

Order PROCELLARIIFORMES

A rather distinct group of some 80–100 species of pelagic seabirds, ranging in size from huge to tiny and in habits from aerial (feeding in flight) to aquatic (pursuit-diving for food), but otherwise with similar biology. About three-quarters of the species occur or have been recorded in our region. They are found throughout the oceans and most come ashore voluntarily only to breed. They are distinguished by their hooked bills, covered in horny plates with raised tubular nostrils (hence the name Tubinares). Their olfactory systems are unusually well developed (Bang 1966) and they have a distinctly musky odour, which suggest that they may locate one another and their breeding places by smell; they are attracted to biogenic oils at sea, also no doubt by smell. Probably they are most closely related to penguins and more remotely to other shorebirds and waterbirds such as Charadriiformes and Pelecaniiformes. Their diversity and abundance in the s. hemisphere suggest that the group originated there, though some important groups occurred in the northern hemisphere by middle Tertiary (Brodkorb 1963; Olson 1975).

Structurally, the wings may be long in aerial species and shorter in divers of the genera *Puffinus* and *Pelecanoides*, with 11 primaries, the outermost minute, and 10–40 secondaries in the Oceanitinae and great albatrosses respectively. The tail varies in length, being forked in *Oceanodroma*, forked to pointed in other forms, usually with 12 rectrices but up to 16 in fulmars. The tarsi are light and cylindrical in aerial forms; strong and laterally compressed with legs set far back in aquatic ones. The front toes are webbed; hind toe small or absent. The proventriculus is long and glandular; the gizzard small and twisted; and the small intestine often spiral in *Pterodroma*, presumably to aid absorption of the unusual lipids in their food. Chicks are helpless and covered in down, with two coats except in some Oceanitinae. Some larger species have a darker immature plumage, and the female is often darker than the male in the great albatrosses. The male is usually larger than the female, though smaller in the Oceanitinae and some other small species. Otherwise there is little difference in appearance with sex or age, except that young birds may have more pronounced pale or dark edges to the feathers. Many have simple counter-shaded markings that often appear to have given rise to uniformly dark or, less often, to pale derivatives; some species in most groups are dimorphic or polymorphic. The more complex groups have often developed distinctive markings of the extremities.

Breed more or less colonially on offshore islands, coastal cliffs, or on hills and deserts inland, where they perform complex vocal and aerial displays. The nest is a simple scrape or cup in a burrow or natural hole, sometimes under vegetation. The s. albatrosses build large cone-shaped nests in the open; may be lined with any debris available in the area. Smaller species visit it only at night, though larger ones and those breeding on remote islands may come to nests in the open by day. Parents incubate for spells of several days in turn and generally leave the chick alone soon after it hatches, only returning at long intervals to feed it by regurgitation. In consequence the chick is vulnerable to introduced predators and some species are now greatly reduced and at least two are now extinct. Some species also periodically liable to have unsuccessful breeding seasons. Many young or even old birds may be wrecked ashore and die when they meet bad weather or suffer shortage of food on migration or in the winter. Though it has been claimed that they are also vulnerable to all sorts of pollution, the evidence is weak (Bourne 1976). There is at present anxiety about the effect of some fishing methods, such as long-lining, which may be endangering species such as the great albatrosses.

All species feed at sea on a variety of fish, cephalopods and small marine invertebrates, either socially or alone; larger species may scavenge all sorts of offal or prey on other birds. Most, except perhaps *Pelecanoides*, can digest the complex lipids formed by some marine animals (Clarke & Prince 1976), and may eject them to soil the plumage of their enemies with lethal results (Swennen 1974). Some species can digest wax (Obst 1986). Many now take wastes from whaling and fishing operations (Fisher 1952). All have long life-cycles in proportion to their size; they disperse on fledging and then prospect for nest-sites for 2–12 years in their youth. They usually lay a single large white egg annually; though a successful breeding cycle may be completed in less than a year in at least one tropical species, *Puffinus lherminieri*, it may take 2 years in larger southern ones. Before laying, the birds court for weeks or months, then go to sea for feeding. Incubation lasts 6–8 weeks, and fledging 2–9 months. Once the fat chick fledges it fends for itself, even in species that immediately make a long migration, sometimes to the opposite hemisphere.

Tendency for failed breeders and non-breeders to begin moult before successful breeders. Five strategies of wing-moult in breeding adults: (1) In albatrosses, remiges replaced in staffelmauser interrupted while breeding; in nearly all other species, primaries moulted outwards; possibly simultaneously in some diving-petrels. (2) In most subantarctic and temperate species, moult begins soon after breeding and is completed shortly before next breeding season. (3) In most tropical species, moult aseasonal, between breeding attempts; resumption of breeding apparently depends on when moult completed. (4) In trans-equatorial migrants, wing-moult delayed until they reach non-breeding quarters, where it is completed; moult rapid but no satisfactory evidence for flightlessness. In

some species, body-moult also in winter quarters; in others, at breeding grounds. (5) In some species of high latitudes, rapid moult completed in summer when they breed; some begin moult long before breeding finished.

The history of the classification of the Order is very confused, as is seen by comparing Timmermann's (1965) discussion of their Mallophagan parasites with that by Klemm (1969) of their leg muscles and that by Harper (1978) of their proteins, but it is now widely agreed that the Order is best divided into four families: Diomedidae or large to huge aerial albatrosses; Procellariidae or medium-sized, mainly aerial but sometimes aquatic, petrels, shearwaters and prions; Hydrobatidae or small to tiny, aerial storm-petrels; and Pelecanoididae or small aquatic diving-petrels.

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Family PROCELLARIIDAE fulmars, petrels, prions, shearwaters

The family Procellariidae represents the main radiation of medium-sized 'true petrels', characterized by having united nostrils with a median septum and the outer functional primary at least as long as the next. It tends to be dominant among the birds of the Southern Ocean, though in the n. hemisphere the Charadriiformes are more numerous. The giant-petrels *Macronectes* have also developed as large scavengers and predators, showing some convergence in appearance and behaviour with the Diomedidae. The Procellariidae may be divided into four main groups with some intermediate species, which makes it hard to draw distinctions between them.

(1) The fulmars *Macronectes*, *Fulmarus*, *Thalassoica*, *Daption* and *Pagodroma* consist of seven species of surface predators and filter-feeders of rather varying structure and appearance (Voous 1949) that breed in high latitudes but may migrate along cool currents into much lower ones. *Fulmarus* appears to have colonized the n. hemisphere in the Tertiary. Six of the seven species are essentially confined to our region.

(2) The gadfly-petrels *Pterodroma* are a large series of some 30 agile species; 16 breed in our region and another six occur rarely or rather rarely. Their short sturdy bills are adapted for seizing soft prey at the surface, and their twisted intestines, for digesting marine animals with an unusual biochemistry, which are also found throughout the warmer oceans (Imber 1985). They show complex markings of face and wings that must serve as interspecific recognition-marks (Murphy & Pennoyer 1952). Some species placed in this group have an intermediate structure and intergrade with all other groups distinguished here: *Pterodroma (Lugensa) brevirostris*, which moves S in winter, has distinctly big eyes like *Pagodroma*; *Halobaena caerulea* has a plumage similar to that of prions; *Bulweria* has some structural resemblance to shearwaters. At present it is difficult to determine their precise relationships.

(3) The prions *Pachyptila* are a specialized group of six (perhaps five) very numerous species, all in our region, that show a progressive adaptation of a small, agile, cryptically coloured, fulmarine form for filter-feeding on zooplankton. There has been dispute over their classification (Cox 1980; Harper 1980) but the arrangement discussed by Fleming (1941) seems best except that the Broad-billed Prion *P. vittata* appears to intergrade with Salvin's Prion *P. salvini* through *macgillivrayi* of Ile St Paul; so they may be better treated as subspecies of the same species.

(4) The shearwaters *Procellaria*, *Calonectris* and *Puffinus* include some 20 agile species with long bills adapted to catch prey more or less under water throughout the warmer seas (Kuroda 1954); 13 species breed in our region, some migrating into the n. hemisphere; six others are chance or perhaps regular visitors. From the fossil record (Brodkorb 1963; Olson 1975); they seem to have been particularly common in the great Tethys Ocean of the middle latitudes of the n. hemisphere in the Tertiary, so this development of aquatic habits may have occurred there without competition from penguins with a subsequent return S by the more successful forms.

General features of the family are: body, ovate, or elongate in shearwaters; wings, long and narrow, 11 primaries, p10 longest, p11 minute; 20-29 secondaries, short, diastataxic; tail, short, 12 feathers; bill, heavy (*Macronectes*), slender (shearwaters), broad (prions) or stubby (gadfly-petrels), hooked, formed of several horny plates; nostrils in dorsal tube of varying length; legs set far back, laterally flattened but round in gadfly-petrels; three toes, webbed, hind toe vestigial, raised. Oil-gland feathered. Peculiar musky odour. Sexes similar, male usually larger than female. Plumage, black or grey above, white below, or all dark; light and dark morphs in some species. Juveniles and immatures usually like adults.

Cosmopolitan throughout the oceans, essentially pelagic; more abundant in cool or cold waters rich in plankton and mostly away from ice. Swim well but usually aerial except when feeding or resting. Fly with alternate swooping and flapping action close to the surface but often arcing high in some gadfly-petrels. Gait on land, a shuffling crouch, being unable to walk properly with feet set so far back; generally avoid open areas on land, being thus vulnerable to predators. Nest colonially; for the most part in burrows and cavities in all sorts of terrain, sometimes far from the sea and in mountainous areas but some species, e.g. *Macronectes*, nest on open ground. Hole-nesters usually nocturnal at colonies, when often extremely vocal, though generally silent at sea. Migratory and dispersive. Some species divide the year between s. and n. hemisphere, often migrating in large flocks that may settle on the sea in huge dense rafts. Feed mostly on fish, cephalopods and crustaceans obtained by flight-feeding, plunge-diving, surface feeding, surface-diving and underwater pursuit; hydroplaning (Murphy) is a characteristic method used particularly by prions.

Probably all defend small nesting territories to which they return regularly while undisturbed; certainly so in some hole- and burrow-nesting forms. Agonistic and sexual behaviour of nocturnal, hole-nesting species very poorly known but generally seem to have little specialization for visual displays. Tactile actions such as allopreening and billing used but olfactory and vocal communication is probably important. Breeding is usually seasonal, generally with synchronized laying, often after a pre-laying exodus but some may not nest annually; some have shorter

cycles or nest continually. For the most part, little attempt to make substantial nests. Eggs, ovate, mat, white. Clutch-size, invariably one; single-brooded; no replacement laying. Incubation by both sexes in alternate spells of 1-11 days. Single median brood-patch. Incubation period, 45-55 days. Eggshells probably always trampled in nest. Young, semi-altricial, nidicolous; hatched in down. Rarely left alone in nest for first 1-2 weeks. Cared for and fed by incomplete regurgitation by both parents. Nestling period generally shorter in cliff- and ledge-nesting species than in hole-nesters. Young attain greatest weight, often well above that of adult, some days before fledging, by which time weight has been reduced to about the same as an adult, but no clear evidence that young are totally deserted for last few days in nest. Adults and young of most species liable to eject stomach-oil in defence. Young independent at fledging. Maturity reached at minimum of 3-4 years, in some 6-12 years.

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Puffinus pacificus Gmelin, 1789, *Syst. Nat.* 1: 560; based on 'Pacific Petrel' of Latham, 1785, *Gen. Syn. Birds* 3: 416 — Pacific Ocean; restricted to Kermadec Island, Mathews, 1912, *Birds Aust.* 2: 80.

Specific name is clearly geographical.

OTHER ENGLISH NAMES Little or Wedge-tailed Muttonbird or Petrel, Mourningbird.

MONOTYPIC

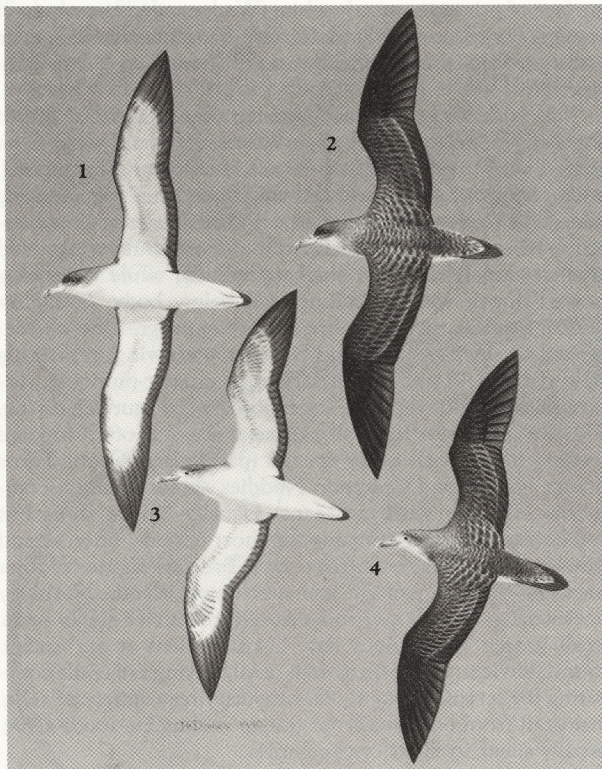


Plate 44

Cory's Shearwater *Calonectris diomedea* Subspecies *borealis*

1. Adult, ventral
2. Adult, dorsal

Streaked Shearwater *Calonectris leucomelas*

3. Adult, ventral
4. Adult, dorsal

FIELD IDENTIFICATION Length 38–46 cm; wingspan 97–105 cm; weight varying, 300–570 g. Large, lightly built polymorphic shearwater of tropical and subtropical Pacific and Indian Oceans. Closely resembles Buller's Shearwater *Puffinus bulleri* in size and shape. Characteristic jizz: small-headed and slender-bodied; long, strongly wedge-shaped tail held tightly folded in normal flight, giving long pointed rear-end; long slender dark bill; broad wings, with carpals held well forward, outerwing bowed down and gently angled back from carpals; buoyant, unhurried flight. Strongly wedge-shaped tail (readily apparent when fanned), diagnostic. Appearance of upperwing, underwing and bill vary with light conditions. Dark and light morphs known from our region; light morph rare in e. Aust. and NZ, but composes about 20–30% of population in w. Aust. Sexes alike. No seasonal variation. Some juveniles separable.

DESCRIPTION **ADULT. Dark morph.** Upperparts, blackish brown, with remiges and tail darker, blackish; scapulars narrowly tipped paler greyish-brown, giving scaled appearance to base of innerwing, obvious in close view. Greater and median secondary coverts appear paler and browner than rest of upperwing, showing as broad pale panel across innerwing and contrasting with blackish secondaries and outerwing. In strong light, secondaries and tips of greater secondary coverts can appear silvery momentarily; lesser inner wing-coverts can appear darker than surrounding coverts showing as ill-defined dark bar across innerwing, from carpal to longest scapulars and, with blackish outerwing, forms subtle dark M across upperwing. Underbody, blackish-brown, slightly paler greyish-brown on face, chin and throat. Underwing: rather uniform dark greyish-brown, with remiges and greater coverts slightly paler and glossier but usually contrasting only slightly with rest of lining; in strong light, whole of underwing appears paler greyish-brown and rather uniform except for transitory effect of narrow diffuse dark border to anterior edge of lining and along trailing-edge. En-

tire plumage wears browner. Bill, long and slender, with tubed nostrils slightly raised over basal quarter of upper mandible; slate- to bluish-grey or brownish horn with unguis blackish, showing as contrasting dark tip; when strongly lit, appears much paler greyish-horn or even whitish, heightening contrast with dark tip. Legs and feet, fleshy-white to pale pink, darker brownish on outer side of tarsus and outer toe; conspicuous against dark of underbody; feet well short of tip of tail. **Light morph.** Upperparts similar to dark-morph and with same general pattern but colour slightly paler, often appearing greyer. Dark brown of cap and hindneck extends below eye-level, merging into white of chin, throat and foreneck, sometimes giving hooded appearance, especially on bird going away in dull light, when white of chin and throat less easy to see. Underbody, from breast to vent, mostly white, with flanks clean white or washed brownish-grey; underside of tail, blackish, combining with dark-brown under tail-coverts and small dark-brown thigh patch to form dark rear-end. Underwing: remiges, greyish-black, forming broad dark trailing-edge and large dark tip, strongly demarcated from white lining. Lining mostly white, with narrow blackish-brown leading-edge, broadest along primary coverts; thin dark streaks radiate across white lesser primary-coverts, forming subtle 'finger-patch'. Outer few median primary-coverts tipped dark brown. Extent of dark on rest of lining varies. Darkest individuals have brown smudging on lesser coverts combining with dark-tipped subhumeral to form pronounced diagonal line from carpal joint to base of trailing-edge; with narrow blackish-brown leading-edge, outlines white triangle on inner wing-coverts. Palest individuals have narrower dark diagonal line that does not extend on to white subhumeral. Bare parts, as dark morph. **JUVENILE.** Closely resemble adults; separable only during first few weeks after fledging (late Apr.-early June) when in fresh plumage and plumage of adults worn. Generally paler, with frosty bloom above. On dark morph, bloom more pronounced on greater secondary-coverts, forming conspicuous pale bar on upperwing, contrasting strongly with blackish secondaries and darker coverts (adults browner without pale bar). On light morph, tips of scapulars, mantle feathers and greater secondary-coverts, white (not greyish-brown), combining with pronounced frosty bloom on median secondary-coverts to give much crisper pattern of pale scaling on saddle and pattern of thin pale tramlines across innerwing coverts. Often primaries not fully grown, giving blunter, more rounded wing-tip.

SIMILAR SPECIES Among dark shearwaters, most likely to be confused with **Flesh-footed Shearwater**: which is slightly larger, with slightly bigger head, thicker neck and fuller body; wings look slightly broader and tend to be held straighter, less angled at carpals, so that tips appear more rounded and carpals not so far forward. Clearest structural difference is much shorter, blunter (less strongly) wedge-shaped tail which can appear rounded at tip when fanned (not strongly wedged); also, bill noticeably thicker and more robust, with tubed nostrils more prominent. Plumage appears darker brown and more uniform; on underwing, greater contrast between blackish part of lining (marginal, lesser and median coverts, sub-humeral and their coverts) and paler glossier greater coverts and remiges, especially obvious on outerwing where primaries typically shade to paler on bases, contrasting sharply with rest of coverts (underwing of Wedge-tailed paler, more uniform with usually little contrast at base of primaries). Bill, much paler yellowish-horn, with sharply

contrasting blackish tip (on Wedge-tailed, bill darker basally, with much less contrast between base and tip; though when strongly lit, base can appear much paler, heightening contrast with tip, contrast much stronger and always far more obvious on Flesh-footed when direct comparisons available). **Sooty P. griseus** and **Short-tailed P. tenuirostris Shearwaters** much less likely to be confused. Both noticeably fuller-bodied, with narrow wings held much straighter and more stiffly; tails much shorter and blunter (less wedged), with toes extending well beyond tip of tail; with obvious pale stripe down centre of underwing, dark greyish legs and feet, and much faster flight broken by short bursts of rapid, stiff-winged flapping. **Christmas Shearwater P. navitatis**; *q.v.* for distinctions from dark morph. **Streaked Shearwater *Calonectris leucomelas***, superficially similar to light morph but much larger, with proportionately smaller head, longer neck and more slender body, broader wings that tend to be held slightly straighter; flight very similar but may glide more, wing-beats may look more powerful. Shows pronounced white streaking on head and white face (latter often visible at long range); some have white V-shaped mark across base of upper tail. **Buller's Shearwaters P. bulleri** sometimes confused with light morph but much paler and greyer above, with sharply contrasting dark cap, tail and open M across upperwing forming striking dorsal pattern; underwing mostly white (without dark diagonal line across wing-pit) and with narrow grey trailing-edge that continues narrowly round wing-tip leaving under-surface of primaries mostly white (Wedge-tailed has whole of remiges darker greyish-black forming broad dark trailing-edge and tip). **Pink-footed Shearwater P. creatopus**; *q.v.* for distinctions.

In wide range of marine habitats, from well inshore to shelf-edge zone and over pelagic waters; commonly seen from land. In light winds, flight buoyant, drifting and unhurried, with periods of gentle arcing, banking and turning and long glides low to water interspersed with brief series of slow measured wing-beats; when seen from in front, innerwings held so that carpals above or level with body, while outerwing bowed down, wing-tip falling well below body. In higher winds, flap less; swifter, more bounding progression characterized by steep banking and twisting, with wings remaining bowed and held well forward. Feed by pursuit-plunging, surface-seizing and dipping; occasionally by surface-diving. Usually solitary or in small parties at sea, but often in large feeding flocks with other species (particularly Sooty Terns *Sterna fuscata* and Common Noddies *Anous stolidus*); commonly associate with cetaceans. Usually ignore ships but sometimes closely accompany for short periods; often attend trawlers and fishing boats for scraps. Breed in dense colonies on well-vegetated tropical and subtropical islands. Normally nocturnal at colonies; at some sites, birds arrive singly or in small groups throughout day. Usually silent at sea except round trawlers, where birds emit nasal braying call while competing for scraps. Noisy at colonies uttering a variety of calls; main call from burrows or ground is wailing *ka-woooo-ahhh*; usually silent in flight over colonies.

HABITAT Marine, pelagic; in tropical and subtropical waters. Tolerate range of surface-temperatures and salinities (King 1974; Dunlop *et al.* 1988); but most abundant where temperature >21 °C and salinity >34.6 ‰ (King 1974). In Tropical Zone may feed over cool nutrient-rich waters; decline in numbers off Christmas I. (Pac.) during El Niño Southern Oscillation, when surface-temperature high and

food supply poor (Schreiber & Schreiber 1984). Occur mainly in offshore and pelagic waters (Storr 1964a; Barton 1977; Dunlop *et al.* 1988), but regular inshore in e. Aust. (Rogers 1975; Marchant 1977; Milledge 1977). Concentrate at sources of food; in Aust., observed feeding along junction between inshore and offshore water masses (Corben *et al.* 1974). May be excluded from NZ waters by competition with other seabirds (Jenkins 1979). In tropical waters, mainly within Equatorial Countercurrent, extending N and S into Equatorial Currents (Bailey 1968; King 1974; Pitman 1986); may be associated with current boundaries and associated upwellings (Pitman 1986). Dark and pale morphs may differ in distribution; in e. Pacific, pale morph more common N of 10°N and close to continental coast; dark morph more common S of 10°N and far from land (King 1974; Pitman 1986).

Breed throughout range, mainly on vegetated islands, atolls and cays, but one colony on Aust. mainland. Nest in rock crevices or in burrows in soft soil or shell grit; on scree and earth slopes, plateaux, headlands, cliff tops, sand dunes and flats (Storr 1964b, 1966; Merton 1970; Holyoak & Thibault 1984). Burrows excavated under forest, low shrubland, native or modified grassland, or mats of succulents (McGill 1954; Storr 1964b; Ogden 1979; Tarburton 1981; Floyd & Swanson 1983); dense, prickly shrubbery and fine-rooted grasses inhibit burrowing (Floyd & Swanson 1983). Prefer climax forest or shrubland, rather than areas regenerating after cyclone damage or fire (Ogden 1979; Floyd & Swanson 1983).

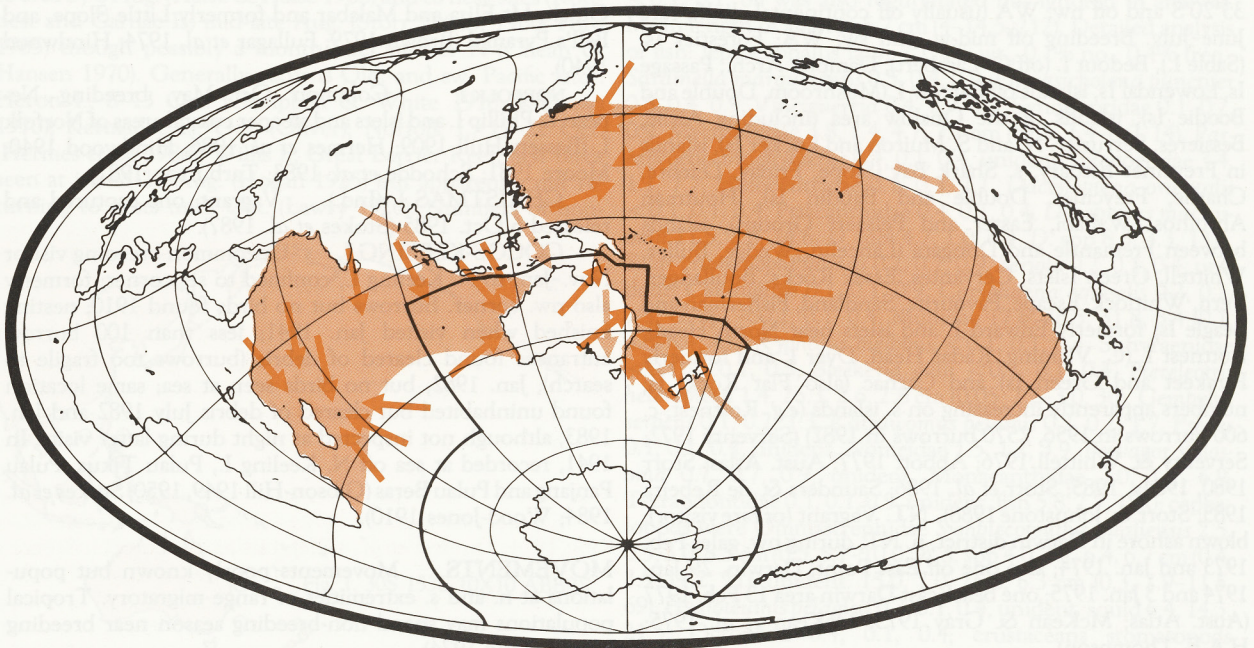
When feeding, fly <10 m above surface (King 1974) and dive to 2–3 m depth (Milledge 1977). Often settle on surface, especially after feeding or before migration (King 1974). Loaf in lee of islands in rough weather (Jenkins 1979).

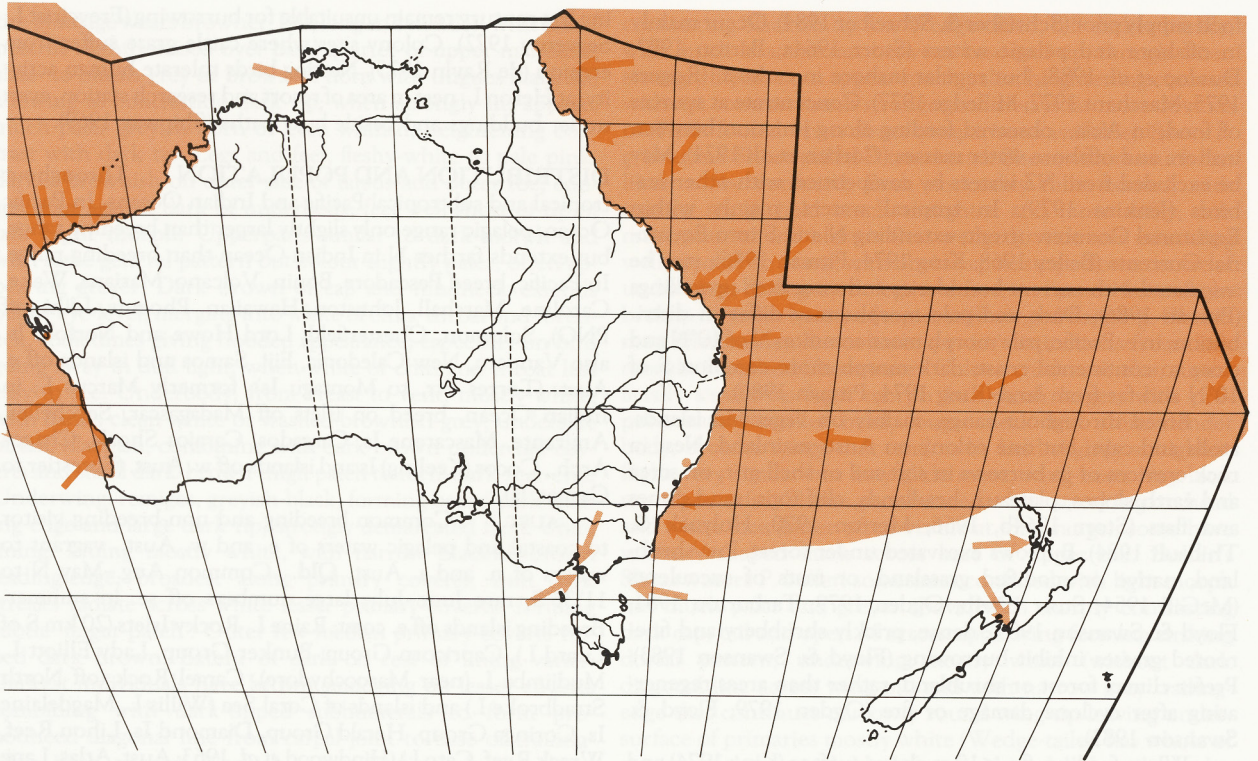
Only mainland colony, at Red Bluff, NSW, partly destroyed by construction of drains (McGill 1958). Colony at Slope I., WA, declined after salt-company began operations; nest-sites and protective vegetation destroyed, and construction of causeway allowed access for foxes and cats (Serventy 1972). Hard ground and rubble left by guano-min-

ing last century remain unsuitable for burrowing (Freyrcinet I.; Serventy 1972). Colony sites where cattle graze suffer from erosion (de Ravin 1975). Nesting birds tolerate human activity; at Heron I., nest in area of resort and research station, even under buildings and beside busy paths (Shipway 1969).

DISTRIBUTION AND POPULATION Throughout tropical and subtropical Pacific and Indian Oceans. In Pacific Ocean, pelagic range only slightly larger than breeding range, but extends farther N in Indian Ocean than breeding range. In Pacific, breed Pescadore, Bonin, Volcano, Mariana, Wake, Caroline, Marshall, Johnston, Hawaiian, Phoenix, Idihi (off PNG), Solomon, Chesterfield, Lord Howe and Norfolk Is, also Vanuatu, New Caledonia, Fiji, Samoa and islands off e. Aust. (Torres Str. to Montagu Is), formerly Marcus I.; in Indian Ocean, breed on islets off Madagascar, Seychelles, Amirante, Mascarene Is, Cargados, Carajos Shoals, Chagos Arch., Cocos (Keeling) Is and islands off w. Aust. (Forestier to Carnac Is).

AUST. Common breeding and non-breeding visitor to coastal and pelagic waters of e. and w. Aust., vagrant to waters of n. and s. Aust. **Qld.** Common Aug.–May N to 11°36'S; rare June–July; large numbers off se. in summer. Breeding islands off e. coast; Raine I., Rocky Islets (20 km S of Lizard I.), Capricorn Group, Bunker Group, Lady Elliott I., Mudjimba I. (near Maroochydhore), Camel Rock (off North Stradbroke I.) and islands of Coral Sea (Willis I., Magdelaine Is, Coringa Group, Herald Group, Diamond Is, Lihou Reef, Wreck Reef, Cato I.) (Hindwood *et al.* 1963; Aust. Atlas; Lane & Battam 1984; Storr 1984b; Qld. Bird Rep. 1983, 1984). **NSW.** Common; present and breeding activity Aug.–May, being regularly recorded off Sydney Heads Aug.–Apr. Breed on 32 coastal islands from Cook I. to Montagu I., with major colonies at Muttonbird, Broughton and Montagu Is; formerly nested at Red Point on mainland opposite Five Is colonies. Visits harbours in bad weather and inland records of storm-driven birds include one caught alive near Bargo 11 May 1979 and one near Dungog 7 May 1979 (Floyd & Swanson 1983;





Hindwood & McGill 1958; Lane 1979; McGill 1961; Morris 1975, 1986; Morris *et al.* 1981; Smith & Chafer 1987; NSW Bird Rep. 1979). **Vic.** Uncommon extreme e. Vic. in summer, e.g. round Gabo I.; vagrant recorded farther w. to area of Port Phillip Bay (Vic. Atlas). **Tas.** Vagrant, e. Bass Str. area June–July 1961, but no records on Tas. mainland; sole record from Seven Mile Beach 24 Oct. 1951 misidentified, proved to be Sooty Shearwater *P. griseus* (Green 1977; Sharland 1981). **WA.** Common off w. coast Aug.–Apr., W of 118°E, S at least to 33°20'S and off nw. WA (usually off continental shelf); rare June–July. Breeding off mid-w. and sw. WA: Forestier Is. (Sable I.), Bedout I. (off C. Lambert), Dampier Arch., Passage Is, Lowendal Is, islands off Barrow I. (Mushroom, Double and Boodie Is), islands of the Onslow area (including Airlie, Bessieres, Serrurier, N. and S. Muiron and Locker Is), islands in Freycinet Estuary, s. Shark Bay (Slope, Friday, Lefebre, Charlie, Freycinet, Double and Baudin Is), Houtman Abrolhos (Wallabi, Easter and Pelsaert Groups), islands between Fremantle and Dongara (Lancelin, Wedge, Buller, Whittell, Green Islets, Cervantes, Essex Rocks, Boullanger, Tern, Whitlock, Escape, Favourite, Sandland, Fisherman and Beagle Is; formerly Edward I. and islets near North Head), Rottneest I. (C. Vlaming, Radar Head, Dyer I. and formerly Parakeet and Green Is) and Carnac (also Flat Rock) Is; numbers apparently increasing on s. islands (e.g. Rottneest, c. 600 burrows in 1956, 2570 burrows in 1982) (Serventy 1972; Serventy & Whittell 1976; Abbott 1977; Aust. Atlas; Storr 1980, 1984a, 1985; Storr *et al.* 1986; Saunders & de Rebeira 1985; Storr & Johnstone 1988). **NT.** Vagrant (or rare visitor); blown ashore in Darwin district, n. NT, during nw. gales Feb. 1973 and Jan. 1974; also one off East Point, Darwin, 29 Jan. 1974 and 3 Jan. 1975; one beachcast Darwin area 13 Feb. 1977 (Aust. Atlas; McKean & Gray 1973; McKean *et al.* 1975; H.A.F. Thompson).

NZ Breed Nov.–May Kermadec Is, where absent June–Oct. Birds range S to c. 35°S; rarely straggle to NI; few records, mostly beachcast specimens, S to Cook Str., recorded Nov., Jan., Apr., June (Falla *et al.* 1981; NZCL; Merton 1970).

LORD HOWE I. Common Sept.–Apr., breeding Admiralty Is (most numerous Blackburn and Roach Is), Mutton Bird I., Goat I.; on Lord Howe I.: Mutton Bird Point, King Point, Johnsons Beach, Signal Point, North Head, New Gulch, Mt Eliza and Malabar and formerly Little Slope, and Ball's Pyramid (Brown 1979; Fullagar *et al.* 1974; Hindwood 1940).

NORFOLK I. Common Oct.–May, breeding Nepean I., Phillip I. and islets and steeper coastal areas of Norfolk I. (Bassett Hull 1909; Hermes *et al.* 1986; Hindwood 1940; Moore 1981; Schodde *et al.* 1983; Tarburton 1981).

CHRISTMAS I. (Ind.) Vagrant: one captured and released 6 Oct. 1985 (Stokes *et al.* 1987).

COCOS-KEELING I. Uncommon breeding visitor Nov.–Jan. to N. Keeling I., confined to se. corner; formerly also nw. corner. Burrows but no birds found 1910; nesting finished when visited Jan. 1941; less than 100 burrow entrances found cleared of debris (burrows too fragile to search), Jan. 1982, but no birds seen at sea; same location found uninhabited but cleared of debris July 1982 and Jan. 1983, although not inspected at night during latter visits. In 1941, recorded at sea off N. Keeling I., Pulau Tikus, Pulau Panjang and Pulau Beras (Gibson-Hill 1949, 1950; Stokes *et al.* 1984; Wood-Jones 1910).

MOVEMENTS Movements poorly known but populations at n. and s. extremities of range migratory. Tropical populations may spend non-breeding season near breeding islands (King 1974).

DEPARTURE Birds breeding in s. hemisphere have a summer breeding season, adults of migratory populations departing early Apr.–early May with chicks fledging two weeks later (Fullagar 1973a, b). Juveniles leave Five Is late Apr.–early May (Gibson & Sefton 1955), latest adult ne. NSW late Apr.–4 May, chicks 25 Apr.–11 May and failed breeders Mar.–early May (Swanson & Merritt 1974; Roberts *et al.* 1975); latest beachcast (fresh) 23 May (Gosper 1981). Marchant (1977) saw major unexplained movement N off s. NSW 10–30 Mar., though most leave waters off Sydney by late Apr. (Rogers 1975). Depart sw. Aust. (Storr 1964a; Ford 1965) and probably Lord Howe I. (Hindwood 1940) by mid-May. Departure later further N; leaves Heron I. (Miles 1964; Kikkawa 1970), Norfolk I. (Hermes *et al.* 1986) and Kermadecs (Oliver) late May–early June though most said to leave Willis I. by 7 May (Hogan 1925); few seen July–Oct. in Coral Sea (Norris 1967). At Raine I. recorded in burrows July (MacGillivray 1914) and may not travel far.

NON-BREEDING Migratory populations from s. hemisphere winter in Tropics N of equator (van Tets & Fullagar 1984); those from WA probably travelling to n. Indian Ocean, those from NSW and Lord Howe I. going to Philippines (Purchase 1974; Rogers 1975) and Kermadec population and probably that of Norfolk I. travelling to se. N. Pacific; virtually absent from sw. Pacific between NZ and Samoa June–Sept. (Jenkins 1979). Movements of population on s. Great Barrier Reef unknown; may disperse over nearby waters (van Tets & Fullagar 1984) but observations of large numbers in Bismarck Sea and off n. PNG until Sept., when density between PNG and s. Great Barrier Reef still low (N.G. Cheshire), and after most have returned to s. breeding sites, which suggests this may be wintering region.

RETURN Arrives Coffs Harbour 1 Aug. (Roberts 1973) with most of population arriving 8–16 Aug. (Swanson & Merritt 1974; Roberts *et al.* 1975), off Sydney and s. NSW mid Aug.–early Sept. (Fullagar 1973a,b; Rogers 1975; Marchant 1977) and earliest beachcast ne. NSW 29 Oct. (Gosper 1981). Timetable w. and sw. Aust. similar, returning to area by 8 Aug. (Halse & Halse 1988) and to nest-sites (Rott-nest and Carnac Is) mid-late Aug. (Storr 1964b, 1966; Ford 1965) though possibly a month later farther N (Cheah & Hansen 1970). Generally returns Qld. and sw. Pacific later: Heron I., 8–13 Oct. (Campbell & White 1910; Kikkawa 1970); Kermadec Is, Oct. (Oliver); Norfolk I., 17–22 Oct. (Hermes *et al.* 1986); Willis I., Great Barrier Reef, first birds seen at island 27 Aug. (Hogan 1925) but apparently not returning to nests until Oct. (Lawry 1926). Numbers of non-

breeding birds build up slowly in colonies until constituting about half the birds present (King 1974).

BREEDING Pre-laying exodus, ne. NSW, c. two weeks in late Nov. (Swanson & Merritt 1974). No information on movements then or on foraging distance from nesting islands, but birds in waters NE of NZ Feb.–May (Jenkins 1979) may include breeding birds from Kermadecs.

BANDING Returns from birds banded Coffs Harbour (ABBBS) summarized Fig. 1. Pattern of returns from other sites on NSW coast similar. Other record: 29S167E 11 1+ U 38 1423 271

FOOD No detailed analysis in A'asian waters but in Tropics mostly fish, some cephalopods and a few insects, jellyfish and prawns. **BEHAVIOUR.** Food taken by contact-dipping, dipping, surface-seizing and, rarely, deep-plunging (King 1974). Quantified observations: dipping 78%, pursuit-plunging 17% (71 observations; Ainley & Boekelheide 1983). Contact-dipping by flying close to surface with feet touching and wings held back while head plunged beneath water. Surface-seizing sometimes associated with dives but seldom complete submergence. Dipping used in pursuit of flying fish. In Tropics often part of flocks feeding on schooling fish along with Sooty Terns *Sterna fuscata*, White Terns *Gygis alba*, noddies *Anous* and boobies *Sula* (King 1974; Jenkins 1979; Au & Pitman 1986) as well as Spotted and Spinner Dolphins *Stenella attenuata*, *S. longirostris*, Common Dolphin *Delphinus delphis* and Rough-toothed Dolphin *Steno bredanensis* (Au & Pitman 1986); large flocks observed feeding in association with tuna off WA (Halse 1981).

BREEDING In Aust. waters, chicks' stomachs contained jellyfish (MacGillivray 1917), cephalopods (MacGillivray 1931) and fish. Stomach-oil consisted of triglycerides and cholesterol, reflecting diet and varying greatly between birds (Cheah & Hansen 1970). In **nw. Hawaiian islands** (233 regurgitated samples, 1963 items, ads 80%, chicks 20; Harrison *et al.* 1983) fish 67.0% vol., 73.3 no., cephalopods 28.6, 23.1, crustaceans 1.1, 2.7, insects 0.1, 0.2, coelenterates <0.1, 0.1, oil was also regurgitated but ignored in analysis. Mean length of all prey 5.7 cm (4–14.5, 212). Detailed analysis of fish: leptocephalus larv. <0.1% wt., 0.1% no., 0.4% freq., *Sardinella marquesensis* 0.5, 0.4, 0.9, *Encrasicholena punctifer* 0.8, 0.4, 0.9, *Vinciguerria* 0.4, 1.9, 0.9, Synodontidae 0.1, 0.2, 0.9, Myctophidae 3.8, 1.4, 4.7, 7.1 cm (SE5, 1.4–8.0, 14), *Paracoxoetus brachypterus* 0.4, 0.1, 0.4, unident. Exocoetidae 3.4, 1.1, 7.7, Holocentridae 0.1, 0.3, 2.1, *Dactyloptena orientalis* <0.1, 0.1, 0.4, Priacanthidae 0.4, 0.1, 0.4, *Decapterus macrossoma* 11.5, 2.8, 14.6, *D. tabl* 4.7, 1.0, 6.4, *D. spp* 8.5, 3.3, 13.3, *Selar crumenophthalmus* 0.2, 0.2, 0.9, *Seriola* 0.2, 0.1, 0.4, unident. Carangidae 0.1, 0.1, 0.9, *Coryphaena equiselis* 0.2, 0.2, 1.3, *C. sp.* <0.1, 0.1, 0.4, Mullidae 17.6, 26.5, 31.8, 5.4 (0.1, 4.8–6.4, 41), *Kyphosus bigibbus* <0.1, 0.1, 0.4, Sphyraenidae <0.1, <0.1, 0.3, *Bleekeria gillii* <0.1, 0.1, 0.4, *Ptereleotris heteroptera* 1.4, 26.3, 2.6, 2.8 cm (0.05, 2.2–3.0, 30), *Gempylus serpens* 0.1, 0.2, 1.3, *Katsuwonus pelamis* 0.2, 0.2, 1.7, *Psenes* 0.1, 0.1, 0.4, unident. Nomeidae 1.5, 1.2, 3.9, *Pervagor spilosoma* 0.7, 0.7, 0.9, unident. Monacanthidae 3.0, 1.7, 6.9, Tetraodontidae 0.1, 0.1, 0.9, unident. fish 5.8, 2.7, 15.0; cephalopods were Ommastrephidae *Symplecoteuthis oualiensis* 2.5, 0.5, 3.0, 8.5 cm (0.5, 5.7–10.0, 9), *S. spp* 4.0, 1.1, 6.4, 6.7 cm (0.4, 3.9–11.2, 21), unident. 15.0, 7.0, 25.8, 6.3 cm (0.3, 2.9–11.5, 69), *Hyaloteuthis pelagica* 0.3, 0.1, 0.4, unident. squid 6.4, 14.3, 21.5, Octopoda 0.4, 0.1, 0.4; crustaceans stomatopods *Lysiosquilla* 0.2, 0.3, 0.4, parasitic isopods 0.1, 0.1, 0.9, crabs

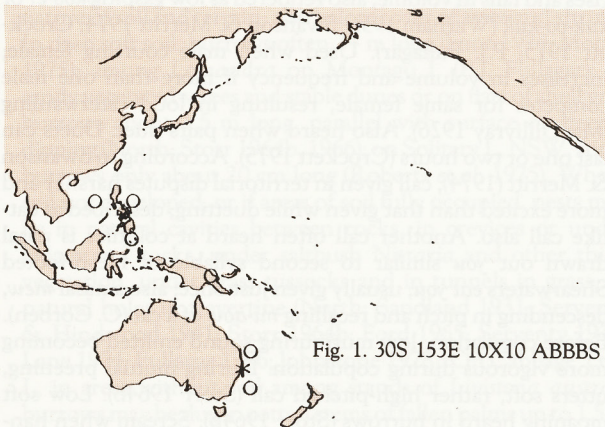


Fig. 1. 30S 153E 10X10 ABBBS

<0.1, 0.1, 0.4, crab megalopa 0.2, 1.0, 0.4, unident. 0.6, 1.2, 1.3; insects *Halobates sericeus* 0.1, 0.2, 1.3 and coelenterates were Scyphozoa <0.1, 0.1, 0.4.

SOCIAL ORGANIZATION At sea at onset of breeding, rarely seen singly but often in small (<20) loose companies within which birds seem to be paired (Marchant 1977). Disperse after nesting, singly or in small flocks. May congregate round source of food or form small rafts round breeding islands in late afternoon (Crockett 1975).

BONDS Monogamous; possibly life-long, at least long-term and may also spend year together (MacGillivray 1926; Marchant 1977), although Roberts *et al.* (1975) noted that some birds changed partners in successive seasons. Youngest breeding birds, 4 years old (Floyd & Swanson 1983), though birds 1 to 4 years old present in burrows during breeding season (Swanson & Merritt 1974). Both parents incubate and feed chick.

BREEDING DISPERSION Colonial. **TERRITORIALISM.** Once burrow excavated, birds frequently quarrel with others that venture too close. However, density of nests may be high: 33 burrows/100m² on Broughton Is (van Gessel 1978), 51/100 m² on Muttonbird I. (Floyd & Swanson 1983), 8/100 m² on Heron I. (Ogden 1929).

ROOSTING At breeding colonies, some birds arrive singly or in small groups throughout day (Crockett 1975) but most begin to fly in 1-2 h after dusk, continuing to stream in for 2-3 h (MacGillivray 1926; Storr 1964b; Swanson & Merritt 1974); before arrival in some localities, congregate and fly offshore in late afternoon (rafting not conspicuous feature as in some shearwater species) (MacGillivray 1926; Crockett 1975). Roost in burrows or on open ground; on sea at other times. Leave roost before dawn.

SOCIAL BEHAVIOUR Little information; much of what is known anecdotal. At colony, mainly active at night, arriving and departing daily at colonies *en masse*. Thus observations hindered by darkness. Scream when handled (Storr 1964b). During birds' daily arrival, usually skim low over vegetation, then sweep out to sea before landing and quickly disappearing down burrow. Early in season, may emerge from burrow during night and squat near entrance (Storr 1964b; Swanson & Merritt 1974). When cleaning burrow, according to MacGillivray (1926) use both feet alternatively, kicking almost continuous stream of dirt, however Warham (1956) describes scratching with one foot for some time (30 s) before changing to other; method used may be related to soil type; cleaning takes three to five nights (Crockett 1975). When digging new burrow, bird tilts body forward, so head almost touching ground, and scrapes vigorously with feet, until a depression forms; takes six nights to complete (Crockett 1975). Pair will sometimes dig together. Courtship similar to that described for other species of shearwater (Crockett 1975).

BEHAVIOUR AT SITE When threatening, birds call at each other, gradually increasing volume; sometimes develops into snarling and biting (Iredale 1910; Swanson & Merritt 1974). **COURTSHIP, PAIR-FORMATION.** Birds congregate on bare ground at night. If possible, previous season's mate courted again. Initially from about a metre away, male approaches female in crouching manner with head and neck extended and gular patch inflated, accompanied by soft moaning calls. If female does not flee, call becomes more frequent and changes to loud wail. Calls increase in volume and

frequency if more than one male competes for same female, reaching climax when female indicates her choice (MacGillivray 1926). In further stage of courtship, pair sit opposite one another, almost motionless and utter wailing or moaning call for an hour or two before settling down for the night; this phase not observed during daylight. Bill rubbing also occurs, followed by head and neck rubbing, during which eyelid is drawn across eye and birds moan with throat well puffed out. Courtship begins on surface, then progresses to burrow (Crockett 1975). During Oct. at Raine I., two birds can be found in each burrow (MacGillivray 1914). **COPULATION** preceded by bill-to-bill caressing and mutual preening of head and neck, accompanied by low wailing (MacGillivray 1926; Norman 1969; HASB). Copulation occurs either at entrance of burrow (just inside or outside) or on bare ground and vigorous murmuring can be heard (Norman 1969; Swanson & Merritt 1974; Crockett 1975; Dunlop & Storr 1981). Afterwards, pair rest, then inspect burrow, which female (and occasionally male) begins or continues to clean out (MacGillivray 1926).

RELATIONS WITHIN FAMILY GROUP Chick fed by both parents at night at irregular intervals and abandoned by day when few days old. Before departure, chicks emerge from burrows and sit at entrance; later emerge fully at night and exercise wings or wander about surface, returning for shelter during day (Swanson & Merritt 1974).

VOICE Detailed study by Shallenberger (1973). No song-agrams. Generally noisy at colonies and silent in flight. Calls often referred to as cat-like or soft moan. Softer than those of Flesh-footed Shearwater (Hindwood 1940). In colonies, calling by mating birds begins soon after arrival (after dark) and gradually increases in volume until assumes proportions of a loud murmuring roar (MacGillivray 1926). Incoming birds usually quite silent (Warham 1956) but late birds fly in, wailing (MacGillivray 1926). Noise level decreases after first few hours but never entirely ceases, and begins again before dawn (MacGillivray 1926); occasionally birds call in burrows throughout day (Tarr 1949). Noise level in colony on Kermadecs, high during Nov, nearly silent during pre-laying exodus (early Dec.), picking up again latter in Dec., then extremely quite from middle Jan. onwards (Crockett 1975).

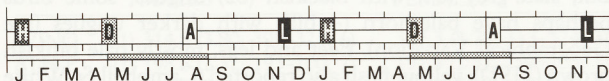
ADULT Slow wailing high-pitched song, often described as cat-like cry (Tarr 1949). First syllable faint, second very forced and strongly exhaled moan, third syllable a short gasping inhaled nasal gargle: *ka-whoooo-ahhh*; *whoooo* becomes more forced and frenzied as tempo of repetition rises; rises and falls in volume; also rendered as low gasping *koo-er* or *kuk-oo-kuk* (Warham 1956; Swanson & Merritt 1974; Crockett 1975; P.J. Fullagar). Used when male courting female; increases in volume and frequency if more than one male competes for same female, resulting in loud caterwauling (MacGillivray 1926). Also heard when pairs duet. Duets can last one or two hours (Crockett 1975). According to Swanson & Merritt (1974), call given in territorial disputes harsher and more excited than that given while duetting; described as cat-like call also. Another call often heard at colonies is nasal drawn out *you* similar to second syllable of Flesh-footed Shearwaters *eat you*; usually given just once; also a nasal *mew*, descending in pitch and recalling *mi-aow* of a cat (C. Corben). Before copulation, low murmuring sound emitted becoming more vigorous during copulation. During mutual preening, utters soft, rather high-pitched call (Storr 1964b). Low soft moaning heard in burrows (Storr 1964b). Scream when han-

dled (Storr 1964b).

YOUNG Large downy young produce continual cheeping when disturbed (Storr 1966); also able to utter warning calls similar to territorial dispute-call of adults (Swanson & Merritt 1974).

BREEDING Many reports in literature of visits to colonies on Aust. coasts, but few record entire nesting cycle; most complete studies by Swanson & Merritt (1974) and Roberts *et al.* (1975) on Muttonbird I., Coff's Harbour, NSW; also studied Kermadec Is (Merton 1970; Crockett 1975) and, extraliminally, Hawaiian Is (Shallenberger 1965). Breeds colonially, often associated with other species of petrel and shearwaters, on flat to sloping ground.

SEASON At Muttonbird I., birds return to colonies in first two weeks Aug.; prepare burrows from late Aug. to mid-Nov.; pre-laying exodus of 2 weeks about mid-Nov.; laying between 21 Nov. and 10 Dec.; hatching last half of Jan.; fledging from 25 Apr. to 12 May (Swanson & Merritt 1974; Roberts *et al.* 1975). At Montagu I., peak laying 27–29 Nov. (D. Purchase). Thus far, account representative of breeding throughout e. NSW coastal colonies and Lord Howe I. (Hindwood 1940; Keast 1943; North; van Tets & Fullagar 1984). In Capricorn Grp, Qld, birds arrive about 7–14 Oct. (Campbell & White 1910; Kikkawa 1970; Ogden 1979) and last young fledge 20–25 May (Miles 1964). At Norfolk I., season one month later than Lord Howe I. (van Tets & Fullagar 1984); birds arrive in Oct. (Bassett Hull 1910) and have eggs Dec.–early Feb. (Schodde *et al.* 1983); eggs erroneously claimed as early as Sept. (North). Similarly in Kermadec Is, laying starts about 12 Dec. (Merton 1970; Crockett 1975). In WA, earliest eggs on Rottneest I., 22 Nov. (Campbell; Storr 1964a,b) and at Houtman Abrolhos, 17 Nov. (Campbell), 12–19 Nov. (Gibson 1908). At N. Fisherman I., Jurien Bay, earliest egg claimed on 14 Oct. (Johnstone 1978), which must be an error, because Ford (1965) reported no eggs before 18–25 Nov. on several islands S from Jurien Bay. Serventy & Whittell (1976) gave earliest known egg in WA as 29 Oct. on Airlie I. off Onslow, much farther N. As far as can be judged, laying period seems similar on e. and w. coasts of Aust., S of about 29°S.



SITE Usually in burrows on flat or flattish areas with dense grassy and tussocky vegetation but much depends on nature of soil and terrain; also below cover of trees and shrubs. In deep soft soil, burrows often 2+ m long (Lane 1974; Morris 1975); among *Lomandra* on Montagu I. (P.J. Fullagar); in sandy vegetated screes and stable dunes or on flats of shell grit, burrows about 1.5 m long, parallel with surface or steeply dipping (North; Storr 1964b, 1966); on Solitary I., NSW, some burrows only about 20 cm long (Roberts *et al.* 1975). Where soil not developed, or if areas of soil fully occupied, nests may be in natural cavities between rocks, in crevices or under ledges and rocks, under saltbush *Nitraria* and other thick vegetation, under grass tussocks and in tunnels in grass, in natural holes in travertine (North; Sandland 1931; Serventy & Hindwood 1941; Storr 1964b; Ford 1965; Serventy 1972; Lane 1974; Fullagar 1976; Johnstone 1978). On Cabbage Tree I., in areas without soil among stands of *Livistona australis* burrows may be dug in rotten stems of fallen palms up to 1.5 m

long (Serventy 1942). On islands of Capricorn Grp, Qld, prefers areas of closed climax forest dominated by *Pisonia* rather than areas of sandy coastal vegetation (Campbell & White 1910; Ogden 1979). On Kermadecs, all types of sites and different lengths of burrows noted, from sea-level to summit of islands (Crockett 1975). At Muttonbird I., density of burrows in occupied areas varied from 9.3 to 4.6/10 m² according to nature of vegetation and terrain. At Broughton I., av. density 3.3/10m² (van Gessel 1978). At Heron I., 8.5–9.5/10 m². At Montagu I., in mixed colony (37% *P. pacificus*, 63% *P. tenuirostris*) over 22 seasons, maximum 15 chicks/100 m², av. 9.6/100 m², (P.J. Fullagar). On Kermadecs, av. 11 occupied burrows/100m². Where density high in soft sandy areas, hard or impossible to walk through colony without damaging burrows severely (MacGillivray 1926); also where burrows very dense, they may merge and two eggs may be found in some (Swanson & Merritt 1974; P.J. Fullagar). Some birds return to same burrows or nearby year after year (MacGillivray 1926; Swanson & Merritt 1974; Roberts *et al.* 1975; P.J. Fullagar).

NEST, MATERIALS Chamber about 30 cm in diameter at end of burrow about 15 cm in diameter (Storr 1964b) but in 'all burrows opened' by Sandland (1931) chamber was 45–75 cm from end of burrow and 60–150 cm from entrance. Some adventitious material often found in chamber (P.J. Fullagar) but Crockett (1975) indicated that pieces of vegetation were carried into nest and could be used to block entrance. When digging or cleaning out burrows, birds scratch with one foot for about half a minute and then change to other (Warham 1956) or use both feet alternatively (MacGillivray 1926). Both male and female may enter tunnel together, vigorously kicking out sand or soil (MacGillivray 1926). Damaged or trampled burrows re-excavated, even after hatching (Swanson & Merritt 1974). New burrows finished in six nights, old burrows cleaned out in three to five nights (Crockett 1975).

EGGS Oval or ovoid, lengthened or swollen, blunted or pointed at smaller end; close-grained, dull; white, becoming stained (North).

MEASUREMENTS:

62.15 (58.42–67.82; 12) x 40.09 (36.83–42.67) (North); 62 (58–69; 32) x 41 (39–44) (Serventy & Whittell 1976); 61.6 (2.1; 64.1–66.6; 11) x 40.4 (1.0; 39.0–42.5) (P.J. Fullagar); laid on surface at Norfolk I.: 67.4 (65.7–68.7; 5) x 43 (41.4–44.4) (Tarburton 1981).

CLUTCH-SIZE One. No replacement laying.

LAYING At Muttonbird I., well synchronized between 21 Nov. and 3 Dec., with peak about 27 Nov.; 65% of eggs within 3 days of mean date (Swanson & Merritt 1974; Roberts *et al.* 1975). At Kermadec Is, peak of laying 15–23 Dec., spread 12–28 Dec. (Crockett 1975) but Murphy (1951) and Oliver claimed peak two weeks earlier. Usually laid at night (Crockett 1975).

INCUBATION By both sexes. First shift by males eight times, by females 16; longest shift 5 days. **INCUBATION PERIOD:** 4 x 52 days, 2 x 54 days, 3 x 54 days, all ± 1 day (Roberts *et al.* 1975).

YOUNG Altricial, nidicolous. Pipping to hatching can take 3 days (Roberts *et al.* 1975). Hatched with upperparts and most of underparts covered in ash-grey down; throat and upper breast, paler grey to white (Bassett Hull 1911); down, rusty red in a few individuals (Swanson & Merritt 1974; P.J. Fullagar). Fed by both adults by incomplete regurgitation. Behaviour during feeding probably as in Short-tailed

Shearwater (Warham 1960). Usually attended by parent for first day after hatching; thereafter usually deserted by day, most adults returning to nest between 19:00 and 20:00 (Swanson & Merritt 1974); Roberts *et al.* 1975). **NESTLING PERIOD** about 14 weeks, determined twice (Roberts *et al.* 1975).

GROWTH At Muttonbird I., weight at hatching c. 50 g, doubling only after one week; maximum weight of c. 550 g when 10 weeks old, declining to c. 450 g on fledging. At Montagu I., in late Mar., 31 chicks averaged 570 (87; 400–775) or c. 150% of average adult weight (380 [30; 300–450]) (P.J. Fullagar). Egg-tooth persists for about 2 weeks, being lost between 13 and 16 days (Roberts *et al.* 1975). Primary quills emerge in Mar., or when about 6 weeks old and burst by mid-Mar.; contour-feathers appear when chick about as large as adult (Swanson & Merritt 1974). Chicks not deserted by parents in last few days before fledging (Miles 1964; Roberts *et al.* 1975). Exodus at Muttonbird I. during 7–10 days at end Apr. to early May, generally complete between 3 and 10 May (Roberts *et al.* 1975; Swanson & Merritt 1974). Not recorded to breed before four years old (Floyd & Swanson 1983).

SUCCESS At Muttonbird I., in 3 years, 32, 47, 54% of sample of occupied burrows (93, 114, 102 respectively) produced a fledgeling; most loss was of eggs (55.8% survival) and not of chicks (78.8% survival), perhaps caused by human interference (Floyd & Swanson 1983). Torrential rain caused loss of 54% of occupied nests during incubation in Kermadec Is (Crockett 1975). **PREDATORS**. On Kermadec Is, cats and rats have caused great decline in breeding population. Particularly vulnerable to foxes *Vulpes vulpes*, rats and feral cats (Serventy 1972; de Ravin 1975; Tarburton 1981); *Varanus* lizards, snakes and gulls *Larus* spp may take eggs and chicks.

PLUMAGES

ADULT Definitive basic. Assumed after first pre-basic, probably at c. 15 months; age of first breeding unknown. Polymorphic. **Dark morph.** **HEAD AND NECK.** Forehead, lores, crown and hindneck, uniform dusky brown (c19) with grey tinge. Feathering round base of bill, ear-coverts, chin, throat and foreneck, ash grey (c84) with brown tinge. **UPPERPARTS.** Mantle, back, rump and upper tail-coverts, uniform dusky brown (c21). All these feathers have grey-white bases, occasionally visible in mantle when feathers ruffled. Scapulars, dusky brown (c19) with pale grey-brown (c79) open pennaceous tips. Longest scapulars, darker brown (-) with narrower grey-brown tips. When worn, scapular tips become pale brown (c119D, 92) and broader. Feathers on back, rump and upper tail-coverts develop narrow pale-brown (119d, 92) tips. **TAIL,** brown-black (-). **UPPERWING.** Marginal coverts, dark dusky brown (-). Humeral, greater, median and lesser coverts, dusky brown (c19) with pale grey-brown (c79) tips, becoming wider and pale brown (119D, 92) with wear. Remiges, brown-black merging to black (89) in outer primaries. **UNDERPARTS.** Axillaries, black-brown. Rest of underparts, brownish grey (brownish 84); all feathers have narrow pale grey-brown (c119D) tips, which become broader and more buff with wear, giving underparts a brown wash. **UNDERWING.** Marginal coverts, blackish brown with pale grey-brown tips. Lesser and median under wing-coverts, brownish grey (c79). Primaries, dark brown-grey with slight silvery gloss (-), and black (89) tegmen. Humeral, secondaries and greater under wing-coverts, similar, but without tegmen. Subhumeral as scapulars and secondaries, but seldom show any signs of abrasion. **Pale morph** (differences from dark morph). **HEAD AND NECK.** Forehead, crown and hindneck,

dark brown (c21). Chin and throat, white. Junction of dark upperside and white underside, brownish grey (brownish 84), sometimes with strip of grey vermiculation immediately below, where feathers white with a grey (84) transverse bar. **UPPERPARTS.** Longest scapulars, black-brown with narrow grey-brown (c79) tips. Feathers of remainder of upperparts, dark brown (c121) with light grey-brown (119C) to white frosted edges. **TAIL,** dark brown (121). **UNDERPARTS.** Breast to vent, white, sometimes with faint light-grey (85) wash; feathers white, sometimes with narrow light-grey bars. Under tail-coverts and lateral rump-feathers covering thighs, dark brown (119A). Flanks, washed brownish grey; feathers, brownish grey (brownish 79) with white mottling most extensive near tip. Axillaries, brownish grey (brownish 79) with white mottling near tip of lower web. **UNDERWING.** Remiges as dark morph. Marginal and lesser under wing-coverts, grey-brown (c121). Outermost coverts on leading-edge of wing between carpal joint and p10, brownish grey (greyish 121) with white tips and inner webs. Remaining under wing-coverts, white with greyish (c79) vermiculations near tip. **Intermediate morph.** Rare; none examined. Some birds have concealed white bases to feathers of underparts, these occasionally giving grey (-) wash to underparts (Loomis 1918; Murphy 1951).

DOWNY YOUNG Proto- and mesoptile, uniform brown-grey (brownish 84) to grey-brown (greyish 119B) with slightly shorter and darker (c121) down on head. At Muttonbird and Solitary Is, NSW, a few birds in mesoptile tinged rufous, some being rust-red (33–121C). Proportion of rust-red chicks 2.5–4%; proportion higher on Solitary Is. Unknown if first down also polymorphic (Swanson 1974; N.M. Swanson).

JUVENILE Similar to adult. Readily identified at breeding grounds, where adults have worn, and juveniles fresh, plumage.

BARE PARTS Based on HLW, NMNZ and A.J.D. Tennyson and photographs in Lindsey (1986), NZRD and AUST. RD.

ADULT, JUVENILE E. coast of Aust., Lord Howe and Kermadecs. Dark phase: Iris, dusky brown (19) to black. Bill, slate-grey (84) with blackish (82) unguis; some birds perhaps have pale-horn (-) bills with darker unguis (see Geographical Variation). Feet and legs, mostly pale pinkish brown (119D); yellow-flesh also reported (Campbell & White 1910 and quotes thereafter) save for dark-brown (19) scutes on outer edge of outer toe; this brown mottling most extensive at toe-joints and also seen on outer side of tarsus and at tibio-tarsal joint. Claws, pink-white (-) to white (van Tets *et al.* 1964 and sources below). Pale phase, similar (Lane 1972).

DOWNY YOUNG E. coast of Aust., Kermadecs. In protoptile: bill black (-) with horn-coloured (-) tip; feet, yellowish white (Mathews 1912). In mesoptile: iris, dark brown (-); bare skin round eyes and base of bill, light grey (85); bill, medium grey (84) with blackish (-) unguis, brownish grey (80) culmicorn and blue-grey (88) base to ramicorn; feet, yellowish white (Mathews 1912); claws, white or pink-white. Jenkins (1986) describes bare parts of chick in mesoptile in Fiji.

MOULTS

ADULT POST-BREEDING Pre-basic. King (1967) provides most complete description available; based on specimens from central and e. Pacific and summarized below.

Primary moult outwards; several inner primaries can be replaced simultaneously but only one distal (p7 to p10) primary replaced at a time. Moult of rectrices irregular; most intense during later stages of primary moult. Body-moult probably starts at same time as primaries but more protracted. Head- and nape-feathers replaced first, followed by scapulars. At Christmas I. (PO), birds completing moult of p10 and tail on return to breeding grounds. No moult of remiges occurs during incubation; moult takes six months or less (Schreiber & Ashmole 1970). Uncertain how well this description applies to birds breeding in our region. Birds breeding in WA, se. Aust., Lord Howe and Kermadecs apparently moult remiges when at sea between May and Aug. (Swanson & Merritt 1974; HLW; NMNZ). Some birds arriving at Muttonbird I., NSW, in Aug. and Sept. were replacing tail-feathers (Swanson & Merritt 1974) and presumably completing prebasic moult. This consistent with data of King (1967) and Schreiber and Ashmole (1970). However, at Muttonbird I., at least some, perhaps all, body-moult done by incubating adults where random replacement of crown-feathers takes place in Dec. and Jan. (Swanson & Merritt 1974). No data from Norfolk I. or Coral Sea. Information on timing in central and e. Pacific in King (1967).

POST-JUVENILE, SUBSEQUENT MOULTS No information from our region. In central and e. Pacific, juvenile plumage probably retained for 15 months and then replaced at same time as that of adults (King 1967). Birds collected at sea further advanced in moult than breeding adults collected on same date in nearby burrows, which suggests non-breeders moult earlier than adults (Loomis 1918).

MEASUREMENTS (1) Kermadec Is, definitive, skins (NMNZ). (2) Kermadec Is, skins; methods unknown (Murphy 1951). (3) Kermadec Is, unknown status, live birds; minimum chord (A.J.D. Tennyson, G.A. Taylor, P. Schofield). (4) Norfolk I., skins (Murphy 1951). (5) NSW breeding ground, definitive, skins (MV, HLW). (6) WA, definitive, skins (NMNZ, MV, HLW). Measurements from other parts of range in Murphy (1951). Information on growth of chicks in Hawaii in Pettit *et al.* (1984).

| | MALES | FEMALES |
|--------|-------------------------------|---------------------------|
| WING | (1) 314.8 (3.80; 309-321; 6) | 317.3 (4.78; 313-324; 3) |
| 8TH P | (1) 198.6 (2.32; 193-200; 7) | 197.4 (2.87; 194-203; 7) |
| TAIL | (1) 140.3 (2.21; 138-144; 6) | 138.7 (5.25; 134-146; 3) |
| BILL | (1) 42.3 (1.09; 41-43.8; 6) | 40.2 (0.70; 39.4-49.1; 3) |
| TARSUS | (1) 52.6 (0.61; 51.5-53.5; 6) | 51.4 (0.76; 50.4-52.2; 3) |
| TOE | (1) 63.8 (1.54; 61.6-66.4; 6) | 64.7 (1.32; 62.8-65.6; 3) |

| | UNSEXED |
|-------|--|
| WING | (2) 314.0 (5.81; 300-327; 39) (3) 317.6 (4.08; 311-324; 15) (4) 305.2 (6.02; 294-317; 18) (5) 290.7 (6.65; 280-300; 9) (6) 186.1 (3.27; 178-190; 10) |
| 8TH P | (5) 186.1 (3.27; 178-190; 10) (6) 183.4 (4.69; 176-190; 7) |
| TAIL | (3) 139.1 (5.29; 128.3-149; 15) (5) 132.2 (5.57; 121-139; 9) (6) 128.1 (5.96; 120-136; 7) |
| BILL | (2) 41.5 (1.31; 39.5-44.2; 39) (3) 41.4 (1.76; 38.4-44.4; 15) (4) 40.5 (1.34; 38.2-43.2; 18) (5) 37.2 (1.24; 34.8-38.8; 10) |

| | |
|--------|--|
| | (6) 38.2 (1.41; 36.2-39.8; 7) |
| BILL D | (3) 15.1 (0.77; 13.7-16.4; 15) |
| BILL W | (3) 14.7 (0.75; 13.5-16; 15) |
| TARSUS | (2) 50.7 (1.25; 47.1-53.4; 39) (3) 51.9 (1.45; 49.7-54.2; 15) (4) 49.9 (0.90; 47.9-51.4; 18) (5) 48.8 (1.06; 46.1-50.1; 9) (6) 47.8 (1.52; 45.6-50.9; 7) |
| TOE | (3) 62.6 (2.19; 59.6-67.2; 15) (5) 57.5 (1.92; 54.5-60.4; 10) (6) 55.8 (1.58; 53.2-58.2; 7) |

WEIGHTS Adults: MacAuley I., Kermadecs, 29 Nov., unknown sex and status, 454.4 (23.74; 415-490; 14) (A.J.D. Tennyson, G.A. Taylor, P. Schofield). Kermadec Is, late Oct.-late Nov., males 457.0 (15.49; 430-475; 6), females 474.6 (45.12; 411-568; 5) (NMNZ). Muttonbird I., between arrival and pre-egg exodus (13 Aug.-4 Nov.), 380.1 (300-500; 310); breeding adults at end of laying and start of incubation (2 Dec.-11 Dec.), 388.0 (300-500; 770); breeding adults at beginning of hatching (mid-Jan.), 320-480; 188 (N.M. Swanson).

Downy young: Muttonbird I., just after hatching (13-15 Dec.), 40-150; 36; maximum pre-fledging weight 600-680 (N.M. Swanson). For information on gain of weight in Hawaii see Pettit *et al.* (1984).

STRUCTURE Eleven primaries, p11 minute. p10 longest, p9 0-5, p8 8-21, p7 29-42, p6 51-68, p5 75-88, p4 100-114, p3 121-141, p2 145-162, p1 155-181. Twenty-one secondaries, 4 of tertial form, 4 small humerals. Tail, wedge shaped, 12 feathers, t1 50-61 longer than t6. Bill, long and rather slender; depth at culminicorn one-fifth to one-quarter length of bill. Upper mandible, hooked at tip; lower mandible, decurved at tip. Nasal tubes, about one-quarter of length of bill; nasal septum, broad and oval; nostrils point forwards and upwards. Tarsus, scutellate and laterally compressed. Outer toe c. 105% of middle, inner toe c. 80%.

GEOGRAPHICAL VARIATION Murphy (1951) recognized two subspecies; *pacificus* from Kermadec Is, Norfolk I. and Kandavu I., Fiji; significantly smaller *chlororhynchus* from rest of range. Within *chlororhynchus* found gradual increase in dimensions from W (Seychelles) to E (central Pacific). No subspecies currently recognized (Peters). In Pacific, pale-phase birds most common in n. breeding colonies e.g. Hawaii, Bonin Is and Pescadore, where nearly all light phase. For more information on proportions of pale- and dark-phase birds in different areas, see King (1967). Only dark-phase birds known to breed Kermadec Is, Norfolk I., Lord Howe I. and e. coast of Aust., but pale-phase bird collected N. Solitary I., NSW, was almost certainly breeding (Lane 1972). At Shark Bay, WA, 20-30% of birds at breeding colony, pale phase (Serventy 1972). No other records of pale-phase birds from Indian Ocean breeding grounds.

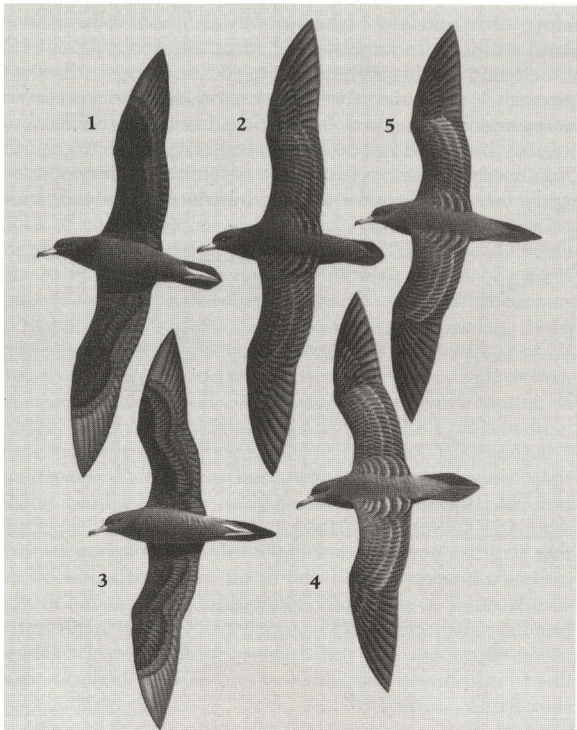
Bill colour may vary geographically. From e. Aust. to Kermadecs at breeding grounds, small proportion of birds may have pale-horn bills with darker unguis. This appears on labels of few skins, but may have been recorded after drying, when blackish bills often discolour to pale horn. Some live birds at sea off e. Aust. coast have pale bills with darker unguis (M.J. Carter). Little information on colour of bill in Indian Ocean. Two birds photographed Indian Ocean (Lindsey 1986) had whitish bills with dark-grey (83) to blackish (82) unguis. Horn (-), flesh-horn (-) and bluish-horn (-) bills also

recorded on labels of most skins from Indian Ocean (HLW; NMNZ; Lesson 1831; Gould 1865; Mathews 1912; Falla 1962). Dark-grey bill recorded on two labels (HLW; MV). Bailey (1966) used grey bills as an identification character in Arabian Sea. No other known variation in bare parts.

DIR

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Volume 1 (Part A), Plate 45

Flesh-footed Shearwater *Puffinus carneipes*

1. Adult, ventral

2. Adult, dorsal

Wedge-tailed Shearwater *Puffinus pacificus*

3. Adult, ventral

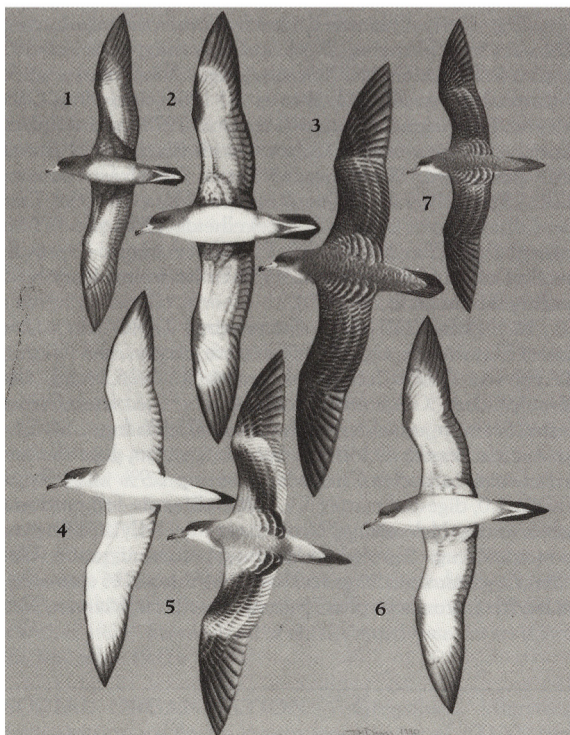
4. Adult, dorsal, worn

5. Adult, dorsal, fresh

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Volume 1 (Part A), Plate 46

Pink-footed Shearwater *Puffinus creatopus*

- 1. Adult, dark morph, ventral
- 2. Adult, light morph, ventral
- 3. Adult, dorsal

Buller's Shearwater *Puffinus bulleri*

- 4. Adult, ventral
- 5. Adult, dorsal

Wedge-tailed Shearwater *Puffinus pacificus*

- 6. Adult, light morph, ventral
- 7. Adult, light morph, dorsal

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