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Order PELECANIFORMES

Medium-sized to very large aquatic birds of marine and inland waters. Worldwide distribution. Six families all breeding in our region. Feed mainly on aquatic animals including fish, arthropods and molluscs. Take-off from water aided by hopping or kicking with both feet together, in synchrony with wing-beat. Totipalmate (four toes connected by three webs). Hind toe rather long and turned inwards. Claws of feet curved and strong to aid in clambering up cliffs and trees. Body-down evenly distributed on both pterylae and apteria. Contour-feathers without after shaft, except slightly developed in Fregatidae. Pair of oil glands rather large and external opening tufted. Upper mandible has complex rhamphotheca of three or four plates. Pair of salt-glands or nasal glands recessed into underside of frontal bone (not upper side as in other saltwater birds) (Schmidt-Nielson 1959; Siegel-Causey 1990). Salt-glands drain via ducts under rhamphotheca at tip of upper mandible. Moist throat-lining used for evaporative cooling aided by rapid gular-flutter of hyoid bones. Tongue rudimentary, but somewhat larger in Phaethontidae. Throat, oesophagus and stomach united in a distensible gullet. Undigested food remains are regurgitated. Only fluids pass pyloric sphincter.

Sexually dimorphic plumage only in Anhingidae and Fregatidae. Selection of nest-site and initiation of pair-formation by male, but in Pelecanidae female first leads several males in a male-selection (or persistence) chase as in ducks. Nest built by female with material brought to nest-site mainly by male. Copulation normally on nest-site. Both sexes take turns guarding nest-site, incubating eggs, and brooding and feeding chicks. Eggs unicoloured with chalky finish except for Phaethontidae. Webbed feet used to warm eggs. Chicks hatch naked (except in Phaethontidae) and blind. Later fully covered with down for several weeks. Newly hatched chicks take fluid food from tip of parental bill. Older chicks take partly digested food from parental gullet, except in Phaethontidae, in which parent inserts bill into gullet of chick. Chicks become independent usually within a few weeks after fledging and at fledging in gannets *Sula* spp. At nesting colonies severe loss of eggs and chicks may result from human disturbance, parents being forced off nests, so that eggs and chicks become cold or overheat or are taken by predators.

Anatomical and behavioural similarities suggest close phylogenetic affinities between Pelecaniformes and Ciconiiformes, which could perhaps be united. Cottam (1957) found skeletal characters that suggest that the Shoe-billed Stork *Balaeniceps rex*, only member of the African family Balaenicipitidae, ought to be in Pelecaniformes rather than Ciconiiformes. Linnaeus (1758) included all pelecaniform birds known to him, except those in *Phaethon*, in the genus *Pelecanus*, from which Brisson (1760) removed the genera *Sula*, *Anhinga*, *Phalacrocorax* and *Fregata*. Subsequently these genera became the bases of six families in the order Pelecaniformes, formerly known as the Steganopodes. Over the last 200 years there has been debate about whether *Phaethon* and even *Fregata* ought to be included, and whether *Anhinga* ought to be in the same family as *Phalacrocorax*. There is ample behavioural (van Tets 1965), osteological and palaeontological (Olson 1985) evidence to demonstrate that there are six distinct extant families in the Pelecaniformes.

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Family **SULIDAE** gannets and boobies

Large to fairly large seabirds, occurring in all oceans except n. North Pacific and s. Southern Oceans. Nine species in two groups: six boobies and three gannets. Though treated here, after Peters, in one genus, for a long time many authorities have proposed two genera: *Sula* (s.s.) for boobies and *Morus* for gannets. Recently a third genus *Papasula* has been recognized for the forest-booby *S. abbotti*. All are separated on behavioural and osteological characters such as distinctive hypotarsus and number of ossicles per sclerotic ring (Nelson 1978; Olson & Warheit 1988; van Tets *et al.* 1988). The family appears close to the ancestral stock that gave rise also to the Anhingidae, Phalacrocoracidae, Fregatidae and to the extinct Pelegornithidae (bony-toothed seabirds), Protoplotidae (slender volant divers) and Plotopteridae (robust flightless divers) (Olson 1977, 1985; van Tets 1965; van Tets *et al.* 1989).

Short thick neck; elongate body; long pointed wings, 11 primaries (p9 or p10 longest) and about 28 secondaries, diastataxic; wedge-shaped, medium-long tail with 12–16 rectrices. Sturdy cone-shaped bill, slightly decurved at tip; cutting edges serrated. Naked skin on gular and facial areas, more extensive in boobies so that eyes set well within bare areas and with thick fleshy eye-ring. Secondary external nares (Ewart 1881; Macdonald 1960). Ventral skin strongly pneumatic with large subcutaneous air-sacs, built for plunge-diving. Plumage, mostly white with black on wings. Some species with white, grey or brown morphs. Bare parts, often brightly coloured. Oil gland, feathered. Sexes similar except in colours of bare parts in some species. Juveniles differ from adults, reaching full adult plumage in 2–4 years. Stance upright, tilted slightly backwards; gait waddling. Diving almost vertical in gannets; at fairly low angle in boobies. Flight, alternate periods of flapping and gliding, often quite high above water. Swim well with head high and tail above water.

Distributed in all temperate and tropical oceans. Gannets are typical of temperate-zone seas and may reach tropics on migration; the three species, of which one breeds and one is a rare vagrant in our region, are allopatric. These are sometimes treated as subspecies of the Northern Gannet *S. bassana* but differ enough in size, distribution of black in wings and tail, length of throat-stripe and pattern on tarsus to be treated as separate species, composing a superspecies. Boobies (excluding Abbott's) are tropical and subtropical; five species, of which three breed in our region, in sympatry. The one species of forest-booby is now confined to Christmas I. (Ind.) but formerly was more widespread (Bourne 1976; Nelson 1974; Olson & Warheit 1988). Strictly marine, inshore and offshore rather than pelagic, except for some boobies, with rather aerial habits, tending to fly quite high. Plunge-dive for food, often spectacularly so when in feeding flocks. White plumage of most species conspicuous, even at considerable distance. Feed chiefly on fish, especially on shoaling species (gannets) or on flying fish (boobies). Migratory and dispersive; juvenile and immature birds may be more so than adults.

Monogamous pair-bond, often long-lasting and probably maintained only at nest-site. Defend nest-site territories. Pairs use same site year after year. Breed mainly in large dense colonies on islands and sometimes on mainland; on cliffs and stacks or on flat sandy cays. Usually nest on ground but *S. abbotti* is entirely arboreal. The Red-footed Booby *S. sula* also nests and roosts in bushes and trees and the Brown Booby *S. leucogaster* perches in trees and bushes but nests on ground. All other species roost and nest on ground. Various displays at breeding grounds for greeting, male-advertising and flight-intention such as sky-pointing, a precursor of various displays in other Pelecaniformes and related to the stretch-display of ardeids (van Tets 1965). Breeding annual and strictly seasonal in gannets; more protracted in boobies, in which it may be non-seasonal and less than annual in some species; in *S. abbotti*, if successful, only once every 2 years. Nests vary from mere shallow depressions on ground without material to substantial heaps of vegetation and debris cemented with guano or to simple stick-nests in trees. Both sexes build but male typically brings material. Density of nests in colonies closest in gannets; often quite dispersed or even solitary in boobies. Eggs, ovate, pale green, blue or white staining brown, with chalky coating. Clutch-size, 1–4, laid at intervals of about 5 days. Replacement laying after loss. Incubation starts with first egg; by both sexes in roughly equal shares; eggs incubated in feet; no brood-patch. Incubation period, 40–55 days. Eggshells left in nest or discarded. Hatching asynchronous. Young, altricial, nidicolous, downy. Cared for and fed by both parents, usually by incomplete regurgitation. Brooded continuously for 2–3 weeks, then guarded for as long as possible (boobies) or to fledging (gannets). If two chicks hatch from clutches of two, typically only one survives. Nestling period, 85–175 days, with great variation in boobies, depending on food supply. Age at maturity, 4–6 years.

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Sula serrator Australasian Gannet

COLOUR PLATE FACING PAGE 756

Sula australis Gould, 1841, *Proc. zool. Soc. Lond.* (1840): 177 — River Derwent, Tasmania.

Pelecanus serrator G.R. Gray, 1843, in Dieffenbach's *Travels NZ*, 2: 200. New name for *Sula australis* Gould, 1841, preoccupied by *Sula australis* Stephens, 1826, in Shaw, *Gen. Zool.* 13 (1): 104.

The generic *Sula* is from Greek συλάειν (to strip or plunder) (Morris 1848) but some say that it may come from 'sula-n' or 'sula-hin' (= 'the' gannet in Icelandic); *serrator* is late Latin for a sawyer, referring to the serrated cutting edges of the beak, which are, however, common to all species of sulid.

OTHER ENGLISH NAMES Gannet, Australian Gannet, Booby, Diver, Solan Goose.

Conveniently named geographically to distinguish it from the very similar Northern *Sula bassana* and Cape *S. capensis* Gannets.

MONOTYPIC

FIELD IDENTIFICATION Length 84–91 cm; wing-span 170–200 cm; weight 2300 g. Large, conspicuous, predominantly white seabird with typical sulid jizz: long neck, slender wings, spear-like bill and pointed tail. Similar in size and appearance to Northern and Cape Gannets, the latter occurring as a vagrant in our area; generally larger than other boobies. Often seen flying steadily over cooler coastal seas and plunging for food, solitarily or sometimes in large congregations; readily seen from shore. Sexes identical; no seasonal plumages. Juveniles and immatures separable: show a great variety of brownish or mottled plumages easily distinguished from adult plumage.

DESCRIPTION ADULT. Mainly white with black flight feathers and central rectrices. Head and hindneck, buff-yellow (fading at hindneck); rest of neck, mantle, back, rump and upper tail-coverts and entire underparts, white. Upperwing pattern, clean-cut: primaries, primary coverts (greater and median) and secondaries, black, sharply demarcated from white forewing (secondary coverts and lesser primary coverts) and upper-parts (including white scapulars, humerals and tertials). Below, underwing pattern like upperwing except that under primary-coverts are white; otherwise white below except for short black gular stripe from below bill, barely reaching throat. Alula, brown and obvious ventrally against white under wing-lining. Pattern of tail varies: typically four black central tail feathers form dark wedge in centre of otherwise white, pointed tail; however, pattern not consistent: some have all or mainly black tails, others as few as two black feathers in tail; further, the number of tail feathers also varies altering appearance of tail-pattern (Sibson 1988). Bill, long and tapering, grey with black edges. Eye-ring, blue. Iris, grey (though two-toned light and dark grey reported by Berutti [1988]). Legs and feet, greyish brown with bright yellowish or green stripes on tarsus and toes. **JUVENILE.** Quite unlike adult. In general, appear brownish-grey finely spotted white: crown, dark brown spotted with white; head and neck mostly white, speckled brown; mantle, back, rump, and upper tail-coverts brown with white tips to feathers. On upperwing, scapulars, humerals, tertials, all upper wing-coverts and remiges, dark brownish-grey tipped white. Tail, entirely dark brown, tipped white. Ventrally, chin, throat and lower neck white with brown fringes; upper breast and flanks, dark brown; rest of underparts whitish with dark-brown fringes; thighs brown. Underwing like upper. **IMMATURE.** Attains adult or near-adult plumage at 2–5 years, but considerable individual variation in age of attainment of various sub-adult plumages and thus not possible to age birds on plumage stages; adult plumage develops gradually from juvenile, appearing increasingly white with age. Crown and nape gradually develop buffy-yellow coloration (after c. 8 months in males). Neck, mantle, back, rump and upper tail-coverts, mostly white with a few dark brown feathers; underparts mostly white but with scattered brown markings. Upper wing-coverts, scapulars and tertials mostly white with scattered brown feathers. Outer rectrices gradually replaced with white feathers.

SIMILAR SPECIES Generally unmistakable from all seabirds except other sulids. Very similar to other gannets but Northern Gannet confined to North Atlantic Ocean and not to be expected in Aust. waters; Cape Gannet only vagrant to Aust. Adults of all three generally separated by amount of black in tail: Northern Gannet typically has wholly white tail (but see *Br. Birds* 81: 683); Cape Gannet typically has tail all or mostly black but never with symmetrical tail pattern of Aus-

tralasian Gannet (but sometimes outer feathers white; 89% [n=3682 birds] had wholly black tails; discussed in detail in Broekhuysen & Liversidge 1954); Australasian typically has only four central tail-feathers black (but see Description). In our area, any gannet with all or mostly black tail needs to be identified with caution as tail coloration not a completely reliable indicator. Cape Gannet can be reliably separated by length of gular streak (3–4 times longer in Cape than Australasian Gannet), colour of iris (silvery cream in Cape Gannet and paler than Australasian) and differences in behaviour and calls (calls of Cape Gannet lower-pitched than Australasian and Sky-pointing displays differ). Thus, danger that Cape may be or has been overlooked in Aust. waters among predominant Australasian Gannets. No known differences between juveniles and immatures of all three species. At close range differ from other seabirds by plumage; pointed, broad-based bill; slender head; pointed tail; long, pointed wings set in middle of long body, resulting in rakish, rather even, regular appearance in all flight attitudes. Though similar, most boobies are smaller and generally do not occur in temperate waters, whereas Australasian Gannet not in tropics. Adults distinguished from Masked Booby by buff to orange colour on head, black in tail, more black in wing and lack of blue-black facial skin; from white-morph Red-footed Booby by deeper buff-orange on head (rather than golden wash), black in tail, grey (not red) feet and blue-grey bill (not pale blue with pinkish base). Juvenile/immatures ought not to be confused, those of Australasian Gannet being mottled brownish-grey rather than more uniform brownish. At a distance and in poor conditions may be less easy or hard to distinguish (especially as immatures) from small albatrosses and even some large shearwaters but structural and flight characters then most important; tending to flap and glide more regularly than the glide, tilt and swoop of procellariiforms.

In light breezes fly steadily, both low above water and fairly high (<30 m), with deep, powerful wing-beats alternating with short, rather level glides; may soar or bank. In stronger winds shorten wingspan and wing-beats, often banking, swooping and side-slipping in the manner of albatrosses and shearwaters. Plunge-dive, partly folding wings during dives, when feeding, at low angle from no great height but also more or less vertically from <20 m; if successful, bring prey to surface, swallow it and may rest on water for a while. Swim and float well and buoyantly with head up and tail above surface. Take-off laboured, especially in light or calm conditions, when may not be possible after heavy meal. Usually indifferent to boats and ships and tend not to follow them. Seldom on land except when nesting; walk awkwardly. Mostly silent at sea but noisy roar from breeding colonies.

HABITAT Marine, mostly within limit of continental shelf. Occur from cool waters of Subtropical to Subantarctic Zone, mainly in Temperate Zone. Feed in shallow waters of coastal shelf. Occurrence may be related to sea-temperature which determines spawning of fish (Wingham 1985). E of NZ, most found near coastal islands, capes, bays and few offshore islands (Norris 1965). In NSW, regularly recorded up to 5 km offshore (Marchant 1977; Milledge 1977); most fishing observed close inshore (Milledge 1977). In SA, frequent inshore waters, including gulfs and waters round islands; off rocky coasts or sandy beaches; fish in shallow (<5 m depth) or deep water (up to 180 m) (Cox 1978). Between Fremantle and Rottneest I., WA, 65% birds seen within 3 km of mainland coast, and density decreased with distance from coast (Storr 1964a).

Enter bays, harbours and estuaries. In Manakau Harbour, NZ, fish along channels where tidal water flows strongly, following tides in and out; peak numbers in harbour in season of rough weather (June–Aug.) (Sibson 1981). At Cat I., Tas., colony, fish closer to Island when brooding than when incubating; also stay close to Island on stormy days, feeding near surface shoals (Warham 1958). Cross open ocean to and from NZ and Aust. (Wodzicki & Stein 1958).

All NZ gannetries N of Subtropical Convergence, except two in mixed water separating Subtropical and Subantarctic Zones; NZ breeding range, 32–47°S, but 99.7% birds breed between 34–40°S. Colony sites largely or wholly surrounded by water; most on rock stacks, pinnacles, small rocky or sandy islands; on large islands, use promontories; three colonies on mainland NZ, on plateaux above cliffs on capes.

Flight zone from just above water to perhaps 50 m or more, even soaring to leeward of tall islands (Wodzicki & McMeekan 1947; Warham 1958), thus using greater range of airspace than many other marine species. Roost mostly near breeding colonies; on breeding islands, at edges of gannetries; also other islands, and occasionally mainland; roosting habitat generally similar to breeding habitat, but sometimes on slopes too steep for nests (Fleming & Wodzicki 1952; Wodzicki & Robertson 1953; Warham 1958; Wodzicki *et al.* 1984); also roost on artificial structures e.g. navigation beacons, Port Phillip Bay. Roosting may precede establishment of breeding (Wodzicki & Robertson 1953; Wodzicki 1967).

Two Aust. gannetries on artificial structures (Wedge Light and Pope's Eye, Port Phillip Bay); extension of breakwater at Pope's Eye may be increasing nesting habitat in bay. Danger to roosting and breeding sites, particularly on mainland, from human disturbance, such as helicopter visits to lighthouse, Cat I. (Warham 1979) and increased numbers of visitors, C. Kidnappers (Robertson 1960). Kelp *Larus dominicanus* and Pacific *L. pacificus* Gulls take eggs and chicks if adults disturbed from nests (Anderson & Anderson 1936; Robertson 1960). Guano was collected from colonies in NZ (E.J. Wingham).

DISTRIBUTION AND POPULATION Along e. and s. coasts of Aust. from N of Rockhampton, Qld to Steep Point, WA and round NZ.

AUST. Present distribution probably less than in the past. At present, continuous from N of Rockhampton, Qld, S through NSW to Vic., round Tas., along SA coasts, except The Coorong, to WA and as far N as Steep Point; few records central s. coasts (Cox 1978; Aust. & Vic. Atlases). Earlier records from Townsville, Qld (Wodzicki & Stein 1958) and Pt Cloates, WA (Carter 1904). Also Lord Howe and Norfolk I.

NZ Essentially continuous along coasts of NI, SI and Stewart I. but more common in N of both main islands (NZ Atlas).

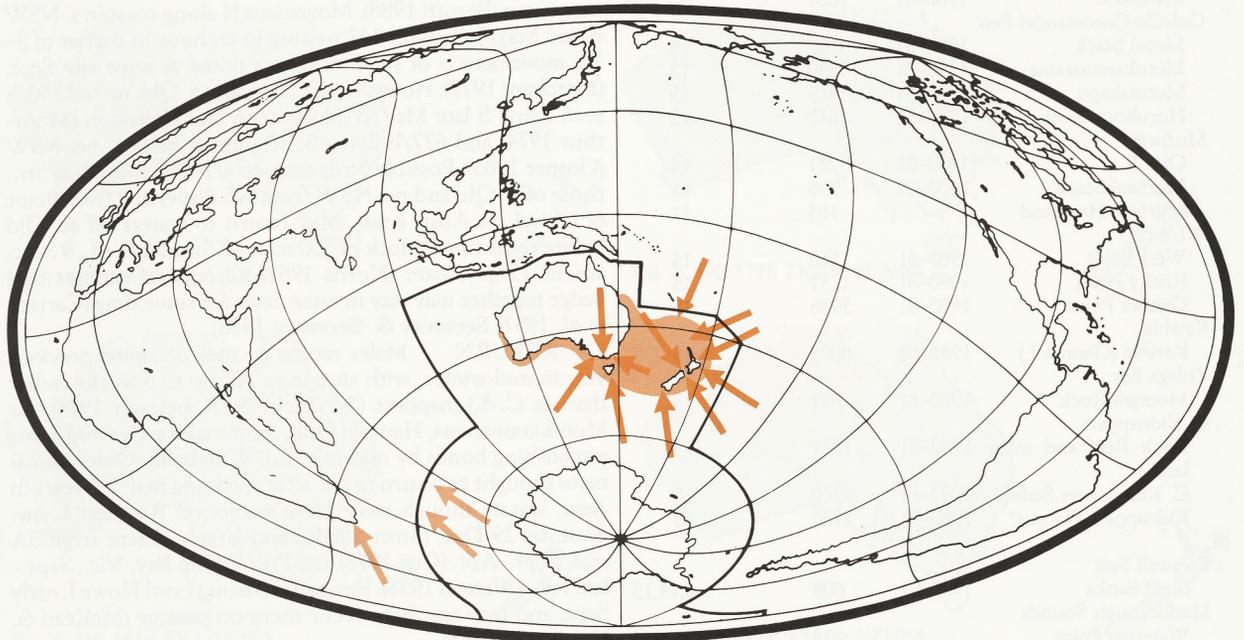
Records of single bird at Malgas I., SW. Cape, S. Africa (Berutti 1988); Marion I. (Brown & Oatley 1982).

BREEDING Colonies listed in Table 1; mostly on offshore islands but three on mainland of NZ, at Muriwai, C. Kidnappers and Farewell Spit and two on man-made structures in Port Phillip Bay. In NZ, mostly N of 40°S (Wodzicki *et al.* 1984).

Formerly bred Matapia Islet and C. Karikari Stacks (Three Kings Is), Bird Rock (Poor Knights Is), Groper Rock (Cathedral Rocks) Sail Rock (Mokohinau Is), Arid I. Stack (Mahuki I.), The Sisters and Never Fail Rock (Motukaramarama), Sugarloaf Rocks (Horuhoru), Club Rock (White I.), Portland I. and Plateau Beach (C. Kidnappers) (Wodzicki *et al.* 1984).

Total population in 1980–81 estimated 52 664 pairs, 6660 in Aust., 46 004 in NZ (Wodzicki *et al.* 1984). Mean annual rate of increase between 1946–47 and 1980–81, 2.3% (Wodzicki *et al.* 1984).

Status, probably stable; decreases in Aust. (Cat I.), may be balanced by increases (Lawrence Rocks). With total population c. 53 000 pairs, rarest sulid except Abbott's Booby *Sula abbotti*. Disturbance by human activity causes predation of eggs by Kelp Gulls *Larus dominicanus* in NZ (Robertson 1960); fishermen take birds for bait (Warham & Serventy



1978; E.J. Wingham). Gannetries are susceptible to oil spills; oiled birds transfer oil to eggs, which do not hatch and, after staying at gannetry for longer than normal, oiled birds left and did not return (E.J. Wingham). Formerly, Maoris harvested young (E.J. Wingham).

Table 1. Breeding localities of Australasian Gannet.

LOCATION	YEAR(S)	POPULATION (pairs)	REF
AUST.			
Vic.			
Port Phillip Bay		28-40	2,5,14
Wedge Light		32	14
Popes Eye		40	7, 8
Lawrence Rocks	1952, 1986-7	2463	14
Tas.			
Cat I.	1908	5000-10,000 birds	1
	1983-4	6	9,12,13
Black Pyramid	1961	900 birds	4
Pedra Branca	1978	500-1000	3
Eddystone Rock	1978	46 birds	3
NORFOLK I.			
Phillip I.	1981	4	10
Nepean I.	1978	6	10
NZ			
NI			
Three Kings Is			
Hinemoa Rock I.	1980-81	4136	15
Hole-in-the-wall	1980-81	1530	15
Tutanekai Rock	1980-81	402	15
Arbutus Rock	1980-81	2652	15
South West I.	1980-81	1135	15
Poor Knights Is			
High Peak Rocks	1980-81	1553	15
Sugarloaf Rock	1980-81	2617	15
Cathedral Rocks			
Mokohinau I.	1980-81	344	15
Great Barrier Is			
Mahuki I.	1980-81	2681	15
Colville-Coromandel Pen.			
Motui Stack	1980-81	96	15
Motukaramarama	1980-81	3530	15
Motutakapu	1980-81	925	15
Horuhoru Rock	1980-81	2647	15
Muriwai			
Oaia I.	1980-81	761	15
Muriwai Stack	1980-81	298	15
Muriwai Headland		165	11
White I.			
West Point	1980-81	1550	15
Rocky Point	1980-81	1257	15
Gannet Point	1980-81	3986	15
Kawhia			
Karewa (Gannet I.)	1980-81	8003	15
Tolaga Bay			
Moutara Rock	1980-81	611	15
C. Kidnappers			
Black Reef and main-land	1980-81	1821	15
C. Kidnappers Saddle	1980-81	2200	15
Kidnappers Plateau	1980-81	1165	15
SI			
Farewell Spit			
Shell banks	1980-81	608	6,14,15
Marlborough Sounds			
Waimaru Point		38	14

Otago			
The Nuggets	1980-81	9	15
Foveaux Str.			
Little Solander I.	1980-81	62	15

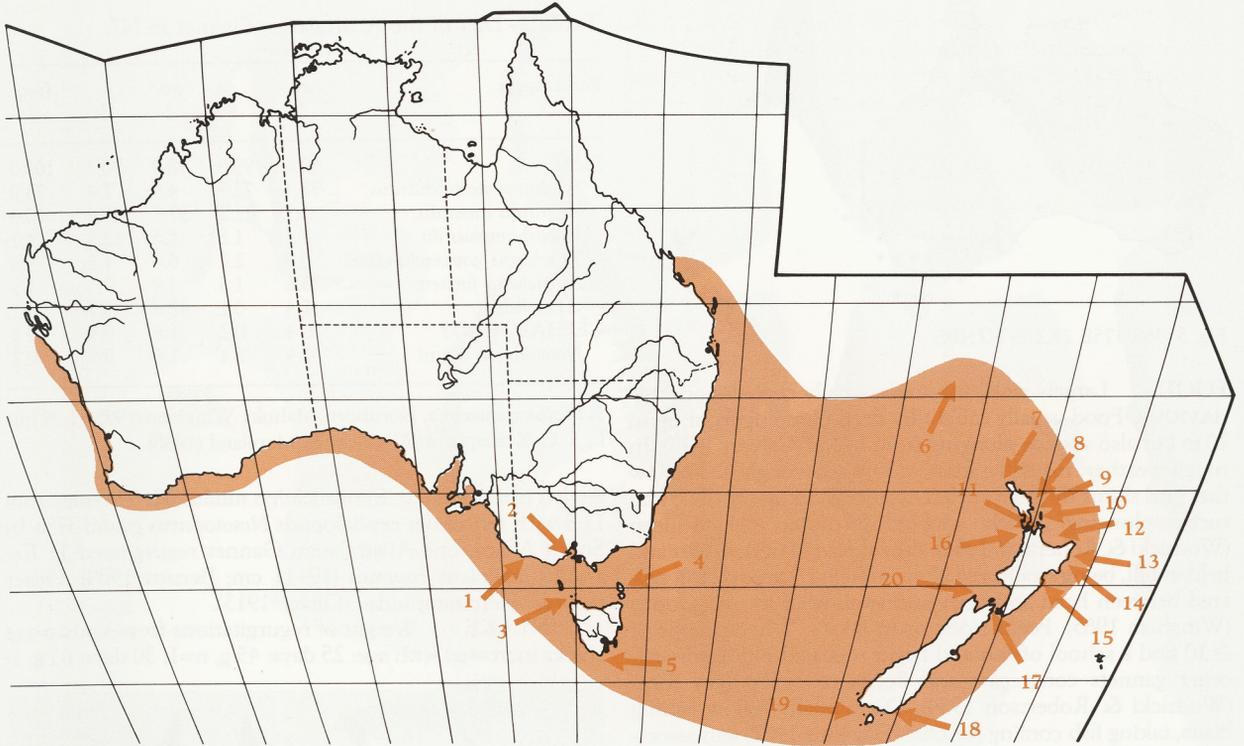
References: 1. Atkins (1909); 2. Aust. NRS; 3. Brothers (1979); 4. Green & McDonald (1963); 5. Harris & Norman (1981); 6. Hawkins (1988); 7. McKean (1966); 8. Pescott (1980); 9. I. Skira; 10. Tarburton (1981); 11. M. Taylor; 12. Warham (1979); 13. Warham & Serventy (1978); 14. E.J. Wingham; 15. Wodzicki *et al.* (1984).

MOVEMENTS Migratory/dispersive, adults leaving breeding sites for 3-4 months annually, though movements non-directional, immatures travelling 1000s km N or W during the 3-4 year pre-breeding period.

DEPARTURE Adults leave colonies round NZ after fledging of juveniles, some individuals staying as late as mid-Apr. (Wodzicki & Robertson 1953) though most leave earlier (Wingham 1985). Chicks fledge: Norfolk I., 22 Jan.-11 Mar. (Hermes *et al.* 1986); Cat I., 8-21 Mar. where adults left 8-12 days after their young (Warham 1958). Adults appear to disperse round coast near breeding sites (Wingham 1985), a few birds using gannetries for roosting, rarely going beyond continental shelf (Norris 1965).

NON-BREEDING Presence away from gannetries peaks during winter (Sibson 1981). Some juveniles move long distances within a few weeks of fledging (Wodzicki & Robertson 1953; minimum time, NZ to Aust., 8 days; Carrick *et al.* 1957), largely to N and W, most travelling round the N of NZ, smaller numbers passing through Cook Str. (Wodzicki & Robertson 1953) and a few possibly travelling overland where they have been observed flying at an altitude of >2500 m (Stein 1960a). Not all juveniles migrate, some being recorded in NZ waters during their first winter (Stein 1960b). Movement W reaches Rottneest I., sw. Aust. by 21 June (Storr 1964b) and sometimes extends to Marion I. (Brown & Oatley 1982), Iles Crozet (Stahl *et al.* 1984) and South Africa (Cassidy 1983; Berutti 1988), where interbreeding with Cape Gannets may occur (Berutti 1988). Movement N along coast in s. NSW noted May-June with 142 passing in an hour in parties of 3-12, movement S of small numbers noted at same site Sept. (Marchant 1977). However, at Caloundra s. Qld, up to 1250/h seen flying S late May to mid-June in late afternoon (McArthur 1974) and 627/h flying S, 28 June at Ballina, ne. NSW (Gosper 1983). Possibly birds seen off s. NSW from Bass Str., those off s. Qld and ne. NSW from NZ dispersing from point of arrival on Aust. coast. May return to waters off se. Qld before returning E; flock of 500 seen off Stradbroke I., 9 Sept. absent 11 days later (Norris 1967). Groups of gannets that fledge together may stay in same flock for some time (Carrick *et al.* 1957; Serventy & Serventy 1958).

RETURN Males return to sites occupied previous year in mid-winter, with sites in n. NZ up to 5 weeks earlier than at C. Kidnappers (Wodzicki & Robertson 1974). At Motukaramarama, Hauraki Gulf, most males arrive mid-June, establishing bonds by mid-July (E.J. Wingham). Older immatures thought to return to NZ after spending first 3-4 years in Aust. waters though most leave waters off Rottneest I., sw. Aust. by 29 Dec. (Storr 1964b) and largely absent from SA seas, Sept.-Apr. (Cox 1978) and Port Phillip Bay, Vic., Sept.-late Feb. (Watson 1955). Recorded passing Lord Howe I. early Sept. and may regularly occur there on passage (McKean & Hindwood 1965).



(1) Lawrence Rocks; (2) Wedge Light, Popes' Eye; (3) Black Pyramid; (4) Cat I.; (5) Pedra Branca, Eddystone Rock; (6) Phillip I., Nepean I.; (7) Three Kings Is; (8) Poor Knights Is; (9) Mokohinau I.; (10) Great Barrier Is; (11) Motui Stack, Motukaramarama, Motutakapu, Horuhoru Rock; (12) White I.; (13) Tolaga Bay; (14) Muriwai; (15) C. Kidnappers; (16) Karewa (Gannet I.); (17) Waimaru Point; (18) The Nuggets; (19) Little Solander I.; (20) Farewell Spit.

BREEDING Feeding range from NZ colonies 268 km (86–450) combining estimates from banding recoveries of breeding birds (range 8–682) and time adults spent away from nest (Wingham 1985) with most feeding within a range of 61 km (Wingham 1989).

BANDING Returns from Black Pyramid, Tas. summarized Fig. 1.; Lawrence Rocks, Vic., Fig. 2. (both ABBBS); C. Kidnappers, NZ, Fig. 3.; White I., NZ, Fig.4.; Hauraki Gulf, Fig. 5 (all NZNBS). Returns (14) from six other sites in NZ showed a similar pattern.

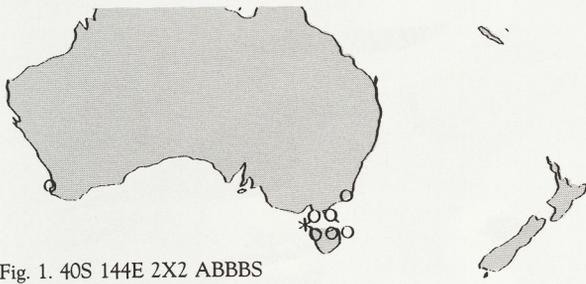


Fig. 1. 40S 144E 2X2 ABBBS

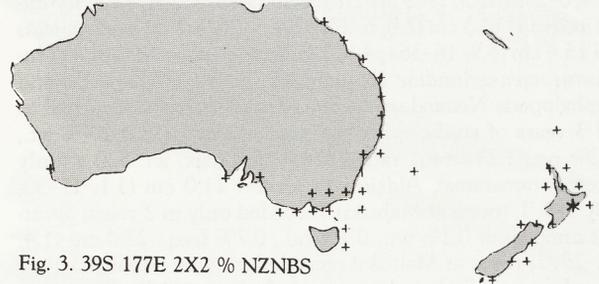


Fig. 3. 39S 177E 2X2 % NZNBS

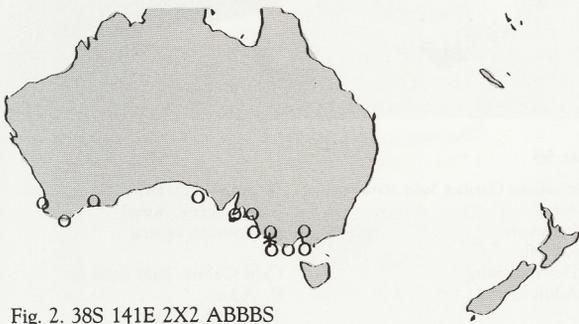


Fig. 2. 38S 141E 2X2 ABBBS

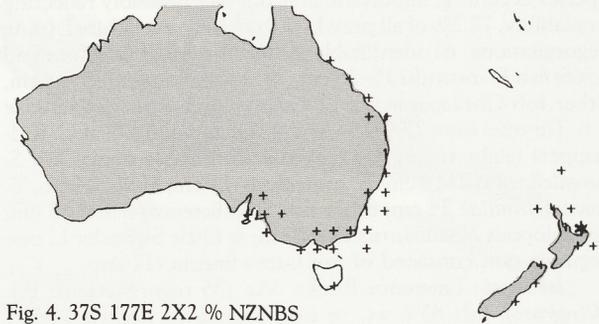


Fig. 4. 37S 177E 2X2 % NZNBS

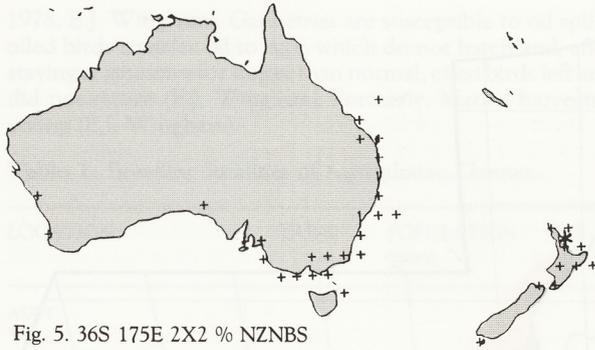


Fig. 5. 36S 175E 2X2 % NZNBS

FOOD Largely small fish, occasionally cephalopods. **BEHAVIOUR.** Food usually caught by deep-plunging from up to 20 m but also surface-plunging from 1–2 m (Calvert 1972). In rough weather, may dive from <3 m, at an angle so shallow that bird skims through surface waters (Wilkinson 1927) and surface-plunging usually adopted in water <3 m deep (Wodzicki & Robertson 1954). Prey captured underwater and held in bill, being swallowed after surfacing. Large garfish severed between head and body and swallowed in two actions (Wingham 1985). Feeds alone or in flocks. When groups of ≥ 10 find a school of fish and begin repeated plunge-diving, other gannets congregate and flocks of >500 may form (Wodzicki & Robertson 1954). Occasionally follow fishing boats, taking fish coming for offal (Hawkins 1982) and associated with schools of predatory fish (Le Souëf 1926). Diurnal but with no daily pattern of feeding activity. Do not feed in high winds.

NON-BREEDING Diet away from breeding colonies almost unknown but assumed to be similar to that of chicks. One bird collected Golden Bay, NZ, contained only *Sardinops neopilchardus* (Wodzicki & Moreland 1966) and seen catching but losing 45–60 cm eel (Basley 1951).

BREEDING Data for NZ, summarized Table 2: at Motukaramarama (443 regurgitations), Horuhoru (19), Mahuki (26) (Wingham 1985) *Sardinops neopilchardus* 15.5 cm (3.4; 6–25; 1820), 1–18 fish/regurgitation, median 4.6, *Engraulis australis* 10.3 cm (2.6; 6–20; 579), 1–38, 8.7, *Hyporhamphus ihi* 25.4 cm (4.9; 16–36+; 44), 1–5, 1.6, (none at Mahuki), *Trachurus novaezelandiae* 18.9 cm (4.7; 11–30; 66), 1–5, 1.0 and cephalopods *Nototodarus sloani* (not at Mahuki) recorded in all 3 years of study, other fish incl. *Arripis trutta* 3.4% wt., 0.2% no., 1.2% freq., range 32–34 cm, max. wt. 520 g (only Motukaramarama), *Aldrichetta forsteri* 21.0 cm (3.1; 11–30; 30), 1–4, 1, (none at Mahuki), recorded only in 2 years; *Spratrus antipodum* 0.2% wt., 0.1% no., 0.2% freq., 22.0 cm (1.4; 22–23; 2; none at Mahuki) recorded only in 1 year. Early in breeding season diet almost entirely *S. neopilchardus*, other species becoming important later on; diet probably reflecting availability; 77.2% of all prey 11–20 cm long. At White I. (nine regurgitations, 61 identifiable items; Wodzicki & Moreland 1966) fish *E. australis* 15–28 cm, *T. novaezelandiae* 15–28 cm, other fish *Cheilopogon/Hirundichthys* 11.5% no., Serranidae 1.6, *Thryssites atun* 27.9 (15–20 cm), *Sphaeroides* 1.6; at C. Kidnappers (eight regurgitations, 81+ identifiable items) fish *S. neopilchardus* 2–15 cm, *E. australis* 6–11 cm, *H. ihi* 24 cm, *T. novaezelandiae* 24 cm, other fish *Scomberesox forsteri* 12 cm, cephalopods *Nototodarus* 15–30 cm; at Little Solander I., one regurgitation consisted of five *Latris lineata* (12 cm).

In Aust.: Lawrence Rocks, Vic. (35 regurgitations; E.J. Wingham), fish 63% wt. or no.: *Trachurus declivis* 11.5%,

Table 2. Diet of the Australasian Gannet in NZ.

Percentages	wt.		no.		freq.
	1	1	2	3	1
FISH	99.6	99.8	98.4	90.1	100.0
<i>Sardinops neopilchardus</i>	78.4	72.5	4.9	7.4	75.0
<i>Engraulis australis</i>	5.7	21.2	37.7	65.4	10.8
<i>Hyporhamphus ihi</i>	2.4	1.8	1.6	12.3	4.7
<i>Trachurus novaezelandiae</i>	6.9	2.7	6.6	1.3	9.6
<i>Aldrichetta forsteri</i>	3.8	1.3	4.9		3.3
other fish	7.4	0.1	42.6	3.7	0.2
CEPHALOPODS	0.4	0.2	1.6	9.9	0.2
<i>Nototodarus sloani</i>	0.4	0.1	1.6	9.9	0.2

1. Motukaramarama, Horuhoru, Mahuki, Wingham (1985); 2. White I.; 3. C. Kidnappers, Wodzicki & Moreland (1966).

Arripis truttaceus 3.0, *Emmelichthys nitidus* 37, *Thryssites atun* 11.5 with remainder cephalopods *Nototodarus gouldi* 37%. In South Africa, one Australasian Gannet regurgitated 11 *Engraulis japonicus capensis* (10–11 cm; Berutti 1988). Other records: Hemiramphidae (Oliver 1913).

INTAKE Weight of regurgitations from known-age chicks increased with age: 25 days: 45 g, n=1; 30 days: 63 g, 1;

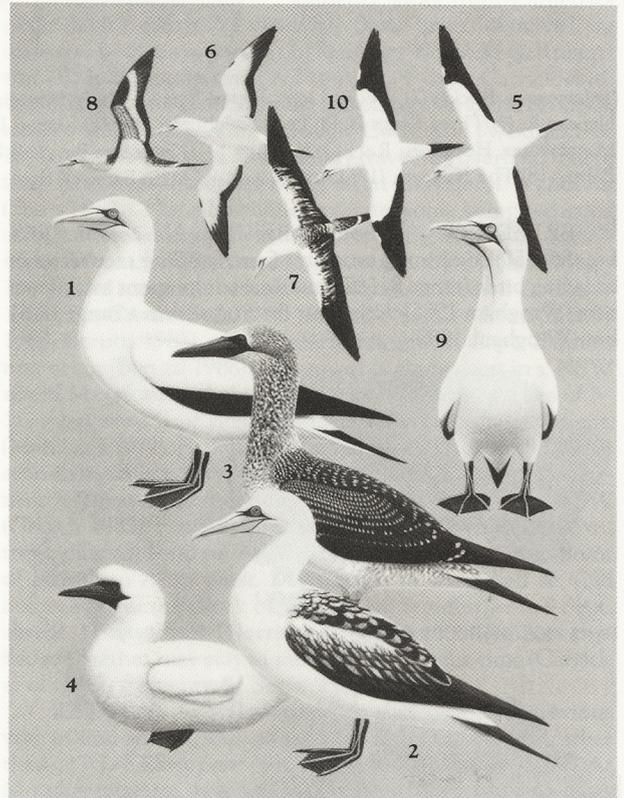


Plate 55

Australasian Gannet *Sula serrator*

1. Adult
2. Immature
3. Juvenile
4. Downy young
5. Adult, dorsal

6. Adult, ventral

7. Immature, dorsal

8. Juvenile, ventral

Cape Gannet *Sula capensis*

9. Adult

10. Adult, dorsal

35–50 days: 226.0 g (60.7; 120–298; 7); 60–90 days: 291.6 g (168.1; 57–495; 9). Regurgitations from adults 259.3 (39–729) with monthly averages varying from 140 g (62.1; 5; Nov. 1978) to 399 g (153.2; 5; Oct. 1978) (Wingham 1985). Probably needs to feed twice per foraging trip to obtain the 470 g/day to satisfy energy requirements when feeding young (Wingham 1989).

SOCIAL ORGANIZATION Loosely gregarious when feeding, concentrating at breeding colonies; solitary at other times. Individuals, by plunge-diving (see Food), soon attract others and thus feeding flocks form. Sexual or age composition of flocks, unknown.

BONDS Generally monogamous, but promiscuity may occur. Pair-bonds usually life-long (Stein 1971) but divorce may occur; most birds probably forced to remate at least once in life by death of partner (Nelson 1978). Males seen to copulate with partners other than their own (3/114 observations). However, males holding nest without mate often copulate with females from neighbouring nests; once female went to bachelor male's nest site and once the reverse occurred (Waghorn 1982). Young birds return to natal breeding grounds at 3 years of age as roosting or unemployed birds; begin to breed at 4–5 years, but only about one half of birds breeding at 6–7 years of age (Wodzicki & Stein 1958). Pair-bond weakened once chick has fledged; re-established

following season when female returns to same nest-site to join waiting male. In Hauraki Gulf, males arrive mid-June to early July. Both parents incubate and tend young until fledging.

BREEDING DISPERSION Colonial. Average inter-nest distances at C. Kidnappers and Motukaramarama were 0.79 m (0.70–0.87) and 0.86 m (0.70–1.17; 246) respectively, or densities of 1.87/m² (Wodzicki & McMeekan 1947; Wingham 1984a). Highly territorial, essentially in nest-site territory, consisting of area where pair-bond is re-established, mating occurs, nest-mound built and where incubation and rearing occur. Occasionally both partners together on nest, which suggests that it is also loafing place when not guarding chick during nestling period. Home-range large compared with size of territory: average feeding range of 268 km (86–450; 493 trips) estimated from time adults away from gannetry, resighting of marked birds and from recoveries of banded, breeding adults (Wingham 1985).

ROOSTING At nest-sites early in breeding season; small numbers present after breeding season and some gannetries used as roosts throughout year (E.J. Wingham). Presumably on sea at other times. At breeding colony on Wedge Light, Vic., birds present throughout year, roosting during non-breeding periods. Clubs of non-breeding birds form near colonies, numbers increasing through season; probably includes non- and failed-breeders.

SOCIAL BEHAVIOUR Based on Wodzicki & McMeekan (1947), Warham (1958) and observations of 13 pairs of marked birds of known sex for 1 or 2 days/fortnight at Motukaramarama, made from hide c. 1 m from nearest nest (Waghorn 1982). Social behaviour reviewed by Nelson (1978). Ritualized displays during breeding obvious; essential for maintaining ownership of site and producing and rearing chick (Wodzicki & Robertson 1974). In gannetry, aggressive individuals live within striking distance of one another, therefore ritualized displays essential to control conflicts. All displays are similar to those of Northern and Cape Gannets (Nelson 1978).

AGONISTIC BEHAVIOUR Birds defend site except on edge of gannetry. **THREAT DISPLAYS.** Aggression involves **Lunging** (of Warham 1958) at another bird (adult or chick) with bill shut (A1), **Lunging and striking** at another bird with bill open (A2; Fig. 6), and sustained **FIGHTS**, usually with bills locked (A3; Fig. 7), occasionally resulting in death. The most intense fighting occurs in July when sites are being

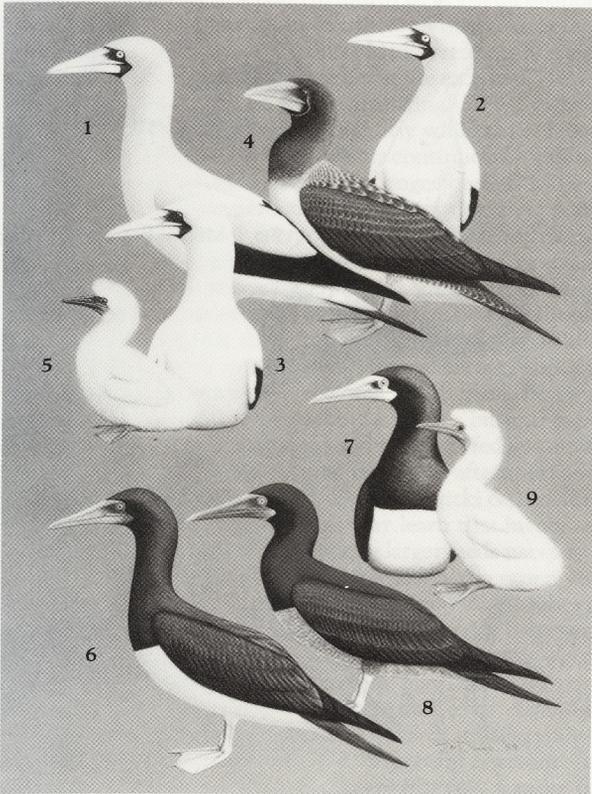


Plate 56
Masked Booby *Sula dactylatra*
1. Adult male
2. Adult female
3. Adult female, subspecies *fullagari*
4. Juvenile
5. Downy young

Brown Booby *Sula leucogaster*
6. Adult male
7. Adult female
8. Juvenile
9. Downy young

Fig. 6 High-intensity Threat

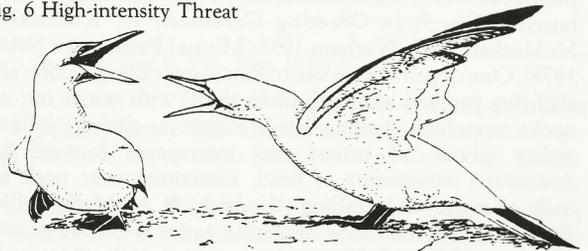


Fig. 7 Fighting



re-established. By Nov., Lunging and striking (A2) and Fighting (A3) increase and lunging (A1) decreases, presumably because chicks wander through colony and because non-breeders become more aggressive. Males were more aggressive than females throughout breeding season (av. aggressions/h: 0.83 v 0.56). Least experienced breeders, most aggressive and, in seven of nine pairs, male aggressive more often than female. Threat Displays include Nest-biting, Solo-bowing and Mutual-bowing (see Sexual Behaviour). **Nest-biting** occurs usually after intruder repelled, probably as re-directed aggression: with wings held out, owner dips head and grips nest or ground while calling loudly. **Solo-bowing** (= **Solo-dance** of Wodzicki & McMeekan 1947; **Curtsey** of Warham 1958; **Bowing** of Nelson 1978; Fig. 8) indicates ownership and acts as threat to repel intruders: standing bird raises from one flank and twists head till bill held high, at about 45°; head then dipped down to side or ground but without biting; wings held out with loud calling and sideways shaking of head between dips, followed by a pelican-like posture (Appeasement Display) in which bill-tip is pressed in against chest (Wodzicki & McMeekan 1947; Warham 1958); movement repeated 3–4 times (Warham 1958); display lasts about 5–7 s; repeated at 3–5 min intervals and infectious in colony (Wodzicki & McMeekan 1947). All birds use Solo-bowing much when re-establishing sites and pair-bonds; bachelor males most (av. 6/h), then males with mates (5/h) and females (3/h); in eight of nine pairs, male used Solo-bowing more than female. At Cat I., most frequent display (Warham 1958). **APPEASEMENT DISPLAYS.** Bird remains still, head slightly bowed and bill tucked into breast; used by adults and chicks. Inhibits attack and continuation of attacks. May also be adopted by birds landing at colony (Warham 1958).

SEXUAL BEHAVIOUR There is no definite evidence that Australian Gannets perform **Flight-circuiting** as observed in other gannets (Nelson 1978). Nelson (1978) also states that males **ADVERTISE** using same displays as Northern Gannet: **Headshake** and **Reach**, where male at site shakes head from side-to-side and stretches bill slightly towards female, though this display is not described in other studies. **COURTSHIP.** **Presentation Ceremony:** as part of courtship, birds collect and present nesting material to partner; often seaweed may be collected at sea or feathers and plant material may be collected from fringes of colony; if flying in from sea bird alights at nest; alternatively may adopt Sky-pointing display at fringe of colony before bounding to nest (Wodzicki & McMeekan 1947; Warham 1958). Often precedes **Mutual-bowing** (Fig. 9) (= **Greeting Ceremony** of Wodzicki & McMeekan 1947; Warham 1958; **Mutual Fencing** of Nelson 1978). One of pair flies to site to join mate, calling loudly; after alighting partners stand chest-to-chest, with wings out and necks stretched, shaking heads sideways, clicking bills together (about 12 times) and intersperse forward and downward movements of head, sometimes over neck and back of mate, while calling (Wodzicki & McMeekan 1947; Warham 1958). Duration of display varies: a minute or more (Warham 1958); 15–20 min interspersed with allopreening (Robertson in Nelson 1978) or 10–12 s and may be repeated (Wodzicki & McMeekan 1947). Starts early in breeding season when male returns to site after repetitive flights and presents female with seaweed; thought to be important in establishment of site and first seen soon after one of pair arrived at gannetry. Mutual-bowing decreases during breeding season; few recorded when chicks large and when attendance at nest not always ending at change-over. Almost always

followed by allopreening (Warham 1958). **Sky-pointing** (Fig. 10) (= **Flying Up Ceremony** of Warham 1958). During display, birds turn round, accompanied by exaggerated walk in which bird slowly lifts feet with webs drooping; head and neck stretched vertically up with wings raised at shoulder joint so that tips are raised and tail depressed; eyes focused binocularly forwards and downwards and head slowly moved up and down; posture may be maintained until bird runs, jumps or launches into flight, calling as it does so. At Cat I., birds alight 1–2 m away (Warham 1958); at other colonies, to fringe of nesting area or occasionally directly into flight. Occurs only when one of pair intends to leave nest; probably synchronizes nest-relief; when partners Sky-point simultaneously, one never leaves until other has stopped, thus exposure of egg or small chick avoided (Nelson 1978). **Nape-biting:** males bite females on back of neck; used infrequently when male joins female at nest (<10% occasions [Robertson in Nelson 1978]); most frequently observed in pairs that have not laid or have lost egg (Warham in Nelson 1978). Used also before copu-

Fig. 8 Solo-bowing

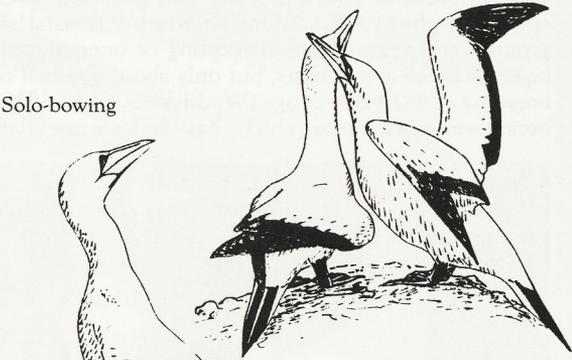


Fig. 9 Mutual Bowing, Greeting

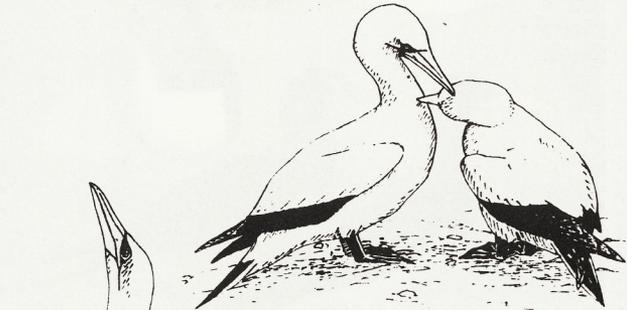


Fig. 11 Kiss-preen



Fig. 10 Sky-pointing

lation (Warham 1958). **ALLOPREENING.** Reciprocal and simultaneous allopreening (Fig. 11) (Kiss Preen of Warham 1958) of head and neck usually follows Mutual-bow; mainly preen throat, continuing for few seconds to a minute before birds begin to preen themselves and display ends. Sometimes leads to pre-copulatory displays. **COPULATION** preceded by allopreening, violent Head-shaking by female and Nape-biting by male; female sits and male, still biting female's neck, climbs onto her back, wing-waving and treading at gathering speed, before cloacal contact, which is made once only; followed by final immobile stage before male lets go of female's neck; female then preens male before male slides off and preens female; birds silent during copulation (Warham 1958) or male may *cackle* (Wodzicki & McMeekan 1947). Copulations increase as laying approaches, and may occur on day of laying.

RELATIONS WITHIN FAMILY GROUP Material brought to nest perhaps by both sexes (E.J. Wingham). Bird on nest usually arranged material but bird bringing material often reluctant to part with it and both birds may try to arrange the material (Warham 1958). Females attended at nests longer than males, except in last 2 weeks of incubation and when chick 4–6 weeks old. Lengths of shifts uncertain when chick 6–8 weeks old because insufficient observations of change-overs. Maximum difference in attendance by males and females occurred in second to fourth weeks of incubation (difference 8.5 h); minimum in fourth to sixth weeks before laying and when chick 12–14 weeks old (difference, 1 h). Pairs spent greatest amount of time together at site each day (11.3%) before eggs were laid; least while incubating (3.7%); slightly more time (5.7%) spent together each day while chick being reared. Chicks guarded by both parents continuously for first 48 days; unattended for increasingly longer periods as nestling-period progresses; parents absent during day, most nests had adult present towards evening (Warham 1958). Both sexes feed chick by regurgitation. Parents do not discriminate between own young and another; accept additional chick in twinning experiments even when the two chicks differ in age. Chicks actively beg for food from c. 10 days of age. While begging, chicks move continuously with sideways, rocking motion and try to keep bill-to-bill contact with adult. Begging usually persistent with chick pecking at adult's bill and nape while making a repetitive yipping sound. Chicks fed less often as age increases and more begging occurs in afternoon and evening than in morning (Nelson 1978; Wodzicki & McMeekan 1947; Waghorn 1982). Chicks may learn that incoming adults may be stimulated to regurgitate larger feeds necessary for older chicks (Montevicchi & Porter 1980). Average number feeds/day for chicks of all ages 1.9 (n=496) (Waghorn 1982); on average, a chick received 2.8 fish per day from two feeds (Warham 1958). Parents often preen chick and, when chick is older, it also preens adult; chick may also attack parents. Chick does not stray from nest until c. 65 days old. Neighbouring adults highly aggressive towards straying young (Wodzicki & McMeekan 1947; E.J. Wingham) cf erroneous statement in Nelson (1978) that young birds may wander to other nests and adults show no hostility to visitor. Fledgelings (100+ days old) leave gannetry by launching themselves into flight from exposed areas near cliffs at edges of colonies; some fly strongly away, others land on sea and paddle away.

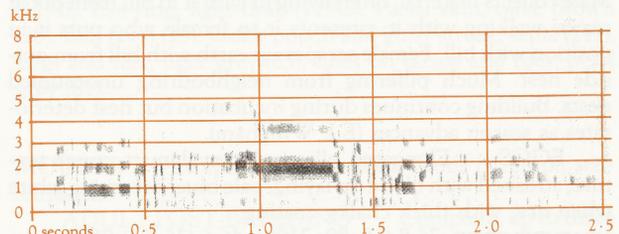
VOICE Limited observations in Wodzicki & McMeekan (1947), Warham (1958), Nelson (1978), Waghorn (1982) and E.J. Wingham. Generally quiet at sea; very noisy at breeding

colonies during day and occasionally at night. Narrow range of calls, main call described as *urrah-urrah* (Warham 1958; E.J. Wingham; A. Berruti), which probably equals Shout of Nelson (1978). Similar to calls of Cape Gannet but noticeably higher-pitched (Berutti 1988); also to Northern Gannet (Warham 1958). Calling at colonies restricted to breeding periods: about July to Feb. Distinct sexual differences: call of males higher pitched than females (Nelson 1978). Also exhibit distinct individual differences, allowing individual recognition between mates and between chicks and parents (Warham 1958; Nelson 1978). **NON-VOCAL SOUNDS:** **Bill-clicking** as bills clash during Mutual-bow; during take-off, birds utter a repeated *herk-herk-herk*, which is probably involuntary and caused by effort of take-off (Warham 1958). No geographical variation reported.

ADULT MALE **Shout:** described as jangling *urrah-urrah* (Warham 1958). Used in flight over colony and in flight when returning to nest, during Solo-Bow, Mutual-bow, usually during Fighting and as Threat/Alarm Call and when parent alights to feed chick (Wodzicki & McMeekan 1947; Warham 1958). Warham (1958) observed that calls vary with circumstances, e.g. repeated more rapidly in flight when returning to colony; also noticeable individual differences (Warham 1958). **Sky-pointing Call:** described as wheezy or snoring two syllable *yorr*; a wheezy note as bird leaps from ground then loud inhalation as it alights (Nelson 1978). **Other Calls.** In flight, birds utter staccato snorts and quacks (Warham 1958). Reported that male utters *cackle* during Copulation (Wodzicki & McMeekan 1947). **Bill-clicking**, created when bills clash during Mutual-Bowing; during display bills clash about 12 times; audible to 3–4 m (Wodzicki & McMeekan 1947).

ADULT FEMALE **Shout:** as for male but lower pitched; used in same circumstances. **Other Calls:** other than Bill-clicking, no direct reports but possibly as for male but with differences in pitch.

Sonagram A shows call of adult attending young at nest.



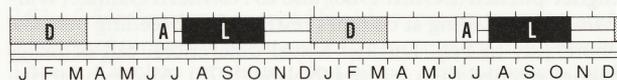
A A. Tubbs, Cat I., Tas., Dec. 1975; P26

YOUNG Young chicks, 10 days old and older, beg with *yips* or *cheeps*; older chicks beg by giving repeated *ugh-ugh* at rate of about three calls/s. **Alarm Call:** loud *quack*.

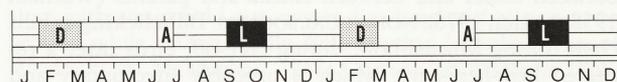
BREEDING Well known. Long-term studies in NZ by Wingham (1984a,b) at Motukaramarama in Hauraki Gulf; by Stein (1971) at Horuhoru; by Wodzicki & McMeekan (1947) and Wodzicki & Robertson (1953) at C. Kidnappers. See also detailed account by Nelson (1978). Information supplied by E.J. Wingham. Colonial nester in small (2–6) to huge (8000) congregations, usually on steep islands near mainland; not associated with other species.

SEASON Broadly from July to Feb.; varies geographically. At Motukaramarama, birds arrive in mid-June; laying starts 20 July–7 Aug., ends 10 Oct.–2 Nov.; chicks

fledge from late Dec. onwards. At C. Kidnappers, return to colony in late July; laying from early-Sept. to end Oct.; chicks fledge from early Feb. onwards. At Motukaramarama, time between first and median egg was c. 3 weeks.



a) Motukaramarama



b) Cape Kidnappers

SITE Colonies usually on small, rocky islands and stacks, often hard to reach, but previous colonies in more accessible places and on larger islands could have been abandoned or destroyed before recording; also on mainland in three places. Generally choose flat ground or gentle slopes on saddles, plateaux, cliff-tops, stacks; where ledges on steeper slopes used (e.g. Poor Knights Is), they are usually broad and flat, not steep, precipitous or vertical cliffs. Often choose higher parts of islands, usually well out of reach of high seas, from 15 to 90 m asl. Nest-sites in compact, well-defined groups on bare ground or rocks or among low vegetation (*Coprosoma*, *Mesembryanthemum*, *Bulbine*, grasses); trampling by birds and deposition of guano may kill vegetation and so extend nesting habitat. Nest on navigation beacon, and on jetty-breakwater in Port Phillip Bay, Vic.; also breed in semi-captivity at Napier Marineland, NZ (Wodzicki *et al.* 1984).

NEST, MATERIALS Compact mound 10–20 cm high with well defined shallow cup c. 30 cm from top of mound to base of cup; made of seaweed and plant material (up to several hundred items) and earth from round nest but mostly built up from guano (Moore & Wodzicki 1950), incorporating feathers, plastic rubbish, etc; lined with seaweed. Male collects material, often flying in with it in bill from out at sea or walking with it; presents it to female who puts it in position with bill. Female scrapes up earth with bill from outside nest. Much pilfering from neighbouring unoccupied nests. Building continues during incubation but nest deteriorates as season advances (E.J. Wingham).

EGGS Elongated, elliptical to oval; matt, rough texture; streaked with blood on laying; pale blue, becoming white when dry; with thick chalky coating.

MEASUREMENTS: 76.8 (65–89; 710) x 46.6 (35–53) (Wingham 1984a);

WEIGHT: 99.8 (84–125; 135) (Wingham 1984a).

CLUTCH-SIZE One. At C. Kidnappers, two eggs in nests at rate of 0.75% (Wodzicki & McMeekan 1947). Single brooded but losses of eggs and chicks up to 8 days old often replaced. During three seasons at Motukaramarama, 49.6% of losses replaced. At Horuhoru, Stein (1971) reported a second relaying once. Shortest interval for replacement 8 days (first egg lost after 21 days incubation); longest, 34 days (after chick lost aged 5 days).

LAYING Poorly synchronized; spread of laying at Motukaramarama about 13 weeks; at C. Kidnappers, about 15 weeks (Nelson 1978). At Motukaramarama, median dates of laying were 10 Aug., 28 Aug., 13 Sept. or up to 34 days earlier than usual in previous years. Interval from first to median egg usually 21 days. Time of day of laying not recorded.

INCUBATION Both sexes incubate, female taking greater share (Waghorn 1982). Nest-relief at any time of day. First and replacement eggs incubated for 44 and 43.3 days respectively; range for all replacements 35–50 days (n=21). Infertile eggs incubated for 88.1 days (51–154; 33) or 7–110 days beyond normal term. Incubation under webs of feet; no brood patch. Ill-adapted to retrieve eggs displaced from nest. No disposal of eggshells beyond lifting fragments over rim of nest. **INCUBATION PERIOD:** for marked eggs: 44.1 days (37–50; 141; Wingham 1984a).

NESTLING Altricial, nidicolous. Hatched with sparse neossoptiles on black skin; eyes closed till 2–3 days old. By 2 weeks covered in white down, 1 cm long, which lengthens considerably by 3 weeks; by a month old, large, white and fluffy. Primaries (40 mm long) and rectrices visible at about 43–47 days, grow rapidly till chick half feathered at 9 weeks. Down persists on flanks, belly, head and neck; not completely lost till about 13 weeks (80–94 days) (Wingham 1984b). Brooded by both parents on top of webs of feet. Completely covered for 2 weeks; becomes visible under parent by 3 weeks; too big to be covered at 1 month old; at 6 weeks looks bigger than adults and often moves from nest (Nelson 1978). At first, spells of brooding lasted for 12 h 43 min on average (9 h 12 min to 18 h 20 min); later averaged 5 h 4 min (Warham 1958). Tendency to desert young increases in last 2–3 weeks before fledging, yet most nests had adult in attendance towards evening (Warham 1958; E.J. Wingham). Fed by both parents by incomplete regurgitation, chick putting its head into parent's bill. At first, feeds frequent and small, decreasing in number; over whole nestling period average 1.89 feeds/day (Wingham 1985). **NESTLING PERIOD:** 102 days (95–109; 12) (Warham 1958); C.J.R. Robertson (Nelson 1978) gave 105–111 days; Stein (1971) at Horuhoru gave commonest period as 107–109 days; all these determinations were taken to time of departure flight. At Motukaramarama: 108 days (95–119; 114), fledging being taken as date when chick left nest; it may spend 6 h to 3 days on cliff-top before flying (E.J. Wingham). Usually fly away from colony strongly and are independent on fledging.

GROWTH Weight at hatching averaged 73.15 g (n=86; Wingham 1984b); 60–70 (Nelson 1978). Grow most rapidly between 20 and 50 days with average increase of about 1685 g; at c. 50 days, weigh more than adult (2350 g; n=50) and reach maximum (3132 g or 132% of average adult weight; n=501) at 90 days; estimated weight at fledging 2800 g or 119% of average adult weight (Wingham 1984b).

FLEDGING TO MATURITY Immatures return to NZ when 2–5 years old, breed at 4–7 years of age. During first seasons at gannetry form clubs (Wodzicki & Robertson 1974).

SUCCESS At Motukaramarama, 90 eggs laid in 100 nests, ten nests belonging to non-breeders; 14 (15.6%) eggs failed to hatch; seven failed pairs relaid, giving 83 eggs in all; 62 first eggs (82%) hatched plus three replacements. Of these 65 young, 61 (94%) fledged, with total success of 73.5% (E.J. Wingham). At C. Kidnappers, annual adult mortality 4.52% (from banded birds; Wodzicki *et al.* 1984) and life expectancy of about 20 years; with 75% total breeding success and 85% mortality before breeding, one pair could produce 15 fledglings of which 12.75 would die before breeding, leaving 2.25 surviving young reared, which agrees with 2.3% increase in colony per annum (Nelson 1978). Silver *Larus novaehollandiae*, Pacific *L. pacificus* and Kelp *L. dominicanus* Gulls take eggs during disturbances at colonies.

PLUMAGES Adult plumage attained in c. 3–4 years (Nelson 1978) but Wodzicki & Robertson (1974) state 4–5 years.

ADULT Differences between breeding and non-breeding plumages slight; buff colour on crown more intense during breeding season. **HEAD AND NECK.** Frons and narrow rim of feathers extending from crown to gape, adjoining facial skin, white. Facial skin, naked. Crown to hindneck, buff (118); less intense (buff 124) on hindneck. Rest of neck, including outer chin and throat, white; narrow strip of bare skin, gular streak, extends beyond gular pouch to end of throat. No sexual difference in length of gular streak known. **UPPERPARTS.** Mantle, back, rump and upper tail-coverts, white. Scapulars, humerals and tertiaries, white. **UPPERWING.** Primaries and secondaries, dark brown (121); pale drab (119D) at base of inner webs. Rachis of primaries, cream (54) at base, sepia (119) at tip. Rest of upperwing, apart from alula, white. Alula, dark brown (121); prominent over white marginal upper wing-coverts. **TAIL.** Rectrices vary: t1–t4, dark brown (121); rachis white at base, sepia (219) at tip; t5–t7, white; rachis entirely cream (54). **UNDERPARTS.** Body, entirely white. **UNDERWING.** All under wing-coverts and axillaries, white. Remiges, as upperwing.

DOWNY YOUNG Naked at hatching, skin black, sparse covering of white neossoptiles from c. 1–4 days; down thicker c. 5–9 days. Second, longer white down, 4 mm long, c. 15–19 days; short on head and neck, absent on face. Nearly all down lost c. 85–94 days; yellow tinge noticed on head. Down totally lost c. 95–108 days (Wingham 1984b). See Wingham (1984b) for full details of feather development to juvenile plumage and guide to ageing chicks. Further details of development of feathers, to juvenile plumage, given in Wodzicki & Robertson (1953).

JUVENILE Narrow rim of white feathers extends from frons to gape, adjoining facial skin. Crown, dark brown (121) with small white triangular tips; tips progressively larger towards base of neck. Sexes distinguishable, with males having variable amount of buff (124) on crown and nape; absent in females (C.J.R. Robertson). Wingham (1984b) found that this character was not obvious in birds aged c. 95–108 days. Outer chin, throat to lower neck mostly white; dark brown (121) edges to feathers with white bases. Gular streak, short. Mantle, dark brown (221); back, rump and upper tail-coverts paler (121); triangular white tips on each feather, spaced wider on mantle. On rump, white tips larger; feathers pale at base. Upper tail-coverts edged white on outer webs, tipped white. Upper breast and flanks, dark brown (121), feathers with white bases, U-shaped dark brown (121) streaks, narrow dark brown (121) edges and white tips. On lower breast, feathers white, fringed dark brown (121). Thighs, dark brown (121) tipped white, and with narrow white shaft streak; with wear, paler brown (119A); worn colour applies to all brown-coloured parts of body. Scapulars, humerals, tertiaries, secondaries, p1–p7, all coverts of upperwing, alula, all coverts of underwing except for greater under primary and greater and inner lesser under wing-coverts, tipped white. Some feathers, largely white; pale-brown outer webs and speckled light brown inner webs. Greater under wing-coverts, glossy. White tips on upper and under wing-coverts, progressively larger from proximal to distal part of wing. Scapulars, humerals, tertiaries, secondaries and primaries, dark brown (121); base, and inner webs of primaries and secondaries, white. Primaries more pointed than adult. Axillaries, white with faint glaucous (80) specks on webs. Tail, dark brown (121), rectrices tipped

white. In NZ, juvenile plumage attained 95–108 days (Stein 1971; Wingham 1984b); in Aust., average c. 102 days (Warham 1958).

IMMATURE Plumage gradually whitens; varying with age and sex. Males reach adult plumage before females (Nelson 1978). Most change in plumage occurs in first 2 years (Wodzicki & Robertson 1974). Detailed sequence of change, insufficiently described. Brief outline of sequences described here for male only, with emphasis on upperparts. At c. 8 months, crown and nape buff (124). Neck, mostly white with few dark-brown (121) feathers. Back and rump, similar. Upper tail-coverts, white, with dark-brown (121) streaks on inner webs. Scattered feathers on breast with dark-brown (121) fringes or U-shaped marks, or both, on webs. At c. 12 months, few dark-brown (121) feathers on mantle, back and rump. Most coverts on upper wing, white; two of the three tertiaries, white. Some outer rectrices, white; varying. At c. 24 months, some dark-brown (121) feathers among scapulars, and inner greater upper wing-coverts. Tertiaries, white (photos in Nelson 1978).

BARE PARTS

ADULT Bare parts similar in breeding and non-breeding; maximum intensity of colour during breeding season. Iris, light grey (85) with pale horn (92) tone. Eye-ring, blue (168C). Facial skin, naked, black (82). Bill, pale grey (86) with pearl-grey (81) tone; cutting edge and ridge between culmicorn and latericorn, black (82). Gular pouch and gular streak, dark grey (83). Legs and feet, dark grey (83); broad light-green (162D) line extends along front of tarsus and along ridge of each toe.

DOWNY YOUNG Iris, dark brown (221), Eye-ring, narrow, black (82). Bill, legs and feet, black (82).

JUVENILE Iris, dark brown (119A). Eye-ring, facial skin and bill, dark brown (121). Legs and feet, dark grey (83).

IMMATURE Bare parts varying; juvenile to adult in appearance. Intermediate described here. Iris, dark drab (119B). Eye-ring, light drab (119C). Facial skin, olive brown (28). Bill, fawn (25). Gular pouch and gular streak, sepia (119). Legs and feet, light grey (85), lines on tarsus and toes, pearl grey (81).

MOULTS Insufficiently described. Mode of moult, staffelmauser.

ADULT POST-BREEDING Complete; up to three active moult centres in wing. Unknown if yellow colour of head due to separate partial pre-alternate moult; possibly due to skin exudate, as suggested in Northern Gannet (BWP) but further study required.

POST-JUVENILE At C. Kidnappers, NZ, in first year, primary moult series begins in Sept. in males; Oct. in females. Moult series concluded in Jan. of second year. Subsequent moults later each year; details of primary moult unknown with respect to onset and timing of second and third series and replacement rate of each primary.

MEASUREMENTS Few data available. (1) Skins (HASB); (2) Skins (AM, SAM, QM, MV, QVM, TM, ANWC).

Full details of growth rates of chicks given in Wingham (1984b).

	MALES	FEMALES
WING	(1) 463 (—, 443–482; 14) (2) 469.6 (11.39; 440–485; 13)	471.7 (7.86; 455–480; 7)
BILL	(1) 89 (—, 85–93; 14) (2) 90.9 (1.92; 87–93; 12)	89.7 (3.61; 85–95.5; 8)
TARSUS	(1) 54 (—, 51–57; 14) (2) 55.7 (1.99; 51–59; 13)	57.5 (2.62; 54.3–62.6; 7)
TAIL	(1) 212 (—, 206–218; 14) (2) 215.3 (8.98; 203–228; 8)	213.4 (10.56; 200–230; 7)
TOE	(1) 107 (—, 105–110; 14) (2) 98.4 (5.80; 83–103; 13)	102.5 (2.56; 98.5–106.7; 8)

WEIGHTS Few data available. Unsexed birds: 2350 (2000–2800; 44) (HASB). Skins, unsexed (AM, SAM, QM, MV, QVM, TM, ANWC): 1925.7 (675.81; 1250–3050; 7). Wodzicki & Robertson (1953) give weights of unsexed adults before and during breeding season and conclude weights probably lighter at end of season: Nov.: 2456 (2280–2800; 7), Dec.: 2456 (2100–2750; 13), Jan.: 2258 (2000–2600; 19), Feb. 2230 (2100–2500; 5). Chicks weigh more than average adult weight (2350, n=50) at c. 50 days old and reach maximum weight of 3132 in c. 90 days; average weight of chicks at c. 34–65 days old: 1596–2858. Weights of chicks vary, attributed to irregularity of food. Average weight at fledging c. 2800 g (Wingham 1984b). Further details of weights of chicks are given in Wodzicki & Robertson (1953); see also Nelson (1978) for general summary.

STRUCTURE Wing, long and slender. Eleven primaries: p9 longest, p10 0–6 mm shorter, p8 21–33, p7 55–71, p6 92–112, p5 135–150, p4 173–215, p3 207–230, p2 237–255, p1 259–275, p11 minute. Outer web of p10 and p9 slightly emarginated, inner webs strongly emarginated. Twenty-four secondaries, three tertiaries, 10–12 humerals. Tail, wedge-shaped; 12 rectrices, t1 longest, t6 92–136 mm shorter. Bill longer than head, conical, high at base, tapering towards tip, where slightly curved. Backward serrations on upper and lower mandibles. Upper mandible composed of culminicorn and latericorn, with secondary external nostril near gape. No external nostrils. Tarsus, short and stout. Claws, strongly curved; middle longest, pectinate. Outer c. 98% of middle, inner c. 74%, hind c. 32%.

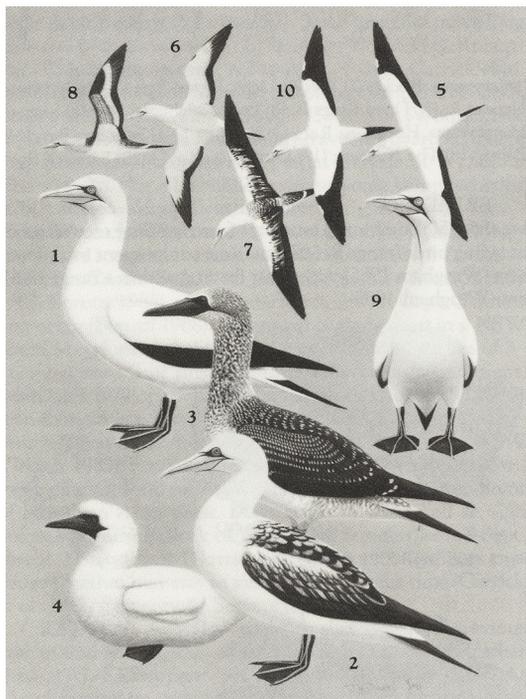
GEOGRAPHICAL VARIATION No variation in Aust. and NZ. The sub-genus *Morus* is not used here. Taxonomic treatment of *serrator* unresolved at specific level: either given specific status (Aust. CL) or treated as a subspecies with either *bassana* (NZCL) or *capensis*. Differ from both *bassanus* and *capensis* in behaviour, ecology, size, plumage and tail-colour (Jarvis 1972; BWP). Tail colour in *bassanus*, white; dark brown in *capensis*; combination of dark brown and white in *serrator* (Jarvis 1972). Broekhuysen & Liversidge (1954), found 11% of *capensis* had tail colour similar to *S. serrator*, supporting view of *serrator* and *capensis* as conspecific. Interbreeding of these two forms observed by Venn (1982) lends support. More characters shared between *serrator* and *capensis*, than either shares with *bassanus* (Jarvis 1972). Until taxonomy resolved, treated as forming superspecies with *bassanus* and *capensis* (Peters).

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RMO



Volume 1 (Part B), Plate 55

Australasian Gannet *Sula serrator*

1. Adult
2. Immature
3. Juvenile
4. Downy young
5. Adult, dorsal
6. Adult, ventral
7. Immature, dorsal
8. Juvenile, ventral

Cape Gannet *Sula capensis*

9. Adult
10. Adult, dorsal

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