CRAIG D. MILLAR¹ & MARK E. HAUBER^{1,4}

¹*School of Biological Sciences, University of Auckland, Private Bag 92019, Auckland, New Zealand (sism007@aucklanduni.ac.nz)*

²*Department of Conservation, Auckland Conservancy, Warkworth Office, New Zealand*

³*Royal Forest and Bird Protection Society of New Zealand, PO Box 108 055, Auckland, New Zealand*

⁴*Department of Psychology, Hunter College of the City University of New York, 695 Park Avenue, New York, NY 10065, USA*

Received 26 May 2010, accepted 29 September 2010

SUMMARY

ISMAR, S.M.H., BAIRD, K., PATEL, S., MILLAR, C.D. & HAUBER, M.E. 2010. Morphology of the recently re-classified Tasman Booby *Sula dactylatra tasmani* breeding on the Kermadec Islands. *Marine Ornithology* 38: 105–109.

Once thought to be extinct, the Tasman Booby *Sula tasmani* has recently been re-classified as a subspecies of the Masked Booby *S. dactylatra* on the basis of genetic data. This re-classification raises the issue of whether this novel clade has a distinct morphology. Morphological differences in size, as well as coloration of integuments, bill and iris have been found in other subspecies of the Masked Booby but have not yet been reported for live Kermadec Islands breeding individuals. Museum specimens from this breeding location have been separated from other Pacific breeding subspecies by their longer wings. We sampled a total of 21 individuals from North Meyer Islet, Kermadec Group, New Zealand, and applied molecular sexing to obtain sex-specific morphometric measurements. We matched dimorphism in vocalization with genetic sexing results and photographic documentation of human-assessed bill, foot and eye coloration. While culmen measurements were consistent with reports from museum specimens, wing chords from living specimens of Tasman Masked Boobies were 3% and 4% larger in males and females, respectively. Females had larger culmens and wings than males, consistent with the low extent of sexual dimorphism reported from museum skins. Adult Tasman Masked Boobies had yellow to buff-yellow feet, while fledglings, as in most sulids, had grey to greyish-yellow feet. Our findings confirm the distinctively long wing and particular iris coloration previously reported for the taxon and provide the first description of integument coloration of live specimens. This study highlights the importance of including *in situ* assessment in taxon descriptions.

Key words: Tasman Masked Booby, *Sula dactylatra tasmani*, coloration, Kermadec Islands, morphometrics, sexual dimorphism

INTRODUCTION

Morphological differences may indicate the genetic distinction of a taxon (Friesen *et al.* 2002). Conversely, the application of recent DNA techniques, in conjunction with palaeontological data, may provide insight into the phylogeny of extant clades, helping to characterize their morphology and that of their extinct relatives in a novel light (Steeves *et al.* 2010).

The Masked Booby *Sula dactylatra* (Pelecaniformes: Sulidae) is a widely distributed pantropical seabird (see Fig. 1 for its Pacific distribution). Extensive studies of this clade include the taxonomic assessment of different populations, differences in morphology among populations, and disjunct patterns of its dispersal behaviour (Pitman & Jehl 1998, Friesen *et al.* 2002, Steeves *et al.* 2005a, b). Recently, morphological differences in bill coloration (Pitman & Jehl 1998) were shown to correlate with genetic distinctness (Friesen *et al.* 2002) in the Masked Booby breeding populations on the eastern Pacific Nazca Plate. These populations were historically classified as subspecies *S. d. granti* (Nelson 1978), but now constitute a separate species, the Nazca Booby *S. granti* (Pitman & Jehl 1998, Friesen *et al.* 2002), with a breeding distribution overlapping that of the Masked Booby subspecies *S. d. californica* (Pitman & Jehl

1998). In a contrasting scenario, the Tasman Booby *S. tasmani*, which was thought to be an extinct full species (van Tets *et al.* 1988), has recently proven to be genetically and morphologically similar (Steeves *et al.* 2010) to the extant Kermadec, Norfolk and Lord Howe islands breeding subspecies of the Masked Booby *S. d. fullagari* (O'Brien & Davies 1990). This discovery resulted in the reclassification of the taxon as a subspecies *S. d. tasmani* (Steeves *et al.* 2010), the Tasman Masked Booby. While morphometrics, including wing, tail, culmen, tarsus and toe measurements, are reported for palaeontological and modern skeletal and museum specimens (van Tets *et al.* 1988, O'Brien & Davies 1990, Steeves *et al.* 2010), measurements of living birds of this subspecies are lacking. Such data would further our understanding of how its genetic distinctness is reflected in the phenotype of this newly re-classified taxon. In addition, sexual dimorphism in vocalization, as reported for several booby taxa (Nelson 1978), has not been described for the Tasman Masked Booby and also warrants confirmation using genetic markers to assign sex in Masked Boobies in general. Adult female Masked Boobies are reported to produce a honking call, while adult males make a distinct whistle, which is acquired with changes to the syrinx at sexual maturity; vocalizations in juveniles resemble the honk of females (Nelson 1978). Published information on coloration of integuments and eye in New Zealand breeding *S.*

dactylatra reports a range of shades from yellowish-green to grey (Oliver 1930, Robertson & Heather 2001, Parkinson 2006), based on museum specimens (O'Brien & Davies 1990). However, the judgment of integument coloration from museum skins has been called into question (Pitman & Jehl 1998).

We present novel morphological information on the recently re-classified Tasman Masked Booby from live specimens gathered *in situ* and evaluated with molecular sexing. We also compare measurements from living birds with morphometric data reported from museum specimens and assess general reports of sexual vocalization dimorphism in this clade as well as provide photographic records of integument coloration from the breeding location.

STUDY AREA AND METHODS

We sampled adult and juvenile Tasman Masked Boobies breeding on North Meyer Islet (29°14'S, 177°45'W) as part of New Zealand Department of Conservation expeditions to Raoul Island, Kermadec Island Group. Six adult and eight fledgling, and two adult and four fledgling Tasman Masked Boobies (Fig. 2) were captured with a shepherd's crook in May 2007 and April 2008, respectively. In addition, one younger chick was caught by hand and sampled during the 2008 expedition. These birds constituted all individuals on human-accessible parts of this remote oceanic locality. Morphometric measurements of bill and tarsus were taken to the nearest 0.1 mm using calipers, and tail and wing were measured to the nearest 1 mm. Blood samples of approximately 50 μ L were taken from each bird

from the metatarsal vein and preserved in Queen's lysis buffer (Seutin *et al.* 1991) for molecular sexing. Genomic DNA was phenol-chloroform extracted and subsequently amplified using P2/P8 PCR primers following a protocol adapted for the related Australasian gannet *Morus serrator* (Daniel *et al.* 2007). When a bird vocalized during observations or handling, the call type was noted, and the sex of the caller determined later from molecular sexing results. Photographs of iris and coloration of foot and bill integuments were also taken in the field for adult breeding males and females and fledglings of both sexes for comparison (Fig. 2).

Means and standard errors of all morphometric measurements were calculated for each adult and fledgling sex, and sexual dimorphism indices (SDI) calculated as $100 \times (\text{female} - \text{male}) / \text{female}$ (Greenwood 2003, Zavalaga *et al.* 2009).

RESULTS

Six of the adult birds were males, and two were female. Fledglings comprised eight females and four males. The single chick sampled was a female. Female adult *Sula dactylatra tasmani* measurements were consistently greater than male measurements for all morphometric parameters, with SDI \sim 5% for culmen (male = 108.4 ± 2.6 mm; female = 113.6 mm) and \sim 6% for tail measurements (male = 179 ± 3 mm; female = 190 mm) (Table 1). Mean male culmen differed by 0.1 mm from previous measurements of museum specimens (O'Brien & Davies 1990), whereas the mean culmen length of the two measured females was 3.5 mm above

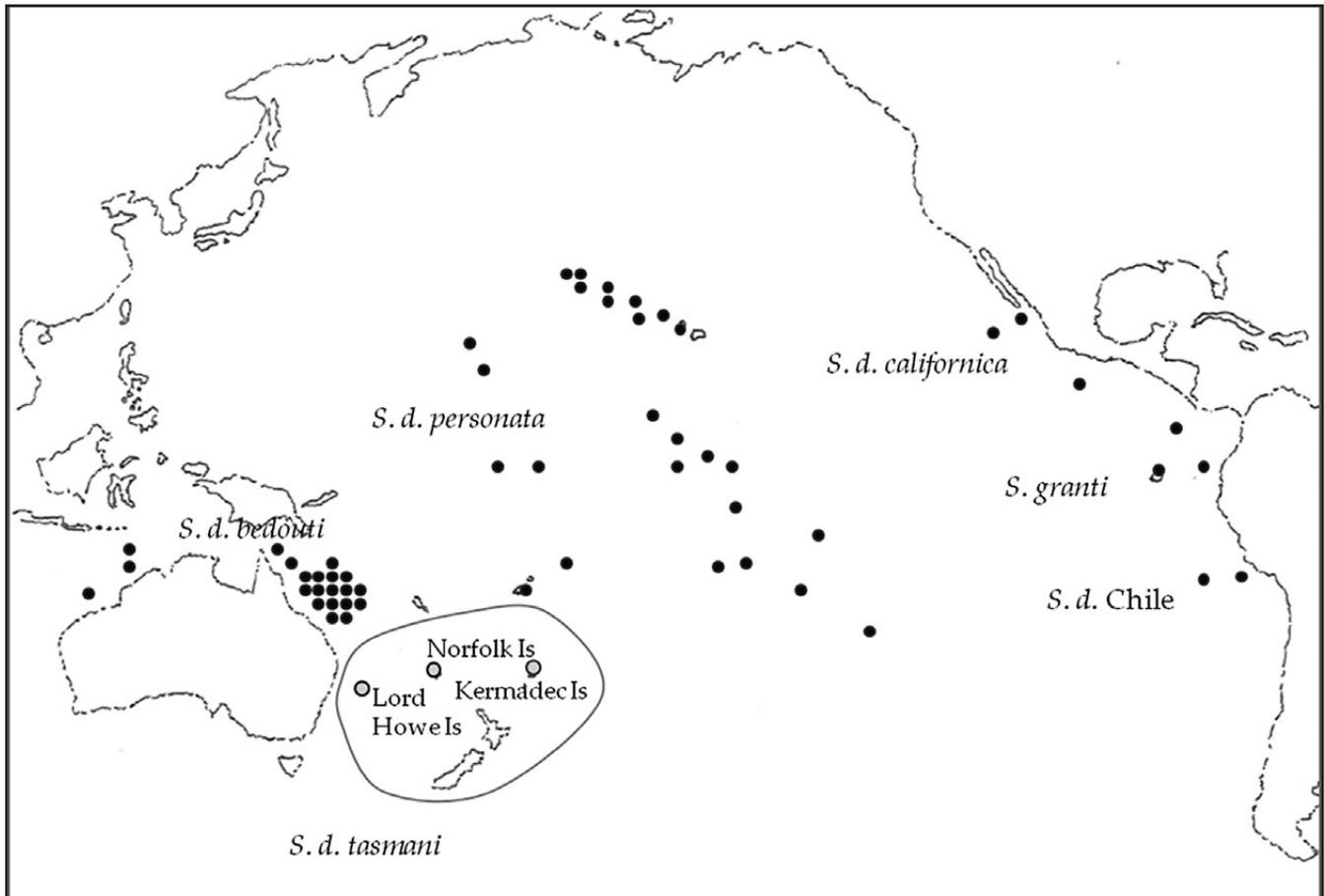


Fig. 1. Breeding sites of Tasman Masked Booby *Sula dactylatra tasmani* in comparison to Pacific breeding sites of other Masked Booby subspecies and Nazca Booby; breeding locations after Nelson (1978); subspecies and distribution after Pitman and Jehl (1998).

the measurements reported in O'Brien and Davies (1990). Wing chord dimensions were of the same scale as the characteristically larger wing chords reported for the former subspecies *S. dactylatra fullagari* breeding in the Tasman Sea region (O'Brien & Davies

1990), with the mean of males lying 3% (12 mm) above those values reported from museum skins. The calculated wing SDI of 4% (male = 459 ± 4 mm, female = 476 mm) was consistent with reports for museum specimens by O'Brien and Davies (1990).



Fig 2. (a) Breeding habitat on the Kermadec Islands, fledgling Tasman Masked Booby on the nest, (b) adult Tasman Masked Booby *Sula dactylatra tasmani* bill and iris coloration: (c) adult male, (d) adult female and chick, (e) fledgling male, (f) fledgling female. Photo credits: (a)–(e), (f2) Stefanie Ismar, (f1) Ben Horne.

TABLE 1

Mean morphometric measurements of adult *Sula dactylatra tasmani* breeding on the Kermadec Islands and fledglings, sampled in May 2007 and March–April 2008 on North Meyer Islet; sexual size dimorphism indices (SDI) following Greenwood (2003)

Age, sex	Culmen, mm (SD)	Bill width, mm (SD)	Bill depth, mm (SD)	Tarsus, mm (SD)	Tail, mm (SD)	Wing, mm (SD)
Adult (n = 8, except tail n = 7)	109.7 (3.6)	31.4 (1.1)	42.4 (1.4)	64.5 (2.2)	182.6 (8.1)	463.6 (12.9)
Male (n = 6, except tail n = 5)	108.4 (2.6)	31.3 (1.2)	41.9 (1.2)	63.9 (2.2)	179.5 (7.2)	459.4 (10.7)
Female (n = 2)	113.6	31.8	43.7	66.4	190.3	476.3
[min, max]	[110.7, 166.4]	[31.4, 32.2]	[43.0, 44.5]	[66.4, 66.4]	[186.5, 194.0]	[467.0, 485.5]
SDI	4.6	1.7	4.1	3.8	5.7	3.5
Fledgling, May 2007 (n = 8)	106.5 (3.2)	32.2 (1.4)	42.5 (2.4)	65.4 (1.9)	^a	456.8 (23.1)
Fledgling, Apr 2008 (n = 4)	104.5 (1.4)	32.0 (1.6)	42.8 (2.1)	60.2 (6.2)	164.5 (10.0)	455.8 (22.2)
Chick, Apr 2008 (n = 1)	65.2	22.6	28.5	61.6	0	83.0

^a Rectrices of all fledglings measured in 2007 were worn, and data were therefore not taken to calculate mean length.

Fledglings appeared sexually monomorphic in bill dimensions, with SDI for culmen 1%, bill width 2% and bill depth 2% (Owens & Hartley 1998); tarsus, tail and wing measurements showed sexual dimorphism of 4%–6%, consistent with our findings for the adults. Fledgling boobies sampled in our study had already grown to near-adult dimensions (Table 1).

Sex, as predicted from vocalizations during handling, was confirmed in all cases of seven adult (five male, two female) birds. Only one juvenile vocalized during handling, with a honking voice, and was molecularly sexed as a female.

Fledgling and adults of both sexes, as well as a chick, showed the dark brown iris colour (Fig. 2b) noted by O'Brien and Davies (1990), in contrast to the yellow iris consistently reported in other subspecies (Nelson 1978). Adult bills were a bright yellow in both male and female birds, and fledgling bills appeared more buff-yellow; the sampled female chick (culmen = 65.18 mm, tarsus = 61.63 mm, tail = 0 mm, wing = 83 mm) still had a greyish bill with a yellow hue (Fig. 2d). Foot colour in fledglings varied between grey and greyish-yellow, whereas adult birds had greyish-yellow to yellow feet. Interestingly, foot colour appeared brighter yellow in adult males and more buff-yellow in adult female Tasman Masked Boobies in our samples, indicating potential dichromatism in the trait, as seen in other booby species (Torres & Velando 2003; Velando *et al.* 2006).

DISCUSSION

The low level of sexual size dimorphism in these live specimens of the Tasman Masked Booby is consistent with the general pattern seen in *Sula dactylatra*, being the least dimorphic *Sula* species except for the Abbot's Booby (*S. abbotti*) (Nelson 1978).

Bills in breeding Tasman Masked Boobies were more brightly yellow-coloured than initially described in museum specimens (described as greenish-yellow by Oliver [1955] or buff-yellow by O'Brien & Davies [1990]). The same held true for foot colour in our samples, which in museum specimens was described as greenish-blue (Oliver 1930) and in other cases is noted as mainly plumbeous (O'Brien & Davies 1990). This trait is still often erroneously described as grey (Robertson & Heather 2001) or greyish-green in *S. d. tasmani* (Parkinson 2006), as is seen in the feet of trans-Pacific breeding subspecies *S. d. personata* (Kepler 1968). Our finding of sexual dichromatism in integument coloration is novel in this species, but has been reported for the formerly conspecific Nazca Booby from different breeding locations (Nelson 1978; Pitman unpubl., in Pitman & Jehl 1998).

The described coloration patterns may be important in social signaling and in individual recognition, as they are found across different peleciform taxa, including boobies (van Tets 1965, Nelson 1978). Both coloration and morphometric data from live specimens of this re-classified taxon are valuable, especially for the assessment of potential assortative mating, which occurs widely among birds (MacDougall & Montgomerie 2003, Bridge & Nisbet 2004, Bearhop *et al.* 2005). Further research is needed to assess morphological variation among the different breeding locations of the Tasman and other Masked Booby subspecies as well as to explore the potential role of lineage-specific or phenotype-dependent assortative mating in the Masked Booby, as has been shown to occur in the related Blue-footed Booby *S. neobouxii* (Torres & Velando 2003, 2005, Velando *et al.* 2006, Morales *et al.* 2009,

Velando *et al.* 2010). Assessment of how assortative mating may restrict gene flow will further our understanding of the evolutionary diversification of far-ranging seabird species.

ACKNOWLEDGEMENTS

We thank the Department of Conservation (DoC) for research and landing permits, the National Institute of Water and Atmospheric Research and the Royal New Zealand Navy for transport, and DoC staff and volunteers on Raoul for their support in the field. Special thanks to Sandra Anderson, Emily Favell, Chris Gaskin, and Luis Ortiz-Catedral for their help with field work, and to Ben Horne for the picture of a female fledgling. Funding was provided by Education New Zealand through an International Research Scholarship and by the Faculty of Science, University of Auckland to S.M.H.I., and by the Research Committee of the University of Auckland Science Faculty (to M.E.H. and C.D.M.).

REFERENCES

- BEARHOP, S., FIEDLER, W., FURNESS, R.W., VOTIER, S.C., WALDRON, S., NEWTON, J., BOWEN, G.J., BERTHOLD, P. & FARNSWORTH, K. 2005. Assortative mating as a mechanism for rapid evolution of a migratory divide. *Science* 310: 502–504.
- BRIDGE, E.S. & NISBET, I.C.T. 2004. Wing molt and assortative mating in common terns: a test of the molt-signaling hypothesis. *Waterbirds* 106: 336–343.
- DANIEL, C., MILLAR, C.D., ISMAR, S.M.H., STEPHENSON, B.M. & HAUBER, M.E. 2007. Evaluating molecular and behavioural sexing methods for the Australasian gannet (*Morus serrator*). *Australian Journal of Zoology* 55: 377–382.
- FRIESEN, V.L., ANDERSON, D.J., STEEVES, T.E., JONES, H. & SCHREIBER, E.A. 2002. Molecular support for species status of the Nazca booby (*Sula granti*). *The Auk* 119: 820–826.
- GREENWOOD, J. G. 2003. Measuring sexual size dimorphism in birds. *Ibis* 145: 124–126.
- KEPLER, C. 1968. The breeding biology of the Blue-faced Booby (*Sula dactylatra personata*) on Green Island, Kure Atoll. Doctoral dissertation, Cornell University. Ithaca, NY.
- MACDOUGALL, A.K. & MONTGOMERIE, R. 2003. Assortative mating by carotenoid-based plumage colour: a quality indicator in American goldfinches, *Carduelis tristis*. *Naturwissenschaften* 90: 464–467.
- MORALES, J., VELANDO, A. & TORRES, R. 2009. Fecundity compromises attractiveness when pigments are scarce. *Behavioral Ecology* 20: 117–123.
- NELSON, J.B. 1978. The Sulidae: Gannets and Boobies. Oxford University Press, London, UK.
- O'BRIEN, R.M. & DAVIES, J. 1990. A new subspecies of masked booby, *Sula dactylatra* from Lord Howe, Norfolk and Kermadec Islands. *Marine Ornithology* 18: 1–7.
- OLIVER, W.R.B. 1930. New Zealand birds. Wellington: Fine Arts.
- OLIVER, W.R.B. 1955. New Zealand birds. 2nd Edition. Wellington: A.H. and A.W. Reed.
- OWENS, P.F. & HARTLEY, I.R. 1998. Sexual dimorphism in birds: why are there so many different forms of dimorphism? *Proceedings of the Royal Society of London B* 265: 397–407.
- PARKINSON, B. 2006. A field guide to New Zealand seabirds. 2nd Edition. New Holland Publishers (NZ) Ltd., Auckland.
- PITMAN, R.L. & JEHL, J.R. Jr. 1998. Geographic variation and reassessment of species limits in the "Masked" Boobies of the eastern Pacific Ocean. *The Wilson Bulletin* 110: 155–170.

- ROBERTSON, H. & HEATHER, B. 2001. The hand guide to the birds of New Zealand. Oxford University Press. Oxford.
- SEUTIN, G., WHITE, B.N. & BOAG, P.T. 1991. Preservation of avian blood and tissue samples for DNA analyses. *Canadian Journal of Zoology* 69: 82–90.
- STEEVES, T.E., ANDERSON D.J. & FRIESEN, V.L. 2005a. A role for nonphysical barriers to gene flow in the diversification of a highly vagile seabird, the masked booby (*Sula dactylatra*). *Molecular Ecology* 14: 3877–3887.
- STEEVES, T.E., ANDERSON D.J. & FRIESEN, V.L. 2005b. The Isthmus of Panama: a major physical barrier to gene flow in a highly mobile pantropical seabird. *Journal of Evolutionary Biology* 18: 1000–1008.
- STEEVES, T.E., HOLDAWAY, R.N., HALE, M.L., MCLAY, E., MCALLAN, I.A.W., CHRISTIAN, M., HAUBER, M.E. & BUNCE, M. 2010. Merging ancient and modern DNA: extinct seabird taxon rediscovered in the North Tasman Sea. *Biology Letters* 6: 94–97.
- TORRES, R. & VELANDO, A. 2003. A dynamic trait affects continuous pair assessment in the blue-footed booby, *Sula nebouxii*. *Behavioral Ecology and Sociobiology* 55: 65–72.
- TORRES, R. & VELANDO, A. 2005. Male preference for female foot colour in the socially monogamous blue-footed booby, *Sula nebouxii*. *Animal Behaviour* 69: 59–65.
- VAN TETS, G.F. 1965. A comparative study of some social communication patterns in the Pelecaniforms. *Ornithological Monographs* 2: 1–88.
- VAN TETS, G.F., MEREDITH, C.W., FULLAGAR, P.J. & DAVIDSON, P.M. 1988. Osteological differences between *Sula* and *Morus*, and a description of an extinct new species of *Sula* from Lord Howe and Norfolk Islands, Tasman Sea. *Notornis* 35: 35–57.
- VELANDO, A., BEAMONTE-BARRIENTOS, R. & TORRES, R. 2006. Pigment-based skin colour in the blue-footed booby: an honest signal of current condition used by females to adjust reproductive investment. *Oecologia* 149: 535–542.
- VELANDO, A., DRUMMOND, H. & TORRES, R. 2010. Senescing sexual ornaments recover after a sabbatical. *Biology Letters* 6: 194–196.
- ZAVALAGA, C.B., TAYLOR, S.A., DELL'OMO, G., ANDERSON, D.J. & FRIESEN, V.L. 2009. Male/female classification of the Peruvian Booby. *The Wilson Journal of Ornithology* 121: 739–744.
-

