OSTEOLOGICAL DIFFERENCES BETWEEN *SULA* AND *MORUS*, AND A DESCRIPTION OF AN EXTINCT NEW SPECIES OF *SULA* FROM LORD HOWE AND NORFOLK ISLANDS, TASMAN SEA

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ABSTRACT

Osteological differences between boobies, *Sula*, and gannets, *Morus*, were found for every major element examined. These differences confirm that *Sula* and *Morus* are generically distinct.

Sula tasmani n.sp. is described from bones found in aeolian coral sand dunes at Lord Howe and Norfolk Islands, Tasman Sea. *Sula tasmani* is larger than extant and known fossil species of *Sula*, the upper part of its massive bill being more concave laterally.

INTRODUCTION AND METHODS

At Lord Howe and Norfolk Islands, Tasman Sea, bones were found *in situ* and as float of two species of booby (*Sula*). The bones were determined as being of the Masked Booby (*S. dactylatra*), which still breeds there, and of a similar but larger booby, which we shall call the Tasman Booby. The Tasman Booby is described in this paper as a new extinct species. The bones were collected from aeolian coral sand, at Lord Howe Island from a storm-eroded cliff at Middle Beach and from sand used for airport construction and at Norfolk Island from storm-eroded beaches and a sand quarry at Emily and Cemetery Bays (van Tets *et al.* 1981, 1984; Rich & van Tets 1982, 1984; and Rich *et al.* 1983).

The bones of the Tasman Booby were compared with those of all extant species of Sulidae and with descriptions of those of fossil Sulidae. Comparative material came from the collections of the Australian Museum, Sydney (AM); the Australian National Wildlife Collection, CSIRO Division of Wildlife and Rangelands Research, Canberra (ANWC); the British Museum (Natural History), Tring (BM); the Monash University Department of Earth Sciences (MU); the Museum of Victoria, Melbourne (MV); the National Museum of New Zealand, Wellington (NMNZ); and the University of Michigan Museum of Zoology, Ann Arbor (UMMZ).

Bones that lack the hard, smooth texture and the detailed sculpturing of fully formed bones are called juvenile and are considered to be of young birds close to fledging, but not chicks or fully grown birds.

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COMPARISON OF THE OSTEOLOGY OF *SULA* AND *MORUS*

At least from the time Linnaeus (1758) placed the boobies in *Pelecanus piscator* and the gannets in *P. bassanus*, there has been debate about the taxonomic distinctions between boobies and gannets. The New Zealand checklist (Kinsky 1970, 1980), the World checklist 2nd Ed. (Dorst & Mougin 1979), as well as Voous (1973), Cramp & Simmons (1977), Nelson (1978) and Harrison (1983), considered boobies and gannets to be congeneric, while the Australian checklist (Condon 1975), the World checklist 1st Ed. (Peters 1931), as well as Serventy *et al.* (1971) and Olson (1985), restricted the boobies to the genus *Sula* Brisson 1760 and placed the gannets in the genus *Morus* Vieillot 1816.

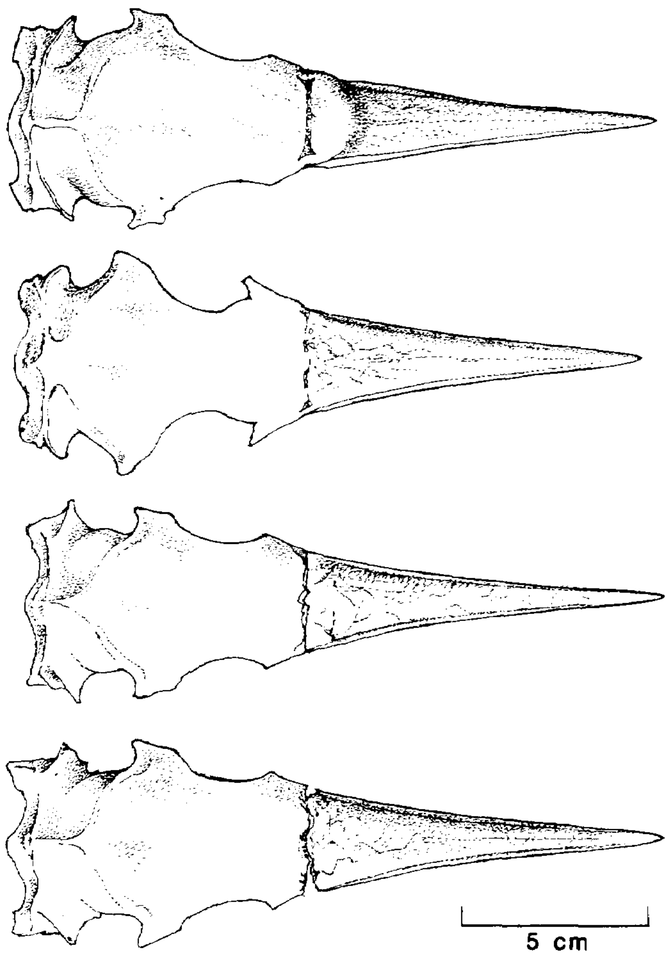

FIGURE 1 — Dorsal view of the skulls from top to bottom of *Morus serrator* ANWC BS2931, *Sula abbotti* ANWC BS1934, *S. dactylatra* ANWC BS2932 and *S. tasmani* n.sp. ANWC BS3322

The differences between *Sula* and *Morus* were based on external features (Ogilvie-Grant 1898, Mathews 1913, Mathews & Iredale 1921, Wetmore 1926, Berlioz 1950, von Boetticher 1957, Palmer 1962, Serventy *et al.* 1971) and can also be made from comparisons of signal patterns (van Tets 1965) and from skeletal morphology as described below.

Skull

In *Sula* the surface of the maxilla is rough all over the portions covered by horny plates. In *Morus* it is also rough except for an area directly in front of the naso-frontal hinge (Figures 1 and 2) where the top of the bill at its base is covered by skin and feathers. Shufeldt (1888, 1902) noted this difference when comparing the maxilla of *Morus bassanus* with those of *Sula sula* (=*piscator*) and other species of Sulidae, presumably *S. nebouxii* (=*gossi*) and *S. leucogaster* (=*brewsteri*), as shown on his Plate XXIII, figures 10 and 11 (1902).

From a lateral view, the dorsal profile of the skull shows a dip in front of the naso-frontal hinge, where the surface is smooth, and a bulge behind the naso-frontal hinge (Figure 2) in *Morus*, whereas in *Sula* the

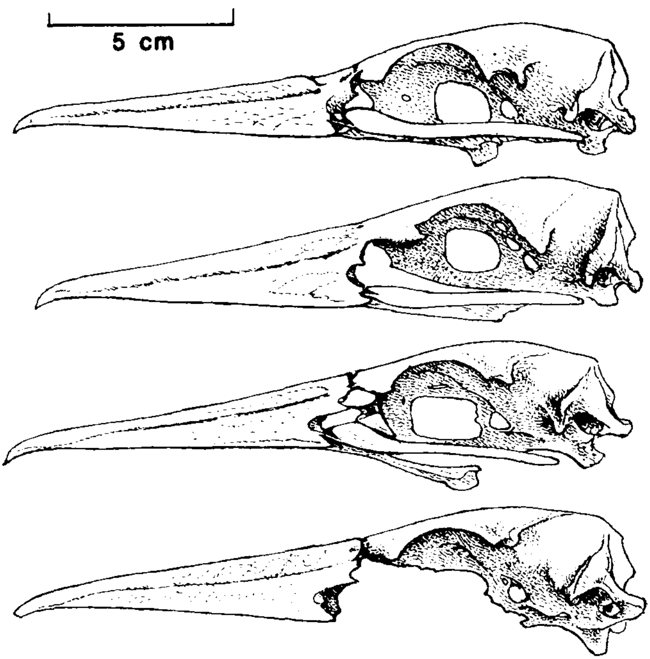

FIGURE 2 — Lateral view of the maxillae and crania from top to bottom of *Morus serrator* ANWC BS2931, *Sula abbotti* ANWC BS1934, *S. dactylatra* ANWC BS2932 and *S. tasmani* n.sp. ANWC BS3322

profile has a slight convex bulge in front of the naso-frontal hinge and a relatively straight slope behind the hinge and above the orbits.

Pectoral girdle

At the cranial end of the sternum there is a prominent ventral manubrial spine in *Morus*, but not in *Sula*, as was noted by Shufeldt (1902). The furcular facet on the carinal apex is from a lateral view deeply concave (Figure 3) in *Morus* and varies in *Sula* from slightly concave to slightly convex. The ventral edge of the carina is relatively narrower in *Morus* than in *Sula* (Figure 4).

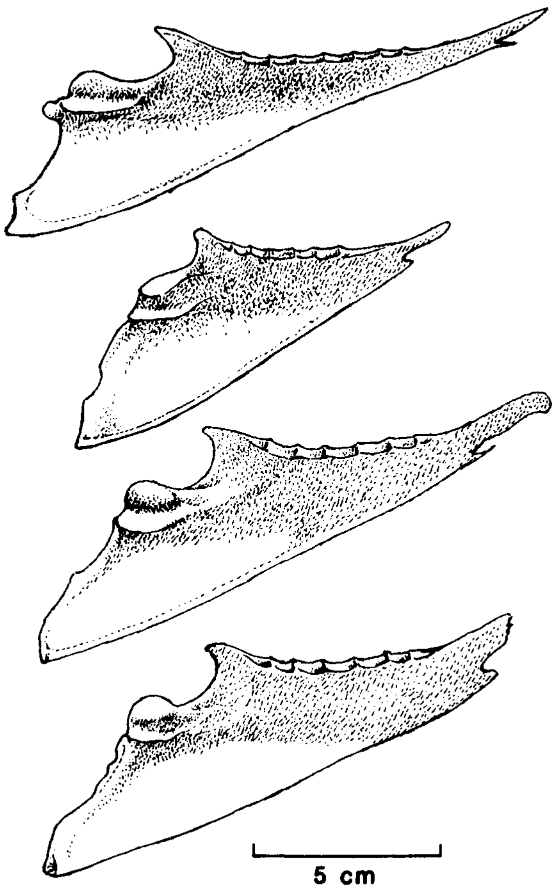

FIGURE 3 — Lateral view of the sterna from top to bottom of *Morus serrator* ANWC BS2931, *Sula abbotti* ANWC BS4374, *S. dactylatra* ANWC BS2932 and *S. tasmani* n.sp. ANWC BS3322

The sternal facet at the symphysis of the furcula is relatively narrower and deeper in *Morus* than in *Sula*. The clavicular shafts are relatively thicker in *Morus* than in *Sula*. There are usually one or more pneumatic foraminae between the coracoidal facet and the scapular tuberosity in *Morus*, but not in *Sula*.

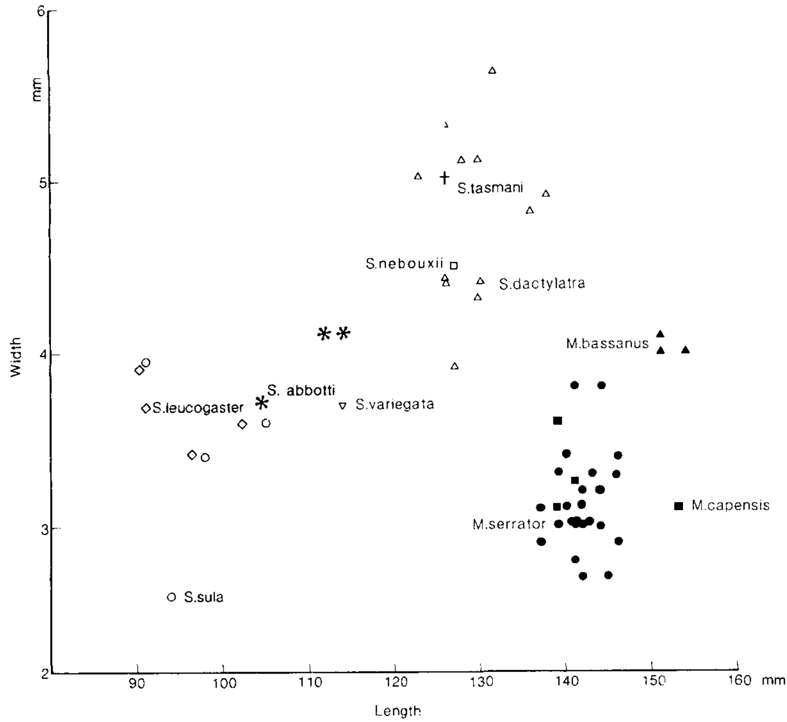

FIGURE 4 — Comparison of carinal widths and lengths in *Morus* and *Sula*. Measured were the length and greatest width of the carinal edge

On the scapula, at the anterior base of the acromion, is a pneumatic foramen on the dorsal side in *Morus* and on the ventral side in *Sula*. The distal end of the blade is less angular with respect to the shaft in *Morus* than in *Sula*.

Above the anterior sternal face of the coracoid, as noted by Wetmore (1926) and Brodkorb (1955), is a bulge in *Sula* and not in *Morus* (Figure 5). On the bulge is the anterior intermuscular line of Fisher (1945). Where the line terminates at the sternal facet is a prominent tubercle in *Sula* and not in *Morus*. The line ends at the sternal facet also more laterally in *Morus* than in *Sula*. Howard (1936) reported that the anterior sternal facet is relatively longer and narrower in *Morus* than in *Sula*, that the dorsal end is relatively broader in *Morus* than in *Sula*, and that the bicipital attachment is small and faintly marked in *Morus* but is a large and prominent pit in *Sula*. From a dorsal view, the furrow between the bicipital attachment and the glenoid facet is relatively broader in *Morus* than in *Sula*. The sterno-coracoidal process is pointed in *Morus* and truncated in *Sula* (Figure 5).

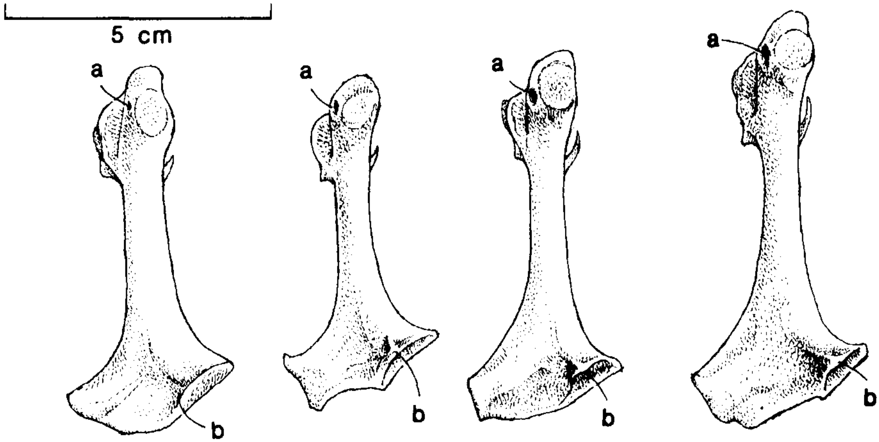

FIGURE 5 — Anterior view of the right coracoids from left to right of *Morus serrator* ANWC BS2931, *Sula abbotti* ANWC BS4374, *S. dactylatra* ANWC BS2932 and *S. tasmani* n.sp. MV164185. a = bicipital attachment, b = ventral end of anterior intermuscular line

Wing

The humerus is longer than the ulna in *Morus* and shorter than the ulna in *Sula*, including *S. abbotti*, where the humerus is almost as long as the ulna (Figure 6, Shufeldt 1902, Miller 1935, Howard 1958, Bourne 1976). The median crest of the humerus extends further distally in *Morus* than in *Sula* (Figure 7) and on the anconal or ulnar side, as indicated by Howard (1958), the central ridge is rounded and indistinct in *Morus* but is angular in *Sula*. At the distal end, *Morus* has a shallower impression for M. brachialis anticus than *Sula*. On the internal side of the olecranal fossa, *Morus* lacks the overhang with a few foramina under it (Wetmore 1930) that is indistinct in *Sula abbotti* and prominent in other *Sula*. The shapes of the external (= radial) condyle and the attachment for M. pronator brevis are too variable for us to confirm any of the differences between *Morus* and *Sula* that were suggested by Wetmore (1926, 1930, 1938).

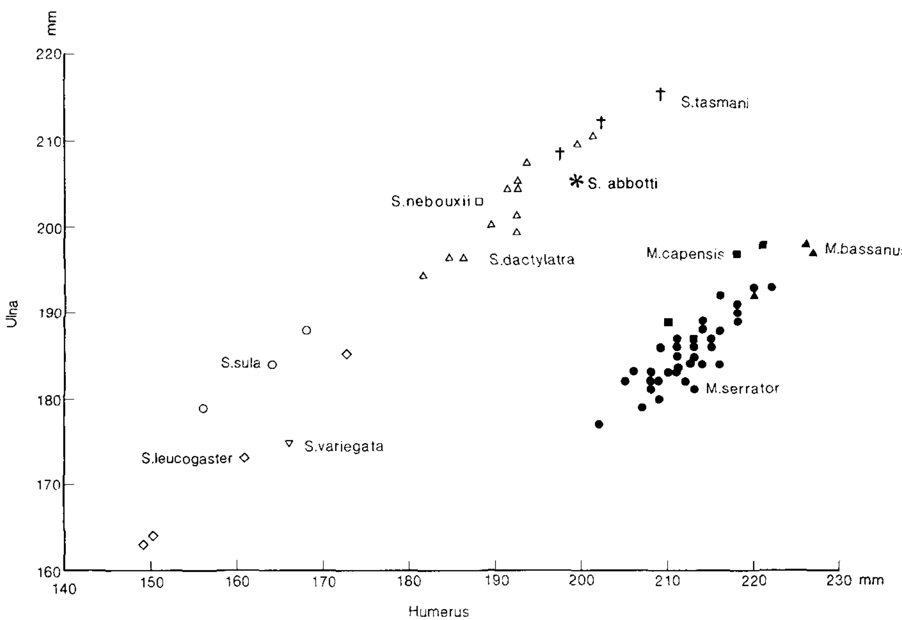

FIGURE 6 — Comparison of humeral and ulnar lengths in *Morus* and *Sula*

There is a foramen in the proximal radial depression of the ulna in *Sula* but not in *Morus* (Figure 8). The impression of M. brachialis anticus is relatively longer in *Morus* than in *Sula.* The shaft of the ulna is relatively thicker in *Morus* than in *Sula.* Relative to the internal and external condyles at the distal end of the ulna, the tip of the carpal tuberosity is more distal in *Sula* than in *Morus.*

At the distal end of the radius on the palmar side, relative to the scapho-lunar facet, a prominent foramen is more proximally located in *Morus* than one or more smaller foramina in *Sula.*

At the proximal end of the carpometacarpus, the pneumatic foramen in the internal ligamental fossa is much larger in *Morus* than in *Sula,* and the anterior carpal fossa has a prominent foramen in *Sula* and not in *Morus.* In *Sula* a ridge extends from the external ligamental attachment almost to the proximal end of metacarpal III. *Morus* does not have this ridge. In *Sula* the groove of the carpal trochlea extends farther on to the proximal end of metacarpal III than in *Morus.* We did not find any significant differences in the shapes of the pollical facet between *Morus* and *Sula,* as was suggested by Brodkorb (1963b).

Pelvic girdle

On the synsacrum, the anterior articular facet of the centrum is in *Morus* as deep as or deeper than it is wide, and in *Sula* it is as wide as or wider than it is deep.

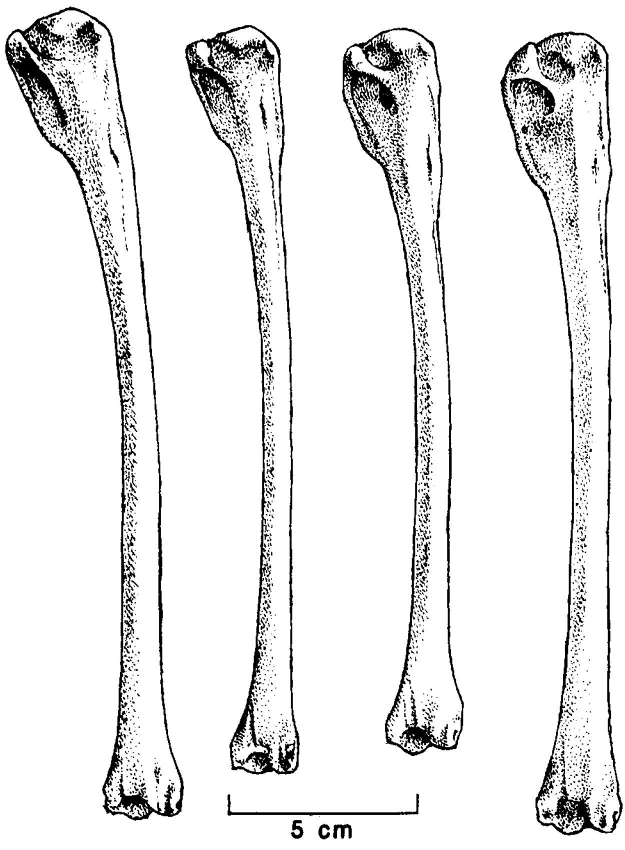

FIGURE 7 — Anconal views of the right humeri from left to right of *Morus serrator* ANWC BS2931, *Sula abbotti* ANWC BS4374, *S. dactylatra* ANWC BS2932 and *S. tasmani* n.sp. ANWC BS3329

The caudal part of the ilium is relatively broader above and behind the ilio-ischiatic fenestra in *Sula* than in *Morus*. The ilial process on the caudal edge of the pelvis is small and knoblike in *Morus* and in *Sula abbotti*, and it is large and pointed in other *Sula*.

Leg

The femur of *Morus* is longer with a relatively thinner shaft than that of *Sula*. At the proximal end, the junction of the trochanter and the trochanteric ridge is more angular in *Sula* than in *Morus*. The distal end is relatively broader in *Sula* than in *Morus*.

The tibiotarsus of *Morus* is longer, with a relatively thinner shaft, than that of *Sula*. The proximal and distal ends are relatively wider in *Sula* than in *Morus*. At the proximal end, the inner cnemial crest in *Morus*

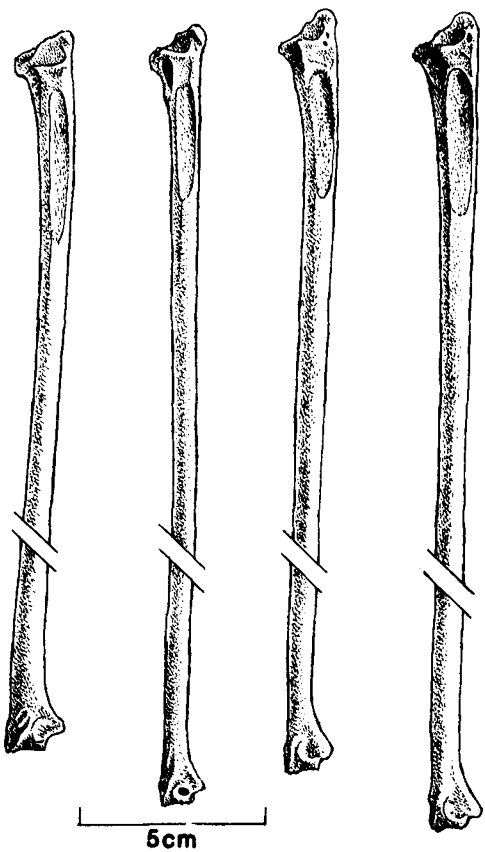

FIGURE 8 — Palmar view of proximal part and dorsal view of distal part of the right ulnae from left to right of *Morus serrator* ANWC BS2931, *Sula abbotti* ANWC BS4374, *S. dactylatra* ANWC BS2932 and *S. tasmani* n.sp. ANWC BS3329

is hooked at the distal end and in *Sula* not hooked. At the distal end, the anterior intercondylar fossa and the posterior intercondylar sulcus are relatively wider in *Sula* than in *Morus.*

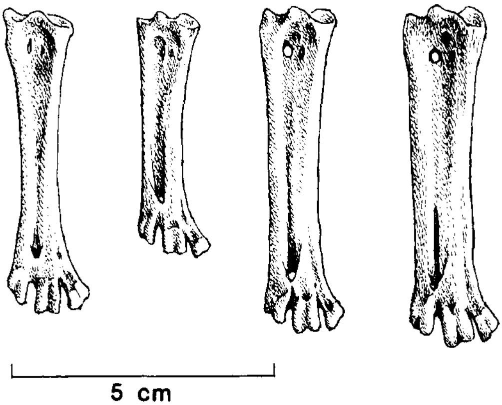

FIGURE 9 — Anterior view of the right tarsometatarsi from left to right of *Morus serrator* ANWC BS2931, *Sula abbotti* ANWC BS4374, *S. dactylatra* ANWC BS2932 and *S. tasmani* n.sp. ANWC BS3336

The tarsometatarsus of *Sula* has a relatively wider shaft than that of *Morus* (Figures 9 and 10). The proximal end of the tarsometatarsus is relatively wider in *Sula* than in *Morus.* The intercotylar prominence is more pronounced in *Sula* than in *Morus.* At the proximal end of the tarsometatarsus, as noted by Harrison (1978 Figure 2), there are differences between *Morus* and *Sula* in the arrangements of the calcaneal ridges and tendinal canals of the hypotarsus. *Morus* and *Sula* have three calcaneal ridges and three canal positions. *Morus* has a closed canal between a large inner ridge and a middle ridge and another closed canal between the middle ridge and an outer ridge. In *Sula abbotti* these two canals are open. In the other extant species of *Sula,* the outer and middle ridges are fused without a canal between them, a closed canal is between the middle and the inner ridges and, as described by Harrison (1978), a single large canal pierces the inner ridge. The inner ridge is not pierced by a canal in *Morus* and *Sula abbotti.*

The second phalanx of digit III is shorter than the first in *Morus* and longer than the first in *Sula.*

The aim of the osteological comparisons reported above was to determine whether the sulid bones found on Lord Howe and Norfolk Islands could be identified initially as either *Sula* or *Morus.* Besides verifying published differences, we found more characters that may be used to distinguish bones of *Morus* from those of *Sula.* These characters strengthen the case for maintaining *Morus* as a distinct genus.

Osteologically *S. abbotti* has most of the characters that separate *Sula* from *Morus*. *S. abbotti* differs from other extant species of *Sula* in having a *Morus*-like ilial process on the pelvis and a unique pattern of hypotarsal canals and ridges. Whether these and other morphological differences merit a new generic or subgeneric name for *S. abbotti* will have to await further study.

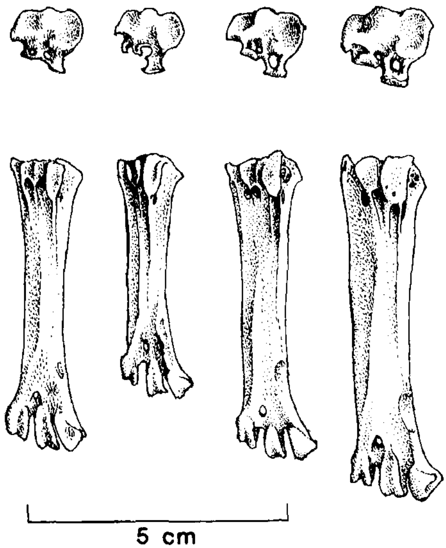

FIGURE 10 — Proximal and posterior views of the left tarsometatarsi from left to right of *Morus serrator* ANWC BS2918, *Sula abbotti* ANWC BS4374, *S. dactylatra* ANWC BS1198 and *S. tasmani* n.sp. MV 164124

SYSTEMATICS

Because the Tasman Booby differs in size and shape from modern and fossil species in the genus *Sula*, we propose for it the following new specific name:

Sula tasmani n.sp.

Holotype: ANWC BS3322, part skeleton, including all or parts of the following elements: maxilla, cranium, mandible, quadrate, cervical and thoracic vertebrae, sternum, ulna and carpometacarpus. Sand dunes near Kingston, Norfolk Island.

Paratypes: ANWC BS3318, part skeleton of a juvenile, including all or parts of the following elements: maxilla, cranium, mandible, quadrate, cervical and thoracic vertebrae, ribs, sternum, pelvis, coracoid, scapula, humerus, radius, ulna, carpometacarpus, wing phalanges, femur, tibiotarsus, fibula, tarsometatarsus, and pedal phalanges; ANWC BS3326, part skeleton of a juvenile, including all or parts of: mandible, cervical vertebrae, ribs, sternum, coracoid, scapula, humerus, radius, ulna, femur, tibiotarsus, fibula, tarsometatarsus and pedal phalanges. Sand dunes near Kingston, Norfolk Island.

Referred specimens: Skeletal elements listed in Table 9.

Etymology: Named after the Tasman Sea in which Norfolk and Lord Howe Islands are situated, and in honour of Abel Janszoon Tasman, who in 1642 sailed across the sea from Tasmania to New Zealand and who may have seen the bird alive.

Diagnosis: Similar to *S. dactylatra* but with a body larger and a bill broader and deeper and more dorso-laterally concave.

DESCRIPTION

Skull

The maxilla of the Tasman Booby [4 specimens — ANWC BS3318 (juvenile), BS3322, BS3323 and BS3333] differs from that of *S. abbotti*, which is similar in length, by being narrower at the base, shallower subterminally, more concave on the sides above the lateral groove, broader at the tip, and in having the maxillo-jugal junction situated relatively less posteriorly (Figures 1 and 2). The maxilla differs from that of *S. dactylatra*, which is similar in length, by being broader at the base, deeper, and more concave on the sides above the lateral groove, and broader at the tip (Figures 1 and 2). It differs from those of the other four extant species of *Sula* by being much larger and by being broader at the tip.

The cranium of the Tasman Booby [6 specimens — ANWC BS3318 (juvenile), BS3322, BS3325 (juvenile), BS3333, MV 150802 (juvenile) and 150805] differs from that of *S. abbotti*, which is similar in length, by being broader except at the naso-frontal hinge, and by having the temporal fossae [=crotaphyte fossae of Shufeldt (1888, 1902) and crotaphyte depressions of Owre (1967)] much larger and meeting at a narrow ridge medially on top of the cranium. It differs from that of *S. dactylatra*, which is similar in length, by having larger temporal fossae. It differs from those of other extant species of *Sula* by being much larger and by having relatively large temporal fossae.

The mandible of the Tasman Booby [11 specimens — AM F56463, ANWC BS3318 (juvenile), BS3320, BS3322, BS3324, BS3326 (juvenile), BS3327, MV 150806, 150808, 163650 and 164118] differs from that of *S. abbotti*, which is similar in length and depth, by having a wider tip, narrower dentaries, wider surangulars, narrower posterior ends and a large foramen on the dorsal surface near the internal articular process. It differs from that of *S. dactylàtra*, which is similar in length, by having a wider tip and deeper posterior ends and by being slightly longer between the articular facet and the coronoid process. It differs from those of the other extant species of *Sula* by being much larger and by having a broader tip.

Pectoral girdle

The sternum of the Tasman Booby [5 specimens — ANWC BS3318 (juvenile), BS3322, BS3326 (juvenile), MV 150802 and 150808] differs from that of *S. dactylatra*, which is similar in size, by having a broader carinal apex, anterior carinal margin and separation between the dorsal lips of the coracoidal sulci. It differs from those of the other five extant species of *Sula* by being much larger (Figure 3).

The furcula of the Tasman Booby [1 specimen — MV 150808] differs from that of *S. dactylatra*, which is similar in size, by having a broader sternal facet and deeper clavicles. It differs from those of the other extant species of *Sula* by being much larger.

The scapula of the Tasman Booby [4 specimens — ANWC BS3318 (juvenile), BS3326 (juvenile), MV 150806 and 150808] differs from that of *S. dactylatra* by being slightly longer with a relatively larger proximal end. It differs from those of the other extant species of *Sula* by being much larger.

The coracoid of the Tasman Booby [6 specimens — ANWC BS3318 (juvenile), BS3321, BS3326 (juvenile), MV 150803, 150806 and 164185] differs from that of *S. dactylatra* by being slightly larger with a relatively broader sterno-coracoidal process, except for ANWC BS3318 (juvenile), which is similar in size. It differs from those of the other extant species of *Sula* by being much larger (Figure 5).

Wing

The humerus of the Tasman Booby [8 specimens — ANWC BS3318 (juvenile), BS3321, BS3326 (juvenile), BS3329, BS3332, BS4298 (juvenile), BS4299, and MV 150806] differs from that of *S. abbotti* by being relatively thicker with much larger proximal and distal ends and more distally located attachments for M. latissimus dorsi. It differs from that of *S. dactylatra* by being larger, except in juveniles. It differs from those of the other extant species of *Sula* by being much larger (Figure 7).

The ulna of the Tasman Booby [8 specimens — ANWC BS3318 (juvenile), BS3322, BS3326 (juvenile), BS3329, BS3332, MV 150806, 150808 and 164123] differs from those of *S. abbotti*, *S. dactylatra* and *S. nebouxii*, which are similar in size, by being thicker. It differs from those of other extant species of *Sula* by being much longer (Figure 8). At the distal end of the ulna, the external condyle extends proximally, relatively less in *S. abbotti*, and relatively more in *S. nebouxii* and *S. variegata*, than in *S. sula*, *S. leucogaster*, *S. dactylatra* and the Tasman Booby.

The radius of the Tasman Booby [7 specimens — ANWC BS3318 (juvenile), BS3321, BS3326 (juvenile), BS3332, MV 150804, 150806 and 150808] differs from that of *S. abbotti*, which is similar in length, by being thicker and having a larger distal end. It differs from that of *S. nebouxii*, which is similar in length, by the shaft being relatively thicker proximally and relatively thinner distally. It differs from that of *S. dactylatra*, which is similar in size, by the bicipital tubercle extending relatively less distally and having a relatively larger muscle scar in the ulnar depression. It differs from those of the other extant species of *Sula* by being much larger.

The carpometacarpus of the Tasman Booby [5 specimens — ANWC BS3318 (juvenile), BS3322, MV 150804, 150808 and 164126] is similar to or larger than that of *S. dactylatra.* Those of the other extant species of *Sula* are smaller.

Pelvic girdle

The pelvis of the Tasman Booby [3 specimens — ANWC BS3318 (juvenile), BS3332 and MV 150802 (juvenile)] is similar in size to that of *S. dactylatra.* Those of the other extant species of *Sula* are smaller.

Leg

The femur of the Tasman Booby [6 specimens — ANWC BS3318 (juvenile), BS3326, BS3328 (juvenile), BS3337 (juvenile), MV 150806 and 164331] is similar to or larger than that of *S. dactylatra.* Those of the other extant species of *Sula* are smaller.

The tibiotarsus of the Tasman Booby [4 specimens ANWC BS3318 (juvenile), BS3326 (juvenile), MV 150802 and 150806] differs from that of *S. dactylatra* by being slightly to much longer, with relatively longer bases to the inner cnemial crests and relatively shorter bases to the outer cnemial crests. It differs from those of the other extant species of *Sula* by being much larger.

The tarsometatarsus of the Tasman Booby [9 specimens — ANWC BS3318 (juvenile), BS3326 (juvenile), BS3327, BS3336, MV 150801, 150806, 164124, 164137 and 164334] differs from that of *S. dactylatra* by being broader and slightly to much longer. It differs from those of the other extant species of *Sula* by being much larger and by having, as in *S. dactylatra,* a tubercle on the internal edge of the internal cotyla (Figures 9 and 10).

General

The bones of the extinct Tasman Booby of Lord Howe and Norfolk Islands have the characteristics of *Sula* as distinct from those of *Morus* as outlined above. In general proportions, shape and size, the bones of the Tasman Booby resemble most those of *Sula dactylatra* from Lord Howe and Norfolk Islands, but are more massive. *S. dactylatra* at these islands is much larger than in the Atlantic Ocean and at low latitude colonies in the Indian and Pacific Oceans. The bones of the Tasman Booby and of *S. dactylatra* from Lord Howe and Norfolk Islands are also larger than those of other species of *Sula,* except for the wing bones of *S. abbotti,* which has a smaller body and shorter legs (cf. Bourne 1976, Nelson 1978). Measurements of the bones of the Tasman Booby and *S. dactylatra* from Lord Howe and Norfolk Islands are given in Tables 1-8.

Of the fossil species of *Sula* listed by Brodkorb (1963a), *S. ronzoni* and *S. arvernensis* of the Oligocene of France are based on poorly preserved pelves and their taxonomic status is debatable (cf. Harrison 1975, Olson 1985). The remaining fossil species, *S. universitatis, S. pohli, S. willetti, S. guano, S. phosphata* and *S. humeralis,* are based on skeletal elements that are smaller than those of *S. dactylatra* and are therefore also smaller than those of the Tasman Booby (Bourne 1976, Brodkorb 1955, 1963b, Howard 1958, Miller 1925, 1935, Miller & Bowman 1958).

TABLE 1 — *Measurements (mm) of skulls of S. tasmani and S. dactylatra from Norfolk and Lord Howe Islands*

		S. tasmani		*S. dactylatra*
		Fully-grown	Juvenile	Modern
Length of maxilla	x	100	96	96
	range	98-102	-	90-100
	n	3	1	10
	sd	-	-	2.8
Width across naso-frontal hinge	x	26	25	24
	range	26-27	-	22-25
	n	3	1	10
	sd	-	-	0.9
Width at preorbital process	x	35	-	33
	range	35-36	-	31-35
	n	2	-	9
	sd	-	-	1.3
Width across opisthotics	x	44	43	41
	range	43-44	-	40-43
	n	2	1	10
	sd	-	-	0.9
Length of cranium	x	73	70	70
	range	72-73	-	66-74
	n	2	1	10
	sd	-	-	1.9
Depth of cranium	x	32	30	32
	range	31-32	-	28-33
	n	2	1	10
	sd	-	-	1.4
Depth of mandible at coronoid process	x	19	-	17
	range	18-20	18-19	15-18
	n	9	2	11
	sd	0.8	-	0.8
Width of mandible in front of coronoid process	x	5.3	5.1	4.6
	range	5.1-5.5	-	3.7-5.1
	n	9	2	11
	sd	0.2	-	0.4
Distance from coronoid to posterior process	x	37	35	33
	range	36-38	-	31-35
	n	7	1	10
	sd	0.6	-	1.3

TABLE 2 — Measurements (mm) of coracoids of *S. tasmani* and *S. dactylatra* from Norfolk and Lord Howe Islands

		S. tasmani Fully-grown	Juvenile	*S. dactylatra* Modern
Greatest length	x	75	75	68
	range	-	-	67-73
	n	3	2	10
	sd	-	-	1.9
Length from head to internal distal angle	x	63	63	58
	range	63-65	62-64	55-61
	n	4	2	10
	sd	0.9	-	1.9
Ventral width	x	32	32	30
	range	-	-	28-31
	n	1	1	10
	sd	-	-	1.1
Length of sternal facet	x	31	31	28
	range	30-31	-	26-30
	n	2	1	10
	sd	-	-	1.1

TABLE 3 — Measurements (mm) of humeri of *S. tasmani* and *S. dactylatra* from Norfolk and Lord Howe Islands

		S. tasmani Fully-grown	Juvenile	*S. dactylatra* Modern
Length	x	209	195	193
	range	206-210	192-199	186-202
	n	3	2	10
	sd	-	-	5.2
Proximal width	x	30	27	29
	range	-	-	28-30
	n	3	2	9
	sd	-	-	0.9
Shaft width at midpoint	x	11	10	8.3
	range	-	9-11	7.8-9.1
	n	3	3	10
	sd	-	-	0.5
Distal width	x	23	21	20
	range	21-23	20-22	19-21
	n	4	3	10
	sd	0.9	-	0.6

TABLE 4 — Measurements (mm) of ulnae of *S. tasmani* and *S. dactylatra* from Norfolk and Lord Howe Islands

		S. tasmani		*S. dactylatra*
		Fully-grown	Juvenile	Modern
Length	x	212	212	204
	range	208-216	207-217	196-211
	n	5	2	9
	sd	4.3	-	4.5
Proximal width	x	17	14	15
	range	16-18	-	14-15
	n	5	2	9
	sd	0.7	-	0.2
Minimum shaft width	x	8.3	7.5	7.4
	range	7.7-8.5	7.2-7.7	7.0-7.9
	n	6	2	9
	sd	0.4	-	0.3
Distal width	x	14	13	14
	range	14-15	13-14	13-15
	n	6	2	8
	sd	0.5	-	0.5

TABLE 5 — Measurements (mm) of carpometacarpi of *S. tasmani* and *S. dactylatra* from Norfolk and Lord Howe Islands

		S. tasmani		*S. dactylatra*
		Fully-grown	Juvenile	Modern
Length	x	92	90	86
	range	-	-	85-90
	n	2	1	9
	sd	-	-	1.8
Proximal width	x	20	18	18
	range	19-20	-	17-19
	n	2	1	9
	sd	-	-	0.7
Minimum shaft width	x	4.7	5.7	5.4
	range	4.6-4.7	-	4.7-5.7
	n	2	1	9
	sd	-	-	0.3
Distal width	x	11	11	11
	range	-	-	10-12
	n	2	1	9
	sd	-	-	0.5

TABLE 6 — Measurements (mm) of femora of *S. tasmani* and *S. dactylatra* from Norfolk and Lord Howe Islands

		S. tasmani		*S. dactylatra*
		Fully-grown	Juvenile	Modern
Length	x	68	66	64
	range	67-70	65-67	61-66
	n	3	3	10
	sd	-	-	1.7
Proximal width	x	15	15	14
	range	-	14-15	13-15
	n	3	3	10
	sd	-	-	0.4
Minimum shaft width	x	8.1	7.7	7.4
	range	8.0-8.2	7.4-7.9	6.6-7.8
	n	3	3	10
	sd	-	-	0.3
Distal width	x	15	15	14
	range	-	-	13-15
	n	3	3	10
	sd	-	-	0.6

TABLE 7 — Measurements (mm) of tibiotarsi of *S. tasmani* and *S. dactylatra* from Norfolk and Lord Howe Islands

		S. tasmani		*S. dactylatra*
		Fully-grown	Juvenile	Modern
Length	x	100	102	95
	range	-	101-102	95
	n	1	3	10
	sd	-	-	2.2
Proximal width	x	12	12	11
	range	-	12-13	11-12
	n	1	3	9
	sd	-	-	0.3
Minimum shaft width	x	8.0	8.3	7.3
	range	-	7.8-8.7	6.9-7.7
	n	1	3	10
	sd	-	-	0.3
Distal width	x	15	15	13
	range	-	-	13-14
	n	1	3	10
	sd	-	-	0.5
Distal depth	x	13	1412	
	range	-	13-14	11-13
	n	1	3	10
	sd	-	-	0.6

TABLE 8 — Measurements (mm) of tarsometatarsi of *S. tasmani* and *S. dactylatra* from Norfolk and Lord Howe Islands.

		S. tasmani		*S. dactylatra*
		Fully-grown	Juvenile	Modern
Length	x	64	63	60
	range	62-65	61-63	57-63
	n	6	3	10
	sd	0.8	-	1.4
Maximum proximal width	x	17	16	15
	range	-	15-16	14-16
	n	6	3	10
	sd	0.2	-	0.4
Minimum shaft width	x	11	10	10
	range	-	-	9-10
	n	6	3	10
	sd	0.1	-	0.5
Distal width	x	17	16	16
	range	-	15-16	15-16
	n	5	3	10
	sd	0.3	-	0.5

DISCUSSION

On Norfolk Island the bones of *Sula tasmani* n.sp. were found *in situ* with those of the kiore or Polynesian rat (*Rattus exulans*) and below charcoal with a radiocarbon date of about 800 years BP or 1200 AD (Meredith *et al.* 1985). The rat was presumably introduced by the Polynesians , who left stone artifacts on the island and introduced a plantain banana (*Musa* sp.) (King MS and Laing 1915). The Polynesians may have directly or indirectly caused the extinction of the Tasman Booby on Norfolk Island.

When Norfolk Island was discovered in 1774 (Hoare 1974) the only booby recorded by Cook, and painted by George Forster, was the Masked Booby (*Sula dactylatra*). King (MS) expressed annoyance that the Masked Booby did not nest on the main island but on relatively inaccessible Philip Island. He landed and settled near the location where the Tasman Booby material was found and reported that the area was so densely covered with scrub that a site had to be cleared to pitch his tents. The area, therefore, was too densely wooded for ground-nesting by boobies.

The extracts from journals and letters of the First Fleet quoted by Rabone (1959) make no mention of sulids at Lord Howe Island at the time of its discovery (15 Feburary 1788) and at the time of the first landing (13 March 1788) by Lieutenant Henry Lidgbird Ball and the crew of the *Supply*. When the *Supply* returned from Sydney with other ships on 16 May 1788, however, the most numerous birds at the same landing site on the sandy shores of the lagoon were "thousands of gannets", very large

TABLE 9 — Bones from Norfolk (N) and Lord Howe (LH) Islands referred to *Sula tasmani*

Museum Number		Elements	Location
AM	F56463	mandible	Middle Beach, LH
ANWC	BS3320	mandible	Cemetery bay, N
	BS3321	coracoid, humerus, radius	" " "
	BS3323	maxilla	" " "
	BS3324	mandible	" " "
	BS3325	cranium	" " "
	BS3327	mandible, tarsometatarsus	" " "
	BS3328	femur	Emily Bay "
	BS3329	humerus, ulna	Blinkey Beach, LH
	BS3332	humerus, ulna, synsacrum	" " "
	BS3333	craniaum, maxilla	" " "
	BS3336	tarsometatarsus	Cemetery Bay, N
	BS3337	femur	" " "
	BS4298	humerus	Blinkey Beach LH
	BS4299	humerus	" " "
MV	150801	tarsometatarsus	Nepean Island N
	150802	cranium, sternum, pelvis, tibiotarsus	Cemetery Bay, N
	150803	coracoid	" " "
	150804	radius, carpometacarpus	" " "
	150805	cranium	" " "
	150806	mandible, scapula, coracoid, humerus, ulna, radius, femur, tibiotarsus, tarsometatarsus	" " "
	150808	mandible, sternum, furculum, scapula, ulna, radius, carpometacarpus	" " "
	163650	mandible	" " "
	164118	mandible	" " "
	164123	ulna	" " "
	164124	tarsometatarsus	" " "
	164126	carpometacarpus	" " "
	164137	tarsometatarsus	" " "
	164185	coracoid	" " "
	164331	femur	" " "
	164334	tarsometatarsus	" " "

and fat. According to Lieutenant John Watts of the *Lady Penrhyn* (Anon 1789), they were in prodigious number, the "females" all being on their nests, which were simple hollows in the sand. Many "gannets" and their eggs were collected for food, but apparently none as scientific specimens. We have not located any drawings of them. It has been assumed that the "gannets" were the Masked Booby, although Hindwood (1940) noted that eggs in May was at variance with the present nesting time of *S. dactylatra* at Lord Howe Island, where breeding occurs from September to January, most eggs being laid in October (Hull 1910). At Philip Island near Norfolk Island, eggs are laid from 5 July to 3 January, with a peak in September (Hermes *et al.* 1986). The nests of *S. dactylatra* are relatively far apart for sulids, some clumping in small groups of a few nests (Nelson 1978). The Australasian Gannet (*Morus serrator*) does nest in very dense colonies, but it is smaller than the North Atlantic Gannet (*M. bassanus*) and its nesting season is similar to that of *S. dactylatra*, August to December in New Zealand (Oliver 1955) and October to January in Australia (North 1912, Mathews & Iredale 1921). At Philip Island eggs are laid from 30 August to 1 Feburary (Hermes *et al.* 1986).

Thus, the dense nesting with a peak of egg-laying in May by a very large fat "gannet" suggests a sulid other than *Sula dactylatra* and *Morus serrator*. The observations by the homeward-bound members of the First Fleet may have been the first, last and only recorded sightings of *Sula tasmani*.

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LITERATURE CITED

ANON 1789. The voyage of Governor Phillip to Botany Bay with an account of the establishment of the colonies of Port Jackson and Norfolk Island. London: John Stockdale. 298 pp.
BERLIOZ, J. 1950. Reflexions sur la notion de "Groupe de formes" dans la systematique ornithologique. Syllegomena Biologica: 50-55. Wittenberg, A. Ziemsen.
BOURNE, W. R. P. 1976. On subfossil bones of Abbott's Booby, *Sula abbotti*, from the Mascarene Islands, with a note on the proportions and distribution of the Sulidae. Ibis 118: 119-123.
BRISSON, M. J. 1760. Ornithologia sive synopsis methodica. Vol. 6. Paris. 543 pp.
BRODKORB, P. 1955. The avifauna of the Bone Valley Formation. Florida Geological Survey Report of Investigations No. 14: 1-45.
BRODKORB, P. 1963a. Catalogue of the fossil birds. Bull. Fla. St. Mus. Biol. Sci 7: 179-293.
BRODKORB, P. 1963b. Miocene birds from the Hawthorne Formation. Quart, Jour, Florida Aca. Sci. 16(2): 159-167.
CONDON. H. T. 1975. Checklist of the Birds of Australia, I. Non-passerines. Melbourne: RAOU. 311 pp.
CRAMP, S.; SIMMONS, K. E. L. (eds.) 1977. Handbook of the Birds of Europe, the Middle East, and North Africa: the Birds of the Western Palearctic. Vol. 1, 722 pp.
DORST, J: MOUGIN, J. L. 1979. Order Pelecaniformes. *In* E. Mayr & G. W. Cottrel (eds.) Check-list of Birds of the World. 2nd ed. Mus. Comp. Zool: Cambridge, Massachusetts. Vol. 1: 155-193.
FISHER, H. I. 1945. Flying ability and the anterior intermuscular line of the coracoid. Auk 62: 125-129.
HARRISON, C. J. O. 1975. The taxonomic status of Milne-Edwards' fossil sulids. Bull. Brit. Ornith. Club 95 (2): 51-54.
HARRISON, C. J. O. 1978. Osteological differences in the leg bones of two forms of *Anhinga*. Emu 78: 230-231.
HERMES, N.; EVANS, O.; EVANS, B. 1986. Norfolk Island birds: a review 1985. Notornis 33: 141-149.
HINDWOOD, K. 1940. The birds of Lord Howe Island. Emu 40 1-86.
HOARE, M. 1974. The Discovery of Norfolk Island. Aust. Government Publ. Service, Canberra. 23 pp.

HOWARD, H. 1936. A new fossil bird locality near Playa Del Rey, California with descriptions of a new species of sulid. Condon. 38: 211-214.
HOWARD, H. 1958. Miocene sulids of southern California. Los Angeles Co. Mus. Contrib. Sci. 25: 1-16.
HULL, A. F. B. 1910. The birds of Lord Howe and Norfolk Islands. Proc. Linn. N.S.W. 34 (4): 636-693.
KING, P. G. 1787-1790. Journal manuscript in the Mitchell Library, Sydney.
KINSKY, F. C. 1970. Annotated Checklist of the Birds of New Zealand. Wellington: A. H. & A. W. Reed for OSNZ. 96 pp.
KINSKY, F. C. 1980. Amendments and additions to the 1970 annotated checklist of the birds of New Zealand. Notornis 27 Supp: 1-23.
LAING, R. M. 1915. A revised list of the Norfolk Island flora, with some notes on the species. Trans. NZ Inst. 47: 1-39.
LINNAEUS, C. 1758. Systema Naturae. Ed. 10, Vol.1.
MATHEWS, G. M. 1913. New generic names, with some notes on others. Austral Avian Record 2(2 & 3): 55-62.
MATHEWS, G. M.; IREDALE, T. 1921. A Manual of the Birds of Australia. London: Witherby, 279 pp.
MEREDITH, C. W.; SPECHT, J. R.; RICH, PV. 1985. A minimum date for Polynesian visitation to Norfolk Island, south-west Pacific, from faunal evidence. Search 16: 304-306.
MILLER, L. 1925. Avian remains from the Miocene of Lompoc, California. Publ. Carnegie Inst. 349: 107-117
MILLER, L. 1935. New bird horizons in California. Univ. Calif. Los Angeles publ. biol. sci. 1: 73-80.
MILLER, L.; BOWMAN, R. I. 1958. Further bird remains from the San Diego Pliocene. Contr. Sci. No. 20: 1-15.
NELSON, J.B. 1978. The Sulidae, Gannets and Boobies. Aberdeen Univ. studies Series No. 154. OUP. Oxford 1012 pp.
NORTH, A. J. 1912. Nests and eggs of birds found breeding in Australia and Tasmania. Aust. Mus. Special Cat. No. 1 Vol. 3 Part 5: 333-362.
OGILVIE-GRANT, W. R. 1898. Cat. Birds Brit. Mus. (Nat. Hist.) 26: 423-441.
OLIVER, W. R. B. 1955. New Zealand Birds. Wellington: A. H. & A. W. Reed, 661 pp.
OLSON, S. L. 1985. The fossil record of birds. *In* D. S. Farner, J. R. King & K. C. Parkes (eds.) Avian Biology 8: 79-238.
OWRE, O. T. 1967. Adaptations for locomotion and feeding in the Anhinga and the Double-crested Cormorant. A. O. U. Ornith. Monographs No. 6, 138 pp.
PALMER, R. 1962. Sulidae, *In* R. Palmer (ed.) Handbook of North American Birds 1: 280-281.
PETERS, J. L. 1931. Check-list of Birds of the World. Vol. 1, 345 pp.
RABONE, H. R. 1959. Lord Howe Island, its discovery and early associations 1788 to 1888. Sydney: Australis Publications. 54 pp.
RICH, P. V.; VAN TETS, G.F. 1982. Fossil birds of Australia and New Guinea. *In* P. V. Rich & E. M. Thompson (eds). The fossil vertebrate record of Australasia. Monash Univ. Offset Printing Unit, Clayton, Victoria: 235-384.
RICH, P. V.; VAN TETS, G. F. 1984. What fossil birds contribute towards an understanding of origin and development of the Australian avifauna. *In* Archer, M. and G. Clayton (eds.) Vertebrate Zoogeography & Evolution in Australasia. Carlisle, W. Aust.: Hesperian Press: 421-446.
RICH, P. V.; VAN TETS, G. F.; ORTH, K.; MEREDITH, C. W.; DAVIDSON, P. 1983. Prehistory of the Norfolk Island biota. *In* R. Schodde, P. J. Fullagar & N. Hermes (eds.) A review of Norfolk Island Birds, past and present. Aust. Nat. Parks & Wildlife Service, Canberra, Special Publ. No. 8: 6-29.
SERVENTY, D. L. ; SERVENTY V.; WARHAM, J. 1971. The Handbook of Australian Seabirds. Sydney: A. H. & A. W. Reed. 254 pp.
SHUFELDT, R. W. 1888. Observations upon the osteology of the order Tubinares and Steganopodes. Proc. U.S. Nat. Mus. 253-315.
SHUFELDT, R. W. 1902. The osteology of the Steganopodes. Mem. Carnegie Mus. 1(3): 109-223.
VAN TETS, G. F. 1965. A comparative study of some social communication patterns in the Pelecaniformes. A. O. U. Ornith. Monographs No. 2, 88 pp.
VAN TETS, G. F.; RICH, P. V.; FULLAGAR, P. J.; DAVIDSON, P. M. 1981. Fossil, sub-fossil and early historic birds of Lord Howe and Norfolk Islands. *In* Recher, H. F. and W. F. Ponder (eds.) Lord Howe Island, a summary of current and projected scientific and environmental activities. Occasional Reports Aust. Mus. No. 1: 29-31.
VIEILLOT, L. J. P. 1816. Analyse d'une nouvelle ornithologie elementaire. Paris. 70 pp.
VON BOETTICHER, H. 1957. Pelikane, Kormorane und andere Ruderfuszler. Neue Brehm-Bucherei, A. Ziemsen, Wittenberg Lutherstadt. 94 pp.
VOOUS, K. H. 1973. List of Recent Holarctic bird species. Non-passerines. *Ibis 115:* 612-638.

WETMORE, A. 1926. Observations on fossil birds described from the Miocene of Maryland. Auk 43: 426-268.
WETMORE, A. 1930. Fossil bird remains from the Temblor Formation near Bakersfield, California. Proc. Calif. Acad. Sci. (4) 19(8): 85-93.
WETMORE, A. 1938. A Miocene booby and other records fom the Calvert Formation of Maryland. Proc. US Nat. Mus. 85 (3030): 21-25.

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SHORT NOTE

Group Sizes of Red Shining Parrots on 'Eua, Kingdom of Tonga

In Fiji, parrots of the genus *Prosopeia* generally occur singly or in small groups of up to five individuals (Porter 1935, Brown & Child 1975, Holyoak 1979); but flocking of up to 40 birds, mostly in fruiting trees, has been reported (Bahr 1912, Wood & Wetmore 1926, Holyoak 1979, Clunie 1984).

During an 18 months field study of Red Shining Parrots (*Prosopeia tabuensis*) on the Tongan island of 'Eua, I made 380 observations of feeding parrots involving 735 birds. These observations are listed in Table 1. Mean group size (MGS, bottom line in Table 1) is lowest ($p < 0.01$) during the breeding season, which is from June to October, although a few pairs start breeding as early as May. The variation of MGS in different plant species apparently depends on the amount of food provided by a plant species: higher MGS (right-hand column in Table 1) occurs in trees which fruit prolifically, whereas in small trees, bushes and vines (*Melodinus vitiense* and many of the 'other species' in Table 1), parrots were most often seen feeding singly.

The data indicate that adult Red Shining Parrots live in pairs, being accompanied by their offspring after the breeding season (when MGS is higher than two). During the breeding season, when females spend most of the time on their nests, the frequency of observations of single birds increased. The data do not give information about the social behaviour of immature birds other than that they do not flock.

Non-feeding Red Shining Parrots have been seen in groups of one to eight birds; aggregations of more than four birds have been very rare. During the course of the study, M. Greenfield (pers. comm.) once saw a flock of more than 10 parrots feeding in guavas (*Psidium guajava*).

From the distribution of group sizes shown in Table 2, I conclude that no permanent associations of different families exist, 86.2% of the