

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 tenuirostris Short-tailed Shearwater

COLOUR PLATE FACING PAGE 656

Procellaria tenuirostris Temminck, 1835, *Planches Col.* 99: text to Pl. 587 — seas north of Japan and shores of Korea.

The specific name refers to the narrowness (*tenuis* slender) of the bill.

OTHER ENGLISH NAMES Muttonbird, Tasmanian Muttonbird, Bonaparte, Slender-billed or 'Sooty' Shearwater, Short-tailed or Slender-billed Petrel, Sealbird.

Short-tailed is well established in Australasian literature but is not specially appropriate because the tail of this species is not obviously short in the field; yet the alternative, **Slender-billed**, is equally useless as a field character.

MONOTYPIC

FIELD IDENTIFICATION Length 40–45 cm; wingspan 95–100 cm; weight 480–800 g (some heavier during late incubation). Medium-large all brown-grey shearwater, very similar to larger Sooty Shearwater *P. griseus* in most respects. Feet extend slightly beyond short rounded tail in flight. Regularly feed in large mixed flocks with other shearwaters, petrels, gannets and terns. Often gather in large flocks, occasionally of millions. Sexes alike. No seasonal or age differences apart from plumage wear.

DESCRIPTION ADULT. Dorsum, dark brown-grey. Upperwing, sooty-brown with black primaries and secondaries. Tail, black-brown. Venter, slightly paler; many have

whitish chins. Underwing varies from uniform grey to having (rarely) white primary coverts and central median secondary coverts. Primaries, secondaries and greater secondary coverts, grey, and tend to be reflective in strong sunlight; primary and central median secondary coverts vary: usually all grey, or grey with white in very centre of median primary and secondary coverts; in some, uncommonly, most primary coverts, white; leading-edge, especially inner part, and axillary region, darkest parts of underwing. At distance looks all-dark apart from paler central underwing coverts; reflected sunlight can make underwing look paler than it is. Bill, short and stubby compared to most shearwaters. Nostril tubes and maxillary unguit

raised only slightly above culmen. Nostrils, culmen, bill-tip and plate-borders black, sides leaden-grey to olive. At sea, bill usually appears black, but in strong light can look brownish. Iris, dark brown. Legs and feet, blackish on outer tarsus and outer toe; inner leg, toes and webs, flesh-pink to purplish pink. Legs, laterally compressed.

SIMILAR SPECIES **Sooty Shearwater:** very similar and hard to separate. Slightly larger than Short-tailed with longer bill and perhaps less slim in appearance (Wahl 1980). White on underwings usually more extensive and closer to leading-edge of primary coverts; often have more streaking and sub-terminal barring throughout underwing. Underwing pattern a general guide, but unwise to rely on this feature for single birds, as variation great in both species; separation of flocks more straightforward. In profile, less 'steep' forehead and flatter crowns. Harrison (1987) suggested that Short-tailed Shearwaters have darker cap and whiter throat, imparting more hooded appearance; but many Short-tailed Shearwaters have dark throats. Short-tailed Shearwaters tend to be faster fliers, more limber-winged and agile, although flight greatly affected by wind-speed. In Bass Str., Jan. to May, many Sooty Shearwaters (probably non-breeders) in heavy moult, whereas Short-tailed Shearwaters never in remex moult at this time. **Wedge-tailed Shearwater** *P. pacificus*: broader wings, cocked forwards and swept back at carpal joint; wedge-shaped tail longer but wedge-shape not often seen; pale feet never extend past tail. Underwing, uniform brown-grey. Flight lazy and graceful, usually close to water, without stiff rapid flapping of Short-tailed. Bill paler brown than Short-tailed and can appear very pale. **Flesh-footed Shearwater** *P. carneipes*: larger with longer rounded tail (without trailing feet), much larger pale bill, totally pale feet and more leisurely flight, without rapid flapping of Short-tailed. **Christmas Shearwater** *P. nativitatis*: smaller, with heavier bill, broader wings and longer tail and feet not extending beyond tail. Flight more buoyant, with more wing-flapping and less gliding and arcing. **Great-winged Petrel** *Pterodroma macroptera*: larger and longer-winged; has short stubby black bill, and large head with high forehead; many have pale grey faces. Long slender wings held well forward and swept back at carpal joint. Underwing, all-dark apart from silvery reflective primaries. Flight fast and graceful, with high arcing and few wing-beats; feet do not protrude beyond tail.

Gait of Short-tailed Shearwater, on land and when swimming, as for Sooty Shearwater. Fly in arcs above sea, flapping on stiff wings in troughs and on upward climb; the stronger the wind the higher the arcs and the less flapping. Very rarely follow boats, though perhaps do so more often in n. Pacific (Wahl 1980). At sea tend to travel in flocks, often large and sometimes by millions; when migrating also small flocks of less than 20 (Guzman 1981). Form large rafts off breeding islands in late afternoon. Mix readily with other shearwaters, petrels, gannets and terns. Strictly nocturnal at breeding colonies. Usually silent at sea and when flying over colonies. Early in breeding season, before eggs laid, highly vocal on ground and in burrows; much quieter later in season; main calls a variety of crooning or hysterical wailing notes, often given in duet.

HABITAT Marine, pelagic; birds ranging S to 65°S in Antarctic Zone probably pre-breeders, non-breeders or failed breeders (Kerry *et al.* 1983). In breeding range, occur mainly over continental shelf waters, both inshore and offshore

(Warham 1960; Cheshire 1982; Montague *et al.* 1986), but also found in pelagic waters (Cox 1976). On passage, cross pelagic tropical waters; food supply in warm waters limited and birds that are unable to reach cool productive waters may suffer mass mortality (Oka 1986). In n. Pacific Ocean, associated with continental shelf, particularly offshore, with small numbers in pelagic waters (Baltz & Morejohn 1977; Wahl 1978); high densities of birds over coastal cool-water upwellings (Ainley 1976; Tanaka & Kajihara 1979). In Gulf of Alaska and Kodiak I., greatest numbers between 60 and 230 km offshore; in Apr.-July birds over shallower water (45-90 m) than in Aug.-Sept. (91-183 m), perhaps because seasonal currents change (Guzman 1981). Distributed over seas of wide range of surface-temperatures (Kuroda 1955; Guzman 1981).

Breed on inshore islands and on headlands and promontories of mainland in se. Aust, breeding range extending to se. WA at Figure of Eight I.; burrow where soft soil of at least 30 cm depth stabilized by vegetation; in native and modified grasslands, herbfields, bracken, scrubland, open forest; occasionally in cliffs of consolidated sand or on bare ground (White 1979a; Harris & Norman 1981; Naarding 1980). Sandy beaches, rocky areas, very dense vegetation and very steep slopes avoided (Norman 1977; White 1979b; Harris *et al.* 1980).

Fly at heights of 0.3-10 m above sea surface, with height increasing with wind-speed (Guzman 1981); on return to Phillip I. colonies, birds may rise to 60 m over cliffs (K. Fitzherbert); in strong winds, skim along wave-furrows and bank upwards against wind (Warham 1960). Feed from and below sea surface, diving to depths of up to 12 m to feed among weed on sea bottom (Skira 1979). Settle in rafts on surface on calm days and before nightly arrival at colonies. Bushes, high ground and rock outcrops near breeding colonies used for take-off (Warham 1960).

Some breeding colonies close to human settlement eliminated or breeding habitat modified by introduced pasture grasses and weeds; annual weeds die back leaving breeding areas susceptible to erosion and collapse of burrows (K. Fitzherbert; Harris & Norman 1981); areas covered by densely growing introduced plants (boxthorn, blackberry, kikuyu grass) or pasture unsuitable for burrowing (Brothers & Milledge 1979; Bowker 1980; Brothers 1983; Skira and Brothers 1988). Grazing (cattle, rabbits), fires and trampling by stock denude vegetation and cause erosion and sand-drifts (Harris & Bode 1981; Harris & Norman 1981); although grazing by sheep did not affect breeding success on Green I. (Norman 1970). After programs to control rabbits on breeding islands, birds recolonize revegetated areas (Norman *et al.* 1980). Predation by foxes and domestic dogs a problem at some colonies.

EXPLOITATION. Long history of exploitation. Archaeological evidence suggests Aboriginal people living on Hunter I., in sw. Tas., took small numbers. In 1820s, sealers began trading in adults, nestlings and eggs. By 1900, annual harvests recorded to be near one million chicks from Furneaux Grp alone (Skira *et al.* 1985). Taking of eggs prohibited from 1902 but taking of adult birds not until 1976. Now only nestlings harvested commercially; industry centred on Furneaux Grp, Tas., illegal in Vic. and little practised in SA. Mostly used for food. Yearly commercial harvest of > 300 000 chicks from seven colonies. Estimated non-commercial harvest of 300 000; non-commercial licences issued with bag limits of 50/day on Bass Str. Is, and 15/day elsewhere. Estimated chicks commercially harvested in colonies: at Great

Dog I., $51.3 \pm 19.2\%$ in 1977, $31.3 \pm 23.3\%$ in 1978, 21.5 ± 24.5 in 1979 (Skira & Wapstra 1980); for all commercial colonies, greater than or equal to 30% (Skira *et al.* 1985). Estimated chicks non-commercially harvested in colonies: C. Queen Elizabeth, $88.3 \pm 8.16\%$ in 1977, $96.3 \pm 4.1\%$ in 1978; 83.2 ± 12.7 in 1979 (Skira & Wapstra 1980); in 24 colonies, greater than or equal to 90% between 1977–81 (Skira *et al.* 1985). Trampling of burrows during harvest and poaching regarded as significant cause of loss (Skira & Wapstra 1980).

DISTRIBUTION AND POPULATION Fully migratory, with extensive movement through Pacific Ocean: N to nw. Pacific, extending N of Bering Str. (to 71°N) and S in ne. Pacific past w. North America, returning sw. through central Pacific (recorded E to Tuamotu Arch.) to breed on islands off s. Aust.; also some, probably regular, movements in e. Indian Ocean, reaching seas of Pakistan, Sri Lanka and s. Thailand, and of non-breeding birds to Antarctic seas in summer (Frith 1978; Kerry *et al.* 1983; Peters).

Occasional or regular non-breeding summer visitor to Antarctica, recorded 20–21 Feb. 1980, $64^\circ 37'\text{S}$, 18 Feb. and 17 Mar. 1981, $60^\circ 57'\text{S}$ (Kerry *et al.* 1983).

AUST. Common breeding visitor to central and pelagic waters of s. and e. Aust. at least as far N as 17°S . Breed on islands off coast of NSW, Vic., Tas., SA and WA (below). **QLD.** Common passage migrant off SE, Aug.–Nov., uncommon Dec.–Feb., rare Apr.–June, most in pelagic waters; vagrant off NE, Sept., Nov., Dec., recorded N to Cairns $16^\circ 56'\text{S}$ (Baker & Gill 1974; Aust. Atlas; Longmore 1985; Qld Bird Rep. 1984). **NSW.** Common Sept.–Mar., less common Apr.–May, rare June–Aug.; first evidence of NSW breeding colony on Tollgate Is confirmed in Nov. 1958. Breeding unconfirmed Lion and Muttonbird Is (Lane 1961, 1970, 1974, 1979; McGill 1961; McKean & Fullagar 1976; Morris 1975, 1986; Morris *et al.* 1981; Aust. Atlas; Smith & Chafer 1987; NSW Bird Rep. 1980, 1984). **Vic.** Common Oct.–Mar., less common Sept., Apr.–May, rare June–Aug. Largest colonies on islands off

Wilson's Promontory (including Seal I.) and Phillip I. (numbers declining) (Cooper 1974; Harris & Bode 1981; Learmonth 1966; Wheeler 1981; Aust. Atlas; Vic. Atlas; Vic. Bird Rep. 1981). **Tas.** Abundant; also King and Furneaux Is, Sept.–Apr., uncommon or rare, May–Aug. (Green 1977; Naarding 1981; Sharland 1981; White 1981, 1985; Skira *et al.* 1985; Aust. Atlas). **SA.** Common Sept.–May, rare Jun.–Aug.; also inland records of storm-blown birds in SE: Waikerie, Renmark, Naracoorte. Possibly once bred on mainland at Douglas Point, 8 km NW of C. Northum and formerly bred Goat I. (in Pandalowie Bay) and Wedge I.; no evidence of breeding on Pearson I. (*contra* HASB) (Condon 1969; Aust. Atlas; SA Bird Reps 1977–81; Cox 1976, 1978; Parker *et al.* 1979; Parker & May 1982). **WA.** Locally common Oct.–May, seas of s. WA, rare off sw. coast (one, Yallingup 6 Nov. 1976; Storr & Johnstone 1977, but not listed by them in 1988; Lane 1982, 1983; Aust. Atlas).

NZ Uncommon (migrant) to waters off w. NZ, Nov.–May; stragglers reaching w. and n. NI; less frequently reach w. SI, but large numbers beachcast some years, e.g. 1968, and large flocks occasionally recorded, mostly off n. NI; also straggles to Kermadec Is (Raoul I.) and Campbell I. (Westerskov 1960; Kinsky 1968; Merton 1970; Falla *et al.* 1981; NZCL).

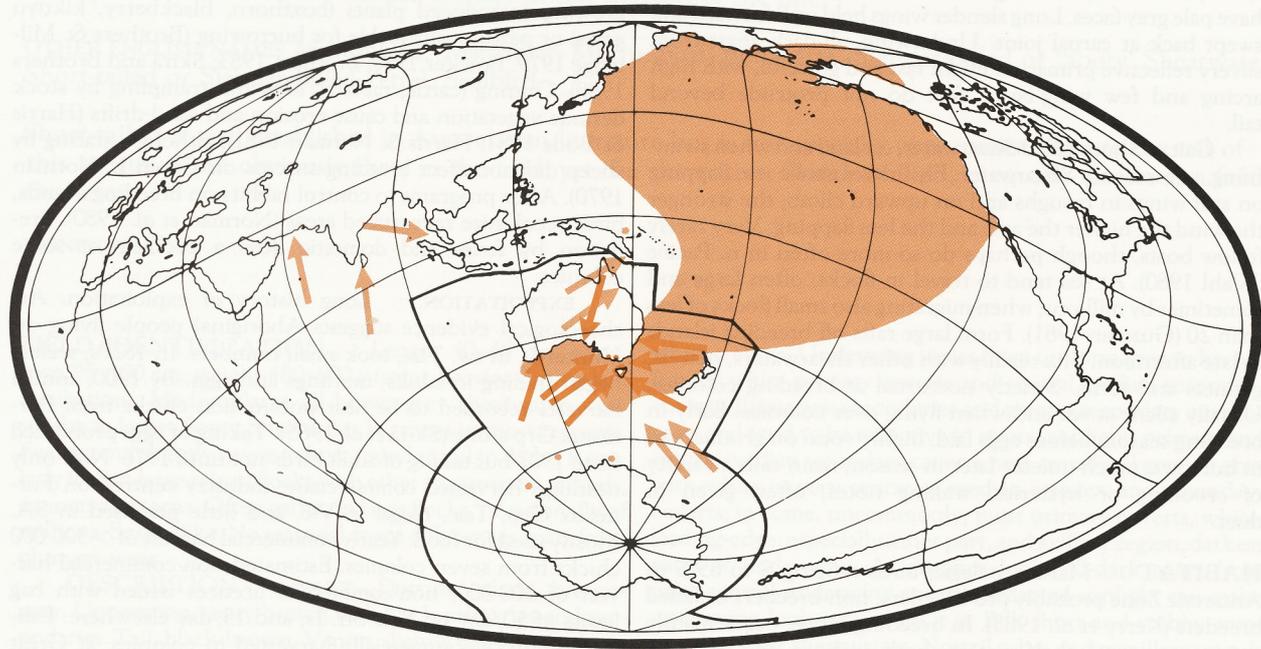
MACQUARIE I. Vagrant: one found dead 19 Nov. 1960, some skeletal remains found later; also observed at sea, S of Macquarie I. Feb. 1966 and one collected at sea 12 Feb. 1967 (Warham 1969; Watson 1975; Green 1977; Kerry *et al.* 1983).

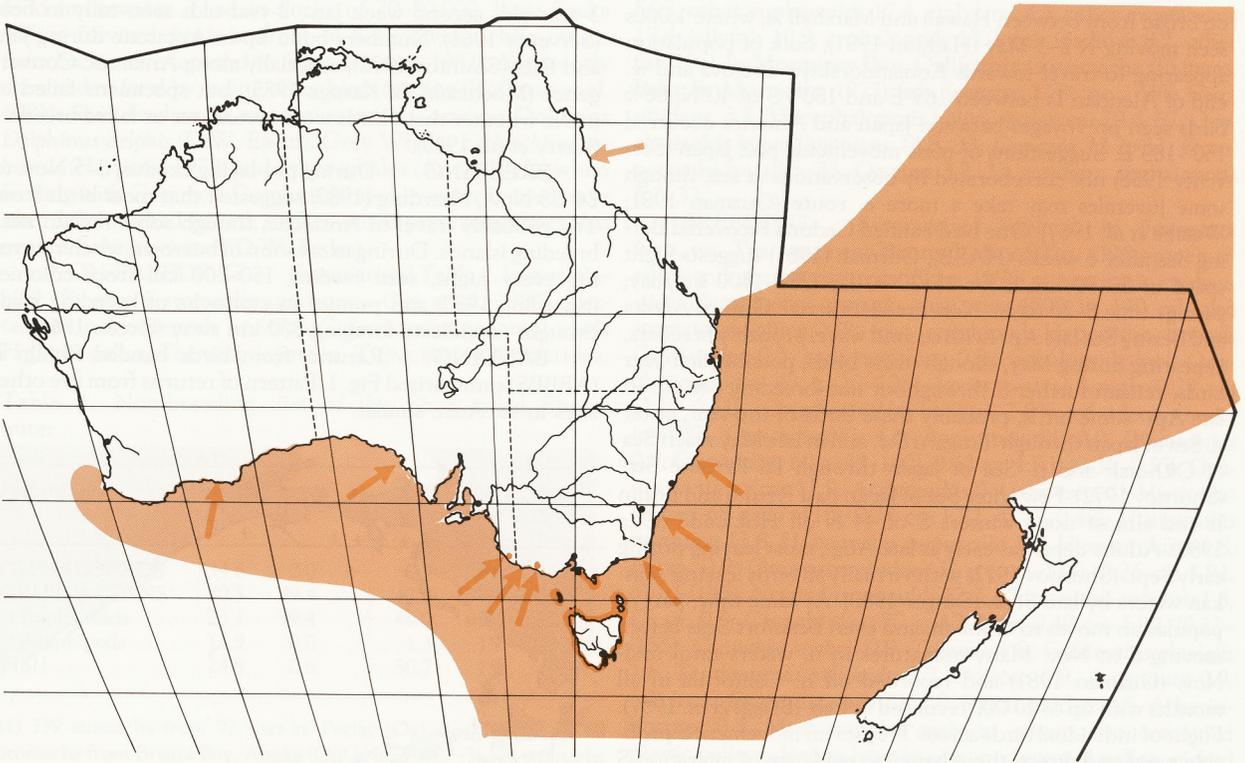
LORD HOWE I. Vagrant: one, sighted, Blinkenthorpe Bay, 12 Nov. 1963 (McKean & Hindwood 1965).

NORFOLK I. Passage migrant in open seas E of Norfolk where several parties of 3–19 birds recorded, 19 Sept. 1982 moving SW (Moore 1985).

BREEDING SITES, POPULATION Total population estimated to be 23 million breeding birds (Skira *et al.* 1985). Numbers apparently increasing NSW. Numbers of pairs given unless stated.

NSW. Total: 25 700. Cabbage Tree I., 20; Broughton I.,





1000; Little Broughton I., 1000+; Boondelbah I., 500; Bird I., 25; Martin Is., 40; Big I., 100; Bowen I., 200; Brush I., 500-1000; Grasshopper I., 400; Wasp I., 200; Tollgates I., 6500; Montagu I., >12 500

Vic. Total: 1.45 million. Gabo I., 30 000-40 000; Granite I., 2100; Benison I., 7200; Doughboy I. 2000 burrows; Rabbit Rocks, 3800 burrows; Seal I., 54 000 burrows; Rabbit I., 131 000 burrows; Notch I., 6000 burrows; Clifty I.; Rag I., 18 200 burrows; Wattle I., 83 500 burrows; Anser I., 251 700 burrows; Kanowna I., 52 000 burrows; McHugh I., 6200 burrows; Citadel I., 111 burrows; Dannevig I., 44 600 burrows; Great Glennie I., 400 300 burrows; Norman I., 145 000 burrows; Shellback I., 109 500 burrows; French I., 3100; Phillip I., 439 300-645 300; Bay of Islands, 10 000; Port Fairy mainland, 52 100 burrows; Griffiths I., 15 000; Lady Julia Percy I., 90 000.

Tas.: Flinders I., 4500; Babel I., 2,860 00 burrows; Cat I., c. 250 000; Chalky I., 2300; Fisher I., 73; Great Dog I., 750 000 burrows; Little Dog I.; Mt Chappell I.; Goose I., 60 000-70 000; Georges I., 20; St Helens I., 15 000+; The Nuggets, 50-60; Fort Direction; Hippolyte Rocks, 1000-2000; Tasman I., 6000; C. Queen Elizabeth, 17 700; Southport I., 21 000; Acteon I., 25 000; Ile de Golfe, 250 000; Flat Top I., 10 000; Round Top I., 12 500-15 000; De Witt I., 20 000; Louisa I., 90 000; Flat Witch I., 300 000; Flat I., 500 000; Maatsuyker I., 480 000; Big Caroline Rock, 15 000 burrows; West Pyramid, 2000-3000; Trefoil I., 1,540 00 burrows; Walker I., 431 200; Steep I., 310 500; Hunter I., North (140 000); Three Hummock I., 236 000; Albatross I., 100s-1000s; King I.

SA. Penguin I., 3000; C. Northumberland, 70; Franklin I., large colony.

WA. Ben I.; Figure of Eight I., 150 burrows.

MOVEMENTS Trans-equatorial migrant to n. hemi-

sphere in non-breeding season with most of population travelling to n. Pacific, the rest to ne. Indian Ocean. W. population: little known, probably travels to n. Indian Ocean between Oman and Thailand though only ever observed there in May (Phillips 1951; Jouanin 1957; Ali & Ripley 1968; Frith 1978). Numbers recorded by Frith (1978) suggest migration to Indian Ocean intentional rather than strays joining migration by Flesh-footed Shearwaters *P. carneipes* (Cox 1976).

DEPARTURE E. population: adults leave breeding colonies mid-Apr., departure usually coinciding with windy weather (Naarding 1980). Non-breeding immatures leave as early as Feb. with 3-year-old birds leaving early Mar., 4-year-olds mid-Mar., 5-year-olds late Feb.-early Mar. (Marshall & Serventy 1956; Serventy 1961). Chicks leave late Apr.-early May, most usually gone by 4 May (Naarding 1980) though small numbers seen off s. NSW as late as 25 May (Marchant 1977). A few birds in worn plumage seen as late as 12 June off Tas., possibly young birds leaving late from Antarctica (D.W. Eades). Adults do not build up fat reserves before departure (Lill & Baldwin 1983); *contra* Lill & Baldwin (1983), fledglings contain large fat reserves (averaging 40% of total body weight) at departure (K. Fitzherbert).

NON-BREEDING The e. population appears to move first E on a broad front across Tasman Sea, largely avoiding e. coast of Aust., then NW, passing both sides of Fiji, possibly as far W as Solomon Is (Guzman 1981). Scarce in Tongan waters during n. migration, which probably passes to W (Jenkins 1980). Large scale migration witnessed S of Lord Howe I., 25 Apr., with numbers passing recorded as 1000 birds/min for 3 min and averaging 50/min for following 22 min, birds flying at 40-50 knots 3-15 m above surface (Cheshire 1980), which suggests some concentration early in migration. Movement across tropics rapid (Shuntov 1972) and

on broad front between Hawaii and Marshall Is, where 1,000s seen moving N 2–3 May (Haddon 1981), bulk of population appearing to travel towards Komandorskiye Ostrova and w. end of Aleutian Is between 165°E and 180° S of 40°N; 86% birds seen on voyages between Japan and America occurred 150°–180°E. Suggestions of mass movements past Japan (Serventy 1958) not corroborated by observations at sea, though some juveniles may take a more e. route (Guzman 1981; Watabe *et al.* 1987). One bird banded Ceduna recovered Bering Sea after 6 weeks (HASB); Guzman (1981) suggests flight speed of 50–90 km/h for 15–20 h/day (750–1800 km/day; passage time 8–20 days). Non-breeders arrive Gulf of Alaska and Bering Sea late Apr. with second wave, probably breeders, appearing during May, though many birds, possibly first-year birds, remain further S throughout non-breeding period. In late Apr. some birds, probably these birds-of-the-year, enter n. Sea of Japan through Tsugaru Str. and in late May reach Sea of Okhotsk and n. Sea of Japan through La Perouse Str. (Shuntov 1972). Few enter Sea of Japan past Ryuku and Bonin Is and almost none winters S of 44°N off Hokkaido (Oka 1986). Adults depart as early as late Aug., most leaving during early Sept. (Shuntov 1972) with virtually all birds leaving Alaskan waters by late Sept. (Sanger 1980). At same time, part of population moves to Chukchi and even Beaufort Seas before moving S in Nov. Many immatures in n. waters until mid-Nov. (Guzman 1981) and recorded off n. California in all months with up to 10 000 recorded in Feb. (Briggs *et al.* 1987). Flight of individual birds across Tropics on movement S probably rapid and direct, there being no evidence of migration S along American coast (Guzman 1981). Movement S in waves with breeding adults travelling S through central Pacific in Sept., immatures in Nov. (Guzman 1981). S of 40°N nearly all birds seen on voyages between Japan and America Sept.–Nov. occurred between 165° and 180°E with constant passage of small flocks (c. 20 birds) moving SSW to S past w. islands of Kiribati and Tuvalu 16 Sept.–22 Oct. (Clark 1976; Oka & Maruyuma 1986). N of equator, movement S in small flocks over broad front, thus very difficult to observe (Mörzer Bruyns 1964), but flocks concentrate as they approach breeding grounds. May travel farther E than on n. migration before moving to e. coast of Aust. Thus common Sept.–Nov. in Tongan waters, s. migration being thought to pass N of Samoa and through Fijian waters (Jenkins 1980), where large numbers seen flying SW 23–26 Sept. with smaller flocks encountered 9 and 12 Nov. (Clunie *et al.* 1978). Migration pattern described above does not support figure of eight migration route as suggested by Serventy (1956, 1957, 1961).

RETURN First individuals seen off e. NSW, 4 Sept., but main movement S, 23 Sept.–1 Oct. (Marchant 1977). In some years passage S of millions of birds, up to 350 000 per hour (P.J. Fullagar), accompanied by significant but unexplained movement N (Marchant 1977) but huge passage not seen every year from land. Adults return Tas. late Sept., occurring in Tas. waters at least a week before landfall, with landfall at islands in Bass Str. (16–23 Sept.) usually 2–4 days earlier than off s. Tas. (19–25 Sept.; Naarding 1980). Pattern of landfall varies between years; sometimes majority of population arrives in one night, in other years population builds up over a week (Naarding 1980). Immatures move S in Nov. but probably less concentrated near Aust. coast than adults with records of flocks E of NZ, possibly of birds moving directly to Antarctic waters (Shuntov 1972; Guzman 1981). Younger birds arrive at colonies progressively later: 5-year-old birds with breeders in Sept. or early Nov., 4-year-olds late Nov.,

3-year-olds second week Jan., 2-year-olds seen only in Feb. (Serventy 1961). Numbers build up in Antarctic during Jan. and Feb. (Shuntov 1972), especially along Antarctic Convergence (Mochizuki & Kasuga 1985), but specimens failed to prove whether these birds were immatures or failed breeders (Kerry *et al.* 1983).

BREEDING During pre-laying exodus, 3–5 Nov. to 24–25 Nov., Naarding (1980) suggested that most birds from Tas. probably travel to Antarctic, though some remain near breeding islands. During excavation of burrows, when returning every night, seen feeding 150–200 km from colonies (Naarding 1980) and pumice in stomachs of breeding birds thought to indicate foraging 800 km away (Green 1966).

BANDING Returns from birds banded Phillip I. (ABBBS) summarized Fig. 1. Pattern of returns from five other sites in se. Aust. similar.

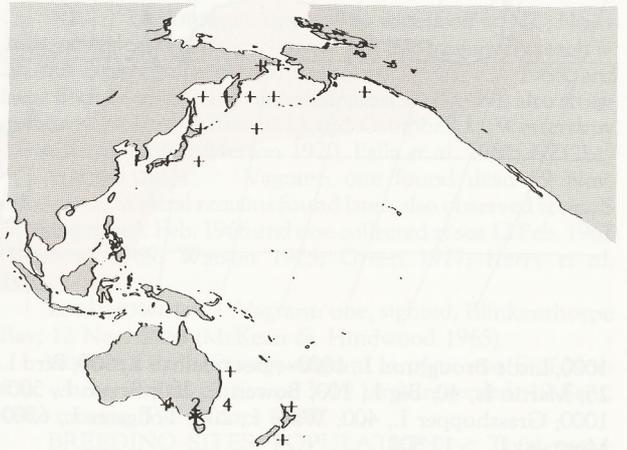


Fig. 1. 38S 145E 10X10 % ABBBS

FOOD Fish, cephalopods and krill. **BEHAVIOUR.** Most food caught by surface-diving and pursuit-plunging; also uses deep-plunging, surface-seizing, pursuit-diving, hydroplaning and scavenging (Ogi *et al.* 1980; Harper *et al.* 1985). One flock feeding at night near Macquarie I. used deep plunging on 56% of observations, pursuit diving 44% (59 observations; Harper 1987). Pursuit-plunges from air with wings held at one-third of full extension, entering water at 45–75° to horizontal (Morgan 1982). Before pursuit-diving usually submerge head while paddling slowly forwards; when prey sighted, run (Sanger 1980) or paddle (Harper 1987) forward strongly, lifting front of body high out of water before diving at angle of 20–30° (Ogi *et al.* 1980) and wing-rowing out of sight with part-opened wings. May swim to depths of at least 20 m (Skira 1979; Naarding 1980; Morgan & Ritz 1982) travelling up to 20 m horizontally, then burst from surface directly into flight (Morgan 1982). When one bird in group dives, others usually congregate and also begin feeding; sometimes whole flocks dive in concert (Bolger 1964). Dives last 8.8 s (6–15; 6; Harper 1987) to 20 s (15–30; Sanger 1980). Probably dive through swarms of crustaceans with bill open, flow of water and structure of bill combining to produce region of lower pressure inside bill, food thus being sucked inside; once in bill, food trapped by retroverted papillae in upper palate that overlap opposing papillae on tongue (Morgan & Ritz 1982). Swallow food at surface, sometimes gulping it down while lifting body from water and flapping wings (Sanger 1980) but must also swallow

food underwater. Feed in flocks of 20–20 000, large flocks rolling forward: birds at front of flock diving while others from back move forward to front (Morgan 1982). Apparently attracted to food by seeing other birds feeding (Hoffman *et al.* 1981). Seen feeding in association with Common Dolphins *Delphinus delphis* (D.W. Eades), Grey Whales *Eschrichtius robustus* (Harrison 1979) and other whales (Anon 1912); when feeding with Common Dolphins landed in water immediately after dolphins had passed, surface-seized prey, sometimes also peered beneath water (D.W. Eades).

NON-BREEDING Summarized Table 1. In **nw. Pacific** (% empty stomachs unknown; Ogi *et al.* 1980) crustaceans incl. copepods 1.6 %wt., *Calanus cristatus*, amphipods *Hyperia galba*, *Themisto japonica*, *T. pacifica*, Gammaridae,

Table 1. Non-breeding diet of the Short-tailed Shearwater.

| Percentages | weight | | vol. 3 | no. 3 | freq. 3 |
|-------------|--------|------|-----------|----------|------------|
| | 1 | 2 | | | |
| CEPHALOPODS | 34.6 | 0.0 | 1.5 | 0.6 | 36.8 |
| CRUSTACEANS | 40.5 | 99.4 | 47.8 | 97.3 | 22.4 |
| Euphausiids | 23.3 | 99.4 | 46.0 | 95.2 | 22.4 |
| Amphipods | 14.9 | 0.0 | 1.3 | 1.7 | 1.5 |
| FISH | 24.8 | 0.6 | 50.7 | 1.9 | 19.9 |

(1) 359 stomachs from 92 sites n. Pacific (Ogi *et al.* 1980). (2) 80 stomachs from Bristol Bay, Alaska (Ogi *et al.* 1980). (3) 201 stomachs from Alaskan shelf waters (Krasnow & Sanger 1982; Sanger 1980, 1986).

Lysianassidae, euphausiids *Thysanoessa longipes*, *T. raschii*, shrimps 0.3, crab larv. 0.3; cephalopods incl. *Berryteuthis anonychus*, *Chiroteuthis*, Gonatidae; fish *Lampetra japonica*, *Mallotus villosus*, Myctophidae, *Theragra chalcogramma*, *Pleurogrammus monoptyerygius*. Also recorded, jellyfish 0.1% wt., pteropods <0.1 and insects <0.1. The euphausiids in the exceptional sample from Bristol Bay were *Thysanoessa raschii*, the fish larv. *Ammodytes hexapterus*. Generally, amphipods taken most commonly over continental-shelf waters, cephalopods in pelagic seas. Most fish were larvae. Over **Alaskan shelf** (stomachs containing food; Krasnow & Sanger 1982; Sanger 1980, 1986) detailed analysis included polychaetes Nereidae <0.1%wt., 0.1%no., 2.1%freq.; cephalopods Gonatidae <0.1, <0.1, 0.5, unident. cephalopods <0.1, <0.1, 0.5, unident. cephalopods 1.5, 0.6, 36.8; crustaceans calanoid copepods <0.1, <0.1, 0.5, amphipods *Themisto libellula* 1.3, 1.7, 1.5, *T. pacifica* <0.1, <0.1, 0.5, unident. Gammaridae <0.1, <0.1, 0.5, euphausiids *Thysanoessa* 2.2 cm (0.18; 505) incl. *Thysanoessa inermis* 9.1% wt., 12.8% no., 13.9% freq., *T. raschii* 1.8, 2.6, 9.0, *T. spinifera* 2.3, 3.5, 9.0, *T. sp.* 32.0, 74.4, 22.4, unident. euphausiids 0.8, 1.9, 6.0, crabs *Telmesus cheiragonus* <0.1, <0.1, 0.5, unident. decapods <0.1, 0.1, 1.5, unident. crustaceans 0.5, 0.3, 2.0; fish: *Mallotus villosus* 41.0, 1.3, 19.9, 9.0 cm (18.2; 55–155; 163), unident. Osmeridae 4.9, 0.2, 7.5, *Theragra chalcogramma* 0.7, <0.1, 0.5, *Ammodytes hexapterus* 2.2, 0.3, 4.0, 1977: 5.4 cm (1.07; 24), 1978: 7.4 cm (0.27), unident. fish 1.0, 0.1, 11.9. Fish *Mallotus villosus* and *Ammodytes hexapterus* important July–Sept. in some years.

Other records: in **ne. Bering Sea** (46 stomachs; Schneider *et al.* 1986) crustaceans, amphipods Hyperiididae 6.5, Gammaridea 2.2% freq., euphausiids *Thysanoessa raschii*

54.3, other euphausiids 17.4, crab larv. 4.3, other crustaceans 17.4; jellyfish 10.9; cephalopods 13.0; fish Gadidae 8.7, other fish 10.9. In **Monterey Bay, California** (3 stomachs, 26 items; Baltz & Morejohn 1977) fish *Sebastes* 3.7% no., 33% freq., unident. 3.7, 33; cephalopods *Loligo opalescens* 29.6, 67, *Onychoteuthis borealjaponicus* 14.8, 33, *Gonatus* 22.2, 33, Octopoteuthidae 18.5, 33, *Octopus* 3.7, 33, unident. cephalopods 3.7, 33.

BREEDING Summarized Table 2. In **Furneaux Grp, ne. Tas.** and near **Bruny I., S. of Tas.** (396 proventriculus and gizzard contents; Skira 1986) crustaceans, euphausiids *Nyctiphanes australis* max. no. 4500 in 140 ml; also stomatopod alima 0.3% freq., amphipods Hyperiididae, isopods Cirolanidae 0.3, crab megalopa 0.8; cephalopods incl. *Onychoteuthidae* 45 g (10–105), lower rostral length 0.29 cm (0.19–0.41): *Onychoteuthis banksii* 2.8% of ident. beaks (n=109), *Onychoteuthis* 4.6, *Ancistroteuthis* 0.9; *Discoteuthis* 0.9; Gonatidae: 60 g (44–100), 0.43 cm LRL (0.36–0.55): *Gonatus antarcticus* 11.9; *Architeuthis* 0.9 [scavenged]; *Histioteuthidae*: 68 g (27–110), 0.34 cm LRL (0.23–0.48): *Histioteuthis atlantica* 12.8, *H. bonnellii corpuscula* 1.8, *H. macrohista* 1.8, *H. sp.* 0.9; Ommastrephidae: 32 g (<5–115), 0.26 cm LRL (0.10–0.45): *Nototodarus gouldi* 47.7; *Chiroteuthis capensis* 1.8, *C. sp.* 0.9; Cranchiidae: 70 g (17–108), 0.40 cm LRL (0.22–0.55): *Cranchia scabra* 0.9, *Taonius* 1.8, *Galiteuthis glacialis* 1.8, *Teuthowenia pellucida* 3.7, *Octopus* 0.9, *Argonauta* 0.9; fish incl.: *Engraulis australis* 1.0, Myctophidae: 0.5, Atheriniformes 0.3. Most samples early in season also contained plastic pellets, decline later in season suggested pellets picked up in n. hemisphere before migration. No difference in diet detected between two sites sampled but seasonal variation with *N. australis* predominating early and most fish taken Feb. At **Phillip I., Vic.** (307 food samples; Montague *et al.* 1986) fish incl. Aluteridae 6.2, *Sardinops neopilchardus* 2.6, *Engraulis australis* 5.5, *Hemirhamphus melanochir* 0.7, Atherinidae 0.3, *Trachurus novaehelandiae* 0.3, *Thryxites atun* 2.0, unident. fish 57.7; crustaceans, euphausiids *Euphausia lucens* 0.7, *E. similis* 1.0, *E. spinifera* 0.7, *Nematoscelis megalops* 2.6, *N. microps* 0.3, *Nyctiphanes australis* 37.1, *Thysanoessa gregharia* 0.7, unident. euphausiids 5.5; also stomatopod alima 0.7, amphipods *Paraprone clausi* 11.4, *Megalanceola* 0.3, Lysianassidae 0.3, isopods 0.7, shrimps *Leptochela sydniensis* 0.3, crab megalopa 7.2, unident. crustaceans 3.6; cephalopods *Nototodarus gouldi* 2.3, *Argonauta nodosa* 0.3, unident. cephalopods 5.9. Fish virtually absent before chicks hatched but made up >60% of diet late in season. In **Antarctic waters** (Feb., 442 items; Kerry *et al.* 1983) euphausiids were *Euphausia superba*. Other breeding season record *Nyctiphanes australis* 75% freq. 13.7 mm (9.5–18.0, 28 stomachs; Morgan & Ritz 1982).

Table 2. Breeding season diet of Short-tailed Shearwater

| Percentages | weight | | no. 1 | frequency | | |
|-------------|--------|------|----------|-----------|----|-----|
| | 1 | 2 | | 1 | 2 | 3 |
| CRUSTACEANS | 96.1 | 98.2 | 98.2 | 100 | 56 | 56 |
| Euphausiids | 93.0 | 90.5 | 90.5 | 75 | 55 | ≥37 |
| Amphipods | 2.3 | 7.7 | 7.7 | 8 | 6 | ≥11 |
| FISH | 3.9 | 0.2 | 0.2 | 8 | 13 | 74 |
| CEPHALOPODS | - | 1.5 | 1.5 | 42 | 28 | 13 |

(1) Antarctic, 12 gut contents, Kerry *et al.* (1983); (2) Tas. breeding colonies, 396 proventriculus and gizzard contents, Skira (1986); (3) Phillip I., Vic., 307 regurgitated samples, Montague *et al.* (1986).

Diet of chicks studied specifically only by Fitzherbert (1985; Table 3). Euphausiids (mostly *Nyctiphanes australis*) dominated diet in Jan. with post-larval fish important thereafter; decapod larv., amphipods and cephalopods also recorded. Oil constituted 10–80% of 32% of samples. Other observers have also noted *N. australis* (Cheah & Hansen 1970), cephalopod beaks (Ommastrephidae) and vegetable matter (Lewis 1946). Stomach oil, 80% wax esters but red carotenoid differed from that in *N. australis* (Cheah & Hansen 1970).

Table 3. Diet of Short-tailed Shearwater chicks (%freq.; Fitzherbert 1985).

| Food type | Jan. | Feb. | Mar. | Apr. |
|-------------------|------|------|------|------|
| EUPHAUSIIDS | 77 | 48 | 33 | 54 |
| OTHER CRUSTACEANS | 32 | 25 | 15 | 15 |
| FISH | 59 | 90 | 91 | 92 |
| CEPHALOPODS | 23 | 15 | 3 | 15 |

INTAKE Mean weight of meals of chicks increased from 27 g in mid-Jan. to 103 g in Feb. (Fitzherbert 1985). In Antarctic waters mean wt. of stomach contents 8.6 g (19.2; 0–75.0; 15; Kerry *et al.* 1983). Triglycerides incorporated into fat bodies directly from diet (Lill & Baldwin 1983).

SOCIAL ORGANIZATION Based on information provided by K. Fitzherbert and references as cited. Throughout year, gregarious, feeding in small groups or flocks of many thousands, often with other species (HASB; Ogi *et al.* 1980). In wintering grounds, seen in small to large (tens of thousands) flocks. Migrate in parties of 20–500 (Pearson & Knudsen 1967) although commonly <100 (HASB; Guzman 1981). Discrete small parties make up the large numbers (hundreds of thousands) recorded on migration pathways (Guzman 1981); close to Aust., amalgamation of these form continuous stream of birds off e. NSW and Vic. in Sept. and Oct. Migrating parties probably made up of individuals of same age-class (Guzman 1981), fledgeling and pre-breeding groups having even sex-ratio (Serventy 1967). During breeding season, evidence suggests flocks may be dominated by one sex (Serventy 1967); of 536 carcasses collected 7 Nov., 435 were male (Rowley 1974). At this time, large rafts form off breeding islands. Naarding (1980) observed rafts c. 2.5 km offshore each comprising 6900–10 000 when seas were calm; in heavy seas, located farther out (10 km) and comprised 15 000–20 000. Rafts over feeding patches, composed of birds from different colonies (Naarding 1980); probably also form rafts in N. Pacific (K. Fitzherbert).

BONDS Monogamous; sustained or long-term (Lewis 1924; K. Fitzherbert). Divorce occurs but causes, besides death of mate, unknown. Sex ratio of populations, unknown. Age of first pairing, unknown but probably in year of first breeding attempt: 5–7 years old for male and 5–8 years old for female (Serventy 1967). No further information on when pair-formation starts or ends. Both male and female incubate and tend young. Brood or guard chick for 2–3 (up to 5) days, then only visit young during feeding. No post-fledging care.

BREEDING DISPERSION Nest in densely packed colonies. Maximum density recorded 2.4 burrows/m² (Norman & Gottsch 1969); minimum 0.053 ± 0.99/m² (Harris &

Bode 1981). Density highly variable especially in succulent vegetation (0.25–0.95/m²), less so under grass (0.14–0.24/m²) (Skira & Wapstra 1980); highest densities recorded under *Poa* (Skira & Wapstra 1980) and *Tetragonia* (Norman & Gottsch 1969). Densities recorded at various colonies (in burrows/m²) include: Little Dog I., Tas., 0.21 (0.03; 0.16–0.23) (Skira & Wapstra 1980); C. Woolamai, Phillip I., Vic., 0.32 (0.26–0.47) (Harris & Bode 1981); C. Queen Elizabeth, Tas., 0.47 ± 0.18; Fort Direction, Tas., 0.65 ± 0.11; Great Dog I., Tas., 0.81 ± 0.14 (Skira & Wapstra 1980); combined 12 colonies, Tas., 0.75 (Skira *et al.* 1985). Territorial; defend area round entrance and within burrow. Pairing, mating, nesting and rearing young occur within territory.

ROOSTING During breeding season, often roosts in colony at night, sleeping with bill tucked under wing; breeders solitarily on ground outside entrance whereas non-breeders anywhere on ground; some sites exposed, often on open ground or on raised tussocks, but others protected near or under vegetation. Most commonly seen late Sept.–Oct. and Feb.–Apr.; breeding birds may roost after feeding chicks (c. 2 h after nightly arrival); roosting or resting may be broken during night. In burrow, chick spends most of its time sleeping. At any time of day but more commonly in late afternoon, rafts form off breeding islands; used for sleeping, loafing, preening and feeding; seen in both calm and rough water but when calm, closer to shore (up to 1 km from coast) than when seas rough (Warham 1960; HASB; Naarding 1980; K. Fitzherbert). Rafts usually break up, and birds come ashore in large groups, at dusk; daily departure begins about one hour before dawn and continues to first light (Warham 1960). No information on roosting outside breeding season, but probably form rafts in North Pacific (K. Fitzherbert).

SOCIAL BEHAVIOUR No major studies, based on information compiled by K. Fitzherbert. Displays extremely difficult to observe as performed at night and often within burrows or obscured by vegetation; easily disturbed by observers and torch-light. Feeding flocks and rafts apparently silent; flocks flying offshore from breeding islands, roughly synchronized as they skim along between waves then rise, tilt and dive (Warham 1960). When arriving at colony, many circle area above nests before landing and move straight to burrows after landing; on ground, walk with head lowered so that body and tail horizontal. When leaving colony: if windy, take off from nearest rise but on calm days, move to higher ground for take-off, often climbing boulders using bill and wings, tail and webbed feet; before taking off, beat wings through shallow amplitude creating lift that straightens bird's legs, then leap into air; may fail and crash into tussocks (Warham 1960).

AGONISTIC BEHAVIOUR Within colony, unpaired birds will rest or roost 80 cm apart; paired birds may sit side-by-side touching wings, or face-to-face touching bills or chests. **THREAT.** Territorial call given from within, or at entrance to, burrow if intruding bird ventures too close to, or into, burrow; also given in response to other birds calling from nearby burrows. Bird will regurgitate or spit and dribble oil if chased or handled (K. Fitzherbert). **FIGHTING.** Rival birds lock bills and twist heads side-to-side, often staggering back and forth with wings outstretched. To escape, bird turns and runs with wings outstretched or tucked into sides. Successful bird ruffles feathers and returns to burrow.

SEXUAL BEHAVIOUR Courtship presumably begins with arrival of birds at breeding grounds. During court-

ship, may toss grass over shoulder (Warham 1960). Greeting Call given when member of pair enters burrow occupied by other member. **ALLOPREENING.** Outside burrow entrance, pair allopreen each other's head and neck; seen up to time of laying. **COPULATION.** Occurs on open ground in front of burrow or in burrow. Mutual preening and frequent tapping of bills may be pre-copulatory displays (Norman 1969). During copulation, male squats on crouched female, with feet flattened along female's wing, toes over her carpal joints and head to one side of female's; male moves head from side to side causing bills of both birds to lap constantly over each other; soft low call given (sex of vocalist not known). After cloacal contact, male extends wings slightly and slides off female. One copulation lasted 160 s, after which male rested next to female for 2 min, occasionally touching her bill, then moved behind her; female moved away and then back to male fanning tail up and towards male; male did not respond (K. Fitzherbert). Earliest observation 12 Oct. (Norman 1969), 15–17 days after first landfall (K. Fitzherbert). Continues throughout nest-building and frequently seen 3–4 days before pre-laying exodus. Sperm remain viable in oviduct 14–20 days (K. Fitzherbert).

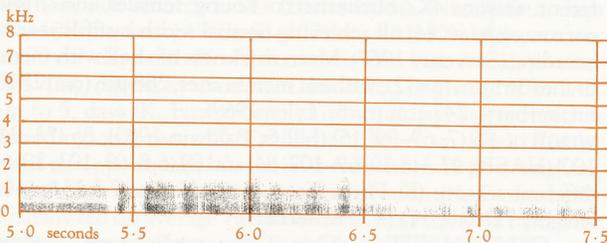
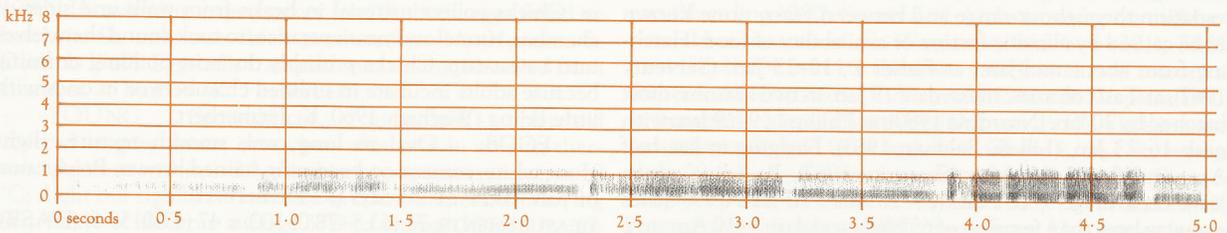
RELATIONS WITHIN FAMILY GROUP

Burrow dug by pair; digging intense for first 3 weeks after landfall, then sporadic; brief (30–60 s) bouts at start of incubation shifts or on returning to feed chick; chick collects material from nest chamber to form cup in which to sit. Both sexes incubate alternately, but off-duty bird does not feed nor visit on-duty bird, see Breeding. During incubation, total attentiveness on egg (96–100%) (K. Fitzherbert); male usually has more days on duty having 28 days compared with 24 for female (K. Fitzherbert). Behaviour of adults in tending young, typical of genus (Warham 1960). Chick brooded or guarded usually by female for 2–3 (sometimes up to 5) days; then deserted by day. One parent, rarely both, visit each night for first 7–8 (sometimes up to 10) days; then visit less often at 7–10 day intervals (sometimes up to 16 days) but one partner may still visit on several successive nights (Warham 1960). Chick fed by both parents alternately, possibly last meal by male (Serventy 1967). Chicks beg by uttering series of soft chirrups and thrusting bill towards parent's head; parent opens bill, points it downwards exposing red interior and arches nape; chick

ceases calling, inserts its bill at right angles to, and between mandibles of, adult and quivers its wings (Warham 1960). Adults sometimes *crow* loudly on arrival at burrow before feeding chick, then preen chick all over before feeding it (Warham 1960). Adults may recognize own chick; when Norman & Gottsch (1969) introduced an extra chick, in seven of eight nests parents raised own rather than introduced chick. No post-fledging care.

VOICE Not well-known and no detailed studies; information supplied by K. Fitzherbert. Generally silent at sea and in the air; occasionally call in flight over colonies but incoming birds almost invariably silent (Warham 1960). Noisy on land, especially immediately after landing and before departure in morning. Calls are loud harsh screeches, cackles and wails, and low crooning and sobbing calls in burrows; no information many calls. Most calling from 10 min before to 30 min after twilight and for about an hour before departure at dawn. Sporadic calling throughout night, in flight and from ground. Colony noisiest before laying, at hatching and early nestling period. Generally quieter during incubation and mid to late chick-period. Vocalizations generally loudest at burrow. Probably noisier on dark nights (Warham 1960). No information on sexual differences, but considerable variation in tone, timbre, rhythm, rate of delivery and length of calls between birds (HASB). Calls similar to congeners (Warham 1960). No geographical variation reported.

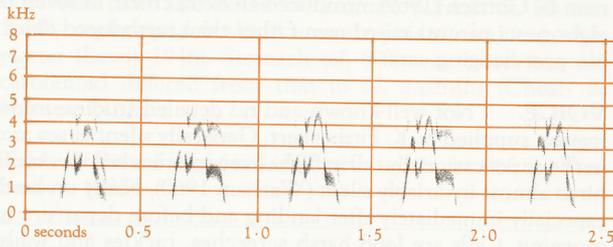
ADULT Most descriptions and interpretations of sounds, other than Copulation Call, anecdotal; function of calls tentative, based on observations by K. Fitzherbert. **Territorial Call.** Loud, harsh squealing *ee-ee-a-a* (as in *see the car*), repeated several to many times, gradually losing pitch and intensity and fading to silence (sonagram A); call consists of inspiratory and expiratory phrases and begins and ends with incoherent splutter (Warham 1960). Most often heard call throughout night at colonies; given when arriving at burrow in evening and, in disputes with neighbours, both from outside and inside burrow. Occasionally, similar calls heard in flight, by birds arriving in evening and throughout night. This call probably given by adults when arriving at nest to feed young (Warham 1960). **Greeting Call.** Quieter version of



Territorial Call but ending in quiet chuckling *cruk-cruk-cruk* or quiet crooning. Most often heard late in period before laying and, during incubation, at nest-relief. Suggested that bird on duty, rather than relieving bird, gives call (HASB). **Distress Call.** Harsh, guttural squawk *aark-aark-aark* used when caught by hand, dogs, etc. **Copulation Call.** Very distinctive *cruk-cruk-cruk-cruk-crooer-cruk-cruk...* given while male is mounted (Norman 1969). Sudden *eh* given when flying birds collide or nearly do so (Warham 1960). **NON-VOCAL SOUNDS:** sluicing sounds made in throat, like noise of grease forced from grease gun (Warham 1960) when feeding young and

dribbling oil in defence.

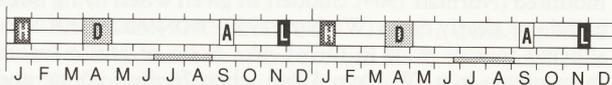
YOUNG Beg with plaintive *see-a see-a see-a* (sonagram B); given by chick when movement detected near burrow and when begging for food from parent; probably same as soft liquid chirrup described by Warham (1960).



B E. Slater; Montagu I., NSW, Mar. 1980; B831

BREEDING Well known. Long-term studies at Fisher I., Tas. (Serventy 1963, 1967); at various Tas. localities (Naarding 1980); at Phillip I., Vic. (Norman 1969, 1970, 1971; Fitzherbert 1985). Information supplied by K. Fitzherbert. Breed in simple pairs, colonially; on islands and on some places on mainland, in flat to sloping grassy and scrubby areas. To a varying extent associated with other species of shearwater and Little Penguins *Eudyptula minor*.

SEASON Broadly from late Sept. to early May. Arrival at colonies sudden, in large numbers: first sightings in Tas., 16–25 Sept., with most birds arriving in 1–4 days and local breeding numbers mostly complete between 20–25 Sept. (Naarding 1980). Pre-laying exodus: late Oct.–early Nov.; birds depart during c. 5 days, but order of departure by sexes not known (Marshall & Serventy 1956); at Tas. colonies all birds had left by 3–6 Nov. (Naarding 1980); individual absences 20–21 days (Serventy 1967), but at Phillip I. colony not totally deserted during exodus (Lill & Baldwin 1983). Return from exodus at Tas. colonies over 4 years, 19–28 Nov. (Naarding 1980; Serventy 1963); some males return before, some after, laying, not quantified (Fitzherbert 1985). Laying highly synchronized within 13 days: mean laying period (10 years' data), 24–27 Nov., when 61–71% of eggs laid; extremes of first and last eggs, 20 Nov. and 3 Dec. in Tas. colonies and at Montagu I., NSW (Serventy 1963, 1967; Naarding 1980); little variation throughout range and between years; none known to be caused by climatic factors or availability of food. Hatching from about mid-Jan.: at Fisher I., 10–23 Jan. (Serventy 1967); at Tas. colonies, mean date 19 Jan. in two seasons, most hatched by 20 Jan. (Naarding 1980); at Phillip I., 9–29 Jan. with peak 16–23 Jan. (Lill & Baldwin 1983). Fledging in last half Apr. and first week May (Serventy 1967). Breeding adults leave on average 9–10 Apr. (29–30 Mar.–20–21 Apr.); males may stay later than females: of 65 birds sexed on 9–10 Apr. in 2 years, 42 males and 23 females (Serventy 1967). Half population at Clifton Bluff, Tas., left by 12 Apr. (Naarding 1980). Many additional physiological data (weights, condition of reproductive tract, body conditions throughout seasons) in Marshall & Serventy (1956), Lill & Baldwin (1983) and Fitzherbert (1985). Time of departure of failed breeders not known. Two-year-old birds seen at colony only in Feb.; 3-year-olds leave early Mar.; 4-year-olds not seen after Mar.; 5+ year-olds not seen after end Feb. (Serventy 1967).



SITE Colonies mostly on coastal islands, in some places on mainland near sea; on level to steeply sloping ground; generally vegetated with grasses (*Poa*, *Spinifex*), herbs (e.g. *Tetragonia*) and scrub, but also on bare areas. Burrows may be conspicuous and unprotected to well hidden among vegetation; in general, dug anywhere in stabilized dunes or soft stable soil of at least 23–31 cm depth; occasionally tunnels made in dense vegetation without burrowing and egg laid on surface. Colonized area may extend from near sea-level to highest point of island (2–73 m, Cat I., Tas., Warham 1960; to 112 m, Phillip I., Fitzherbert 1985). Length of burrows: 83 cm (28–150; 50) (Norman 1969); maximum 185 cm. Diameter: 25 cm (15–35; 40). Nest-chamber: 45 cm (29–59; 71) high. Mean depth below surface: 28 cm, in soil 66 cm deep (Norman 1969). Burrows used year after year by same pair, but sometimes nearby burrow claimed or new burrow dug close to original one. At Fisher I., all known chicks that have returned to breed have established burrows at natal colony, 6.7 m (males; 0.6–18.3; 12) and 7.6 m (females; 1.2–18.3; 12) distant from where they had been reared (Serventy 1963, 1967). Tiger Snakes *Notechis* sp. and Blue-tongued Lizards *Tiliqua* sp. sometimes use burrows as refuges and may be found in them with adult birds or with chicks a few weeks old (Naarding 1980). Roles of sexes in selection of burrows not known; excavation by both sexes but shares not known. Males reported as arriving and preparing burrows before females (K. Fitzherbert). Burrows dug by using first one foot (5–30 scrapes) and then the other; soil or sand flicked backwards; roots and obstructions tugged out by bill, bird pulling itself backwards on braced feet, perhaps with wings extended; most digging soon after nightly arrival, sporadically through night; digging throughout 6 weeks before pre-laying exodus, most intense during first 3 weeks. Some modifications of burrows made after laying and repairs effected after damage. Burrows usually complete 20–24 days before laying but interval probably varies much (Serventy 1967). May use burrows dug by Little Penguins and perhaps those dug by other species of shearwater.

NEST, MATERIALS Nest-chamber unlined or lined with grass, dead leaves and occasionally down; objects left at entrance taken in by chicks. Entrance often blocked with grasses and dead leaves during incubation and nestling periods; material may be collected from distances of up to 4.5 m. Chicks collect material in beaks from walls and sides of chamber, tunnel and near entrance, to tuck round themselves into a neat-cup. Chicks probably do most building or lining because adults incubate in unlined chambers or in ones with little lining (Warham 1960; K. Fitzherbert).

EGGS Oval to long oval; smooth texture, slight gloss; white, some soon becoming stained brown. Production of yolk takes 14–20 days (K. Fitzherbert).

MEASUREMENTS: 71 (63.5–78.0; 100) x 47 (43.0–50.5) (HASB); 71.8 (2.6; 84) x 47.1 (1.4) and 72.3 (3.0; 30) x 47.9 (2.2) in different seasons (K. Fitzherbert). Young females (n=7) laid narrow eggs (av. 44) till achieving normal width by fifth year of breeding (Serventy 1967). Mean thickness of shell with membranes 361 µm (n=12); without membranes, 288 µm (n=12) (K. Fitzherbert), 247 µm (n=6; Tyler 1969).

WEIGHTS: 86 (7; 69–99; 15) (Lill & Baldwin 1983); 85 (73–94; 100) (HASB); 97.3 (6.39; 69–107; 84) and 89 (6.8; 69–103; 30) in different seasons (K. Fitzherbert). Egg contains 7.3 kJ/g (wet weight; 7.0–8.0; 11) (K. Fitzherbert).

CLUTCH-SIZE One. No replacement laying. Single brooded.

LAYING Highly synchronized (see above, under

Season). During four seasons, two individuals laid: 24, 26, 23, 23 Nov. and 26, 25, 27, 26 Nov. (Serventy 1963). Time of day of laying not certain but probably at night (Serventy 1967). All eggs laid on surface and not in burrows ($n=60$), infertile but not significantly different in size from those laid in burrows (Naarding 1980).

INCUBATION By both sexes in alternate shifts. If male not present when egg laid, some females leave egg at once, others stay and start incubation, still others stay but do not incubate. Incubation usually started by male (K. Fitzherbert). Shifts: 4–5 in all. At Phillip I., first shift (male) 11 days (10–18), second (female) 11 (10–12), third (male) 13 (12–15), fourth (female) 13 (12–15), fifth (male) 4 (0–7; 16); most eggs hatched at start of fifth shift (K. Fitzherbert). At Fisher I., first shift 12.6 (10–16; 79), second 11.8 (10–14; 18), third 15 days (second, fourth 9 and 14 days; most eggs hatched at end of fourth (second female) shift ($n=23$; ex 27); in eight nests female left immediately after hatching; in five nests male present from 1–5 days into that second female shift and stayed with chick when female left (Serventy 1967). At Phillip I., males lost on average 164 g per shift and gained 190 g per absence; females lost on average 156 g per shift and gained 166 g per absence (K. Fitzherbert) *contra* HASB, where claim that weight declines steadily during incubation. More details of gains of weight and other physiological matters during incubation period in Fitzherbert (1985), Lill & Baldwin (1983) and Farner & Serventy (1959). **INCUBATION PERIOD:** 53 days (52–55; 24 marked eggs) (Serventy 1967). Incubating bird not fed in nest; makes short forays to entrance of burrow and beyond late in shift; usually stays on egg till relieved; longest period of duty, 20 days, before deserting when not relieved (K. Fitzherbert). Eggs withstand some period of desertion: 8, unattended for 1–2 days hatched successfully; 15, unattended for 4 or more days failed to hatch. Mean relative humidity in burrows varies: $93.5\% \pm 2.2$ in long burrows in sand to $69.1\% \pm 4.2$ in surface nests covered only by vegetation. Mean air temperature below incubating bird: 33.1°C ($n=54$); mean internal incubation temperature: 35.8°C ($n=24$). Mean range of temperatures in long burrows in sand, $4.8\text{--}2.8^\circ\text{C}$ when range of ambient temperature averaged $25.1 \pm 5^\circ\text{C}$. For temperatures of incubated eggs, see Fitzherbert (1985) and Naarding (1980). Adults will accept any egg or other similarly shaped object (Naarding 1980). In twinning experiments ($n=20$), both eggs failed to hatch ($n=9$), only one chick produced ($n=11$) (Norman & Gottsch 1969). Eggshells trampled into nest or removed from chamber or burrow (K. Fitzherbert).

YOUNG Semi-altricial, nidicolous. Hatched covered in grey down; eyes open after c. 4 h; able to thermoregulate to within $1\text{--}2^\circ$ of ambient temperature, even at 10°C ; slight but significant increase in body temperature during first 4 days of life from average 37.9 to average 38.6°C ($n=15$; Farner & Serventy 1959). Downy stages and development of feathers not recorded. **NESTLING PERIOD.** Ninety-four days (88–108) (Serventy 1963); 82–107 days with 60% of departures at 90–99 days old (K. Fitzherbert). For first few days after hatching, parent in attendance, brooding or guarding for 2–3, up to 5, days (K. Fitzherbert); during cold spells recorded as brooding only twice (K. Fitzherbert; Warham 1960). Fed by both parents, equally. Sometimes fed within 12 h of hatching if male has recently taken over incubation (K. Fitzherbert). Usually fed on average 7–8 times until c. 10 days old by one or both parents: 5–9 times (K. Fitzherbert), 3–12 times (Serventy 1967; Naarding 1980); averages 0.87 meals/day when 10–19 days old, 0.36 when 27–34 days old and 0.04 when 74–90 days

old (Naarding 1980). Period of desertion from last meal to fledging claimed as averaging 14 days (1–23; HASB), during which time young bird leaves burrow at night, tests wings by flapping, returns to own or any burrow by day; young first seen outside burrows 2–3 Apr., commonly 11–12 Apr., at Fisher I. (Serventy 1967). Larger young defend themselves in burrow by vigorous pecking, sometimes maintaining hold and twisting head from side to side. No sanitation of nest; eight species of *Acarina* recorded in detritus on floor of nest-chamber (Womersley 1955). In twinning experiments ($n=20$), complete failure in eight: twelve produced single underweight chick (Norman & Gottsch 1969).

GROWTH Mean weight at hatching, 64 g (5.3; 55–75) or c. 73% of mass of fresh egg and 11% of mean adult mass. Gain c. 20 g/day until 10 days old; average four times weight of hatching by 14 days old. Most chicks (73%) reach maximum weight when 50–75 days old (29–89) (K. Fitzherbert; Lill & Baldwin 1983); average maximum 859.6 (121.8; 510–1160; 88) or 140% of average adult mass. At fledging, average weight (last weight in burrow): 617 (15.6; 175) (Naarding 1980); 615 ($n=45$; K. Fitzherbert); 616 (68; 131) (Lill & Baldwin 1983). At departure, 6% heavier than mean adult weight of departing adults (Lill & Baldwin 1983). At departure, mean body composition of chicks >400 g: 43.1% water, 14.8% protein, 39.9% fat ($n=8$) (K. Fitzherbert).

FLEDGING TO MATURITY Young leave in darkness, often in strong winds, which give them lift off the ground. Many leave about 04:00. Totally independent of parents at departure; fly well into wind and take-off from standing start or short run; rapidly lose height to fly low over water or splash into it; may scramble to water's edge and swim away; form large flocks on water after departure (Naarding 1980). Age at first pairing not known. First breeding: females, 5.3 years old (5–7); males, 6.6 years old (5–8) (Serventy 1967).

SUCCESS Rate of occupation of burrows varies between colonies from 73–86% (Norman 1971; Skira & Wapstra 1980; Harris & Bode 1981); not effected by sheep grazing (Norman 1970); in mid-Mar. (mid-growth), well down in areas where harvesting of young occurs (38%) compared to areas of no harvesting (52–65%) (Skira & Wapstra 1980). Hatching success at C. Queen Elizabeth, Tas., 93% and 95% in two years; lower (59–68%) in colonies with high numbers of feral cats (Naarding 1980). Survival of chicks to mid-growth (Mar.): over three seasons at C. Woolamai, 56.2% ($n=201$), 71.5% ($n=142$), 77.5% ($n=116$) (Norman 1971); over two seasons at Fisher I., 55.9% ($n=98$), 61.8% ($n=90$) (Skira & Wapstra 1980); at Benson I., Vic., 72% ($n=50$) (Norman 1971). Fledging success (chicks fledged from eggs laid): Goose I., 66.7%; average from 20 colonies (where some harvesting), $59 \pm 5\%$ (Skira & Wapstra 1980); Trefoil I. 1979 and 1980, 79.7% and 84.6%, respectively (Naarding 1980); mean from 12 colonies (where some harvesting), 1979 and 1980, 56.6% (13.0–89.9%) and 54.1% (11.7–94.3%), respectively (Naarding 1980). At Pineapple colony, Tas., burrows at periphery had lower fledging success than those at centre; in mid-Apr., mean weight of chicks in colony 935.8 ($n=150$); peripheral chicks 693.2 ($n=26$). At Fisher I., 20–59% of young returned (data collected over 10 years); age of first recovery at natal colony after fledging: 1.4% at 2 years of age, 23% at 3, 47.4% at 4; 16.7% at 5, 9.6% at 6; 1.9% at 7, 0% at 8 ($n=209$ recoveries) (Serventy 1967). Estimated mortality (on limited data) during first year, 63% (Serventy 1967), 50% (HASB); third to fifth year birds, 37% (Serventy 1967). Annual survival of breeding adults, 91%; possibly 95% in stable breeding populations (Palmer 1962).

Mean life span, 15–20 years but recorded up to 36 years. **PRE-DATION.** Pacific *Larus pacificus* and Silver Gulls *L. novaehollandiae*, ravens *Corvus* spp, skinks *Tiliqua* spp and Tiger Snakes *Notechis scutatus* take eggs and small chicks. Pacific Gulls, ravens, Brown *Falco berigora* and Peregrine Falcons *P. peregrinus*, Swamp Harriers *Circus approximans* and White-bellied Sea Eagles *Haliaeetus leucogaster* take adults and large chicks (HASB). At C. Woolamai over three years, mean predation rate by foxes, 0.55% (0.43–0.89%) of annual production (Norman 1971). Ants and fly maggots also cause mortality of hatching eggs and neonates (K. Fitzherbert). In low-lying burrows, eggs and chicks lost from flooding (HASB). High nestling and fledgeling mortality from starvation in some years (K. Fitzherbert). **DISEASE, PARASITES.** Limy-bird disease causes periodic severe mortality. Ornithosis (psittacosis) widespread in mild form (HASB).

PLUMAGES

ADULT (DEFINITIVE BASIC) Age of first breeding 6 years (5–8; 44; Serventy 1967). **Dark phase.** **HEAD AND NECK.** Top of head and neck blackish brown (c119), merging at level of mid-eye to dark brown-grey (brownish 83) remainder. All feathers have concealed white bases. Lower eyelid has short downy white feathers at base. **UPPERPARTS,** blackish brown (c119) with slightly lighter brown scalloping on back and shorter scapulars. Feathers blackish brown (c119) with concealed brownish grey (brownish 85) bases and narrow dark brown-grey (c121) tips; tips fade to dark grey-brown (c119D) with wear. Tips absent in mantle, longest scapulars, rump and upper tail-coverts. **TAIL,** blackish brown (119). **UPPERWING.** Remiges, blackish brown (119) with slightly greyish gloss. Alula, primary and secondary coverts, blackish brown (119). Remaining coverts, blackish brown (c119) with slightly lighter-brown (c121, fading to c119D) open penaceous fringes. **UNDERPARTS,** dark brown-grey (brownish 83) feathers with concealed whitish bases. Axillaries, dark grey-brown (c121). **UNDERWING.** Remiges, grey (84), appearing silvery white when reflecting direct light. Most under wing-coverts, pale brownish grey (c84), with concealed white bases, and dark-brown (c121) rachis. Greater under wing-coverts appear silvery white when reflecting direct light. Marginal coverts, blackish brown (c119). **Light phase.** Proportion of birds have light underwings. Uncommon, over-represented in museum collections. Much white on underwing; median under wing-coverts, and broad tips of lesser under wing-coverts, white; bases, brownish grey (c84), sometimes exposed in outer median coverts. Marginal coverts sometimes have narrow white tips. White underwing usually associated with white chin and upper throat. Sometimes chin, throat and underparts have partly concealed white bases, making these areas appear paler than in dark-phase birds.

DOWNY YOUNG Protophyle, thick and grey; replaced in about 10 days by dark grey-brown (grey 28) mesophtile.

IMMATURE (DEFINITIVE BASIC), JUVENILE
Same as adult.

ABERRANT PLUMAGES Complete and partial albinism recorded (Palmer 1962; MV).

BARE PARTS

ADULT Iris, dark brown (21). Bill, dark (83) to blackish grey (83), sometimes with dark-olive (c129) tinge to latericorn and ramicorn. Tarsus and toes, scutellate; spaces between scales, narrow and white. At tibio-tarsal joint, and

distal end of tarsus, scutes dark brown (19). Scutes, medium pink-brown on outer side of tarsus and outer toe, slightly paler elsewhere. Some birds have dark-brown to blackish outer side to tarsus and outer toe. Webs light brownish pink, merging to pale drab at tip. Claws, dark brownish grey (c83).

DOWNY YOUNG Unknown.
JUVENILE As adult.

MOULTS

ADULT POST-BREEDING Pre-basic. Complete. Head and body moult begins end of first week Dec., when males completing, and females starting, their first incubation shifts; brood-patch downy by last week Jan., and body-moult completed in mid-Feb. (Palmer 1962). Moult of remiges and rectrices believed to begin in wintering grounds in N. Pacific (Marshall & Serventy 1956), but no information during n. migration. Wing- and tail-moult recorded late June, July (Jacques 1930; Dementiev & Gladkov 1951). Moult completed before return to breeding grounds; record of one bird completing moult of remiges at colony in late Sept. anomalous (Stresemann & Stresemann 1970). Primaries outwards; in 11 captive birds average duration was 90 days and average rate of growth was 4.5 mm/day. P6 (and perhaps p7) shed before full-grown; p10 shed before p8 (and perhaps p7) full grown (Stresemann & Stresemann 1970). In these captive birds, wing- and tail-moult start at similar times to wild birds but moult said to be protracted (Marshall & Serventy 1956).

POST-JUVENILE, SUBSEQUENT PRE-BASIC MOULTS Birds have been recorded moulting wing, tail and body from Sept. to early Dec., most off w. coast of America (Loomis 1918) but including bird E of NZ (Murphy 1930) and NZ beachcast on 7 Sept. with primary moult N³4¹3¹2O³ (NMNZ). These probably in post-juvenile moult, certainly no older than third year because moult not recorded in immatures, 3 years or older, revisiting breeding colony at this time (MV; implied by Serventy 1956, 1967). Timing of wing-moult in older immatures probably similar to adult, primary wear of breeders and non-breeders at colony being similar (MV).

MEASUREMENTS (1) Breeding colonies in se. Aust., definitive, skins. (2) NZ, recently dead beachcasts (NMNZ).

| | MALES | FEMALES |
|--------|--|---|
| WING | (1) 273 (6.8; 262–288; 19) (2) 279 (6.3; 261–287; 18) | 275 (5.2; 269–284; 16) 276 (5.5; 261–282; 13) |
| 8TH P | (1) 159.6 (3.80; 152–166; 19) | 160.0 (4.72; 154–171; 17) |
| TAIL | (1) 81.0 (3.28; 74–87; 19) (2) 81.7 (1.81; 79–84; 18) | 82.4 (3.76; 75–91; 17) 83.7 (2.85; 79–87.5; 13) * |
| BILL | (1) 31.8 (1.26; 29.4–33.7; 20) (2) 32.4 (1.11; 30.5–35.2; 18) | 31.4 (1.21; 29.1–34.2; 17) 32.3 (0.69; 31–33.3; 13) |
| BILL W | (1) 14.9 (1.01; 12.7–16.5; 17) | 14.2 (0.84; 12.2–15.5; 13) |
| TARSUS | (1) 52.7 (1.32; 49.5–55.9; 20) (2) 52.8 (1.49; 49.1–55.3; 18) | 51.4 (1.21; 49.6–54.3; 17) ** 52.3 (1.33; 50–55.3; 13) |
| TOE | (1) 61.2 (2.24; 55.5–66; 14) (2) 60.5 (1.97; 57.2–64; 18) | 60.0 (0.74; 58.9–61.4; 8) 59.4 (1.27; 56.2–61; 13) |

WEIGHTS Lill & Baldwin (1983) and Fitzherbert (1985) studies, both C. Woolamai, Vic.

ADULT On first arrival at breeding colony: males 560 (508–614), females 528 (473–594) (HASB); unsexed 559 (53; 460–740; 67) (Lill & Baldwin 1983); unsexed, 1980, 575

(490–720, 67) and 1981, 649 (520–800; 50). Mean weight of fat reserves of adults on arrival: males 104 ± 23 ($n=11$), females 88 ± 13 ($n=9$); in both cases, 17% of body weight. Weight of adults at departure on pre-laying exodus: males, 1981, 520 (30; 460–610; 50); females, 1980, 564 (35; 480–640; 50). Weight of male at egg laying, 1980, 688 ± 53.7 (560–800) and 1981, 612 ± 54.7 (530–730) (Fitzherbert 1985). A few days after egg-laying unsexed birds 593 (59.3; 490–720; 67); females probably lighter than males at this stage. At about time of hatching 678 (60.6; 38). Immediately before leaving colony 583 (32; 500–680; 50) (Lill & Baldwin 1983); 588 (52; 520–780; 37) (K. Fitzherbert). NZ beachcasts: males 424 (381; 355–506; 17), females 428 (33.3; 388–510; 13; NMNZ).

IMMATURE At breeding grounds, weights range from 541 (39; 480–600; 38) in Oct. to 612 (54; 500–720; 55) in Nov. No appreciable fat deposition before departure (Lill & Baldwin 1983). Beachcasts (99% juveniles) in Japan in late May and early June 266.4 (22.3; 59); birds at sea caught in fishing nets 399.4 (32.7; 22) (Oka & Maruyama 1986).

STRUCTURE Wing, long and narrow. Eleven primaries, p11 minute, p10 longest, p9 3–7, p8 15–23, p7 35–44, p6 56–65, p5 75–87, p4 97–112, p3 118–133, p2 135–152, p1 150–165. Twenty-two secondaries, five of tertial form. Five humerals. Tail rounded, 12 feathers, t1 16–21 longer than t6. Bill, short, width at base 0.4–0.5 length, minimum depth at culminicorn c. one-quarter length. Upper mandible hooked at tip, lower mandible decurved at tip. Nasal tubes about one-quarter length of bill; nasal septum broad, oval nostrils point forwards and upwards. Tarsus scutellate, laterally compressed. Outer and middle toes about equal, inner c. 80%, hind claw c. 10%.

AGEING, SEXING Information on skull ossification in Oka *et al.* (1985). Breeding adults can be sexed on cloacal dilation of females about laying period (Serventy 1956).

GEOGRAPHICAL VARIATION None (but little biometric information from WA).

DIR

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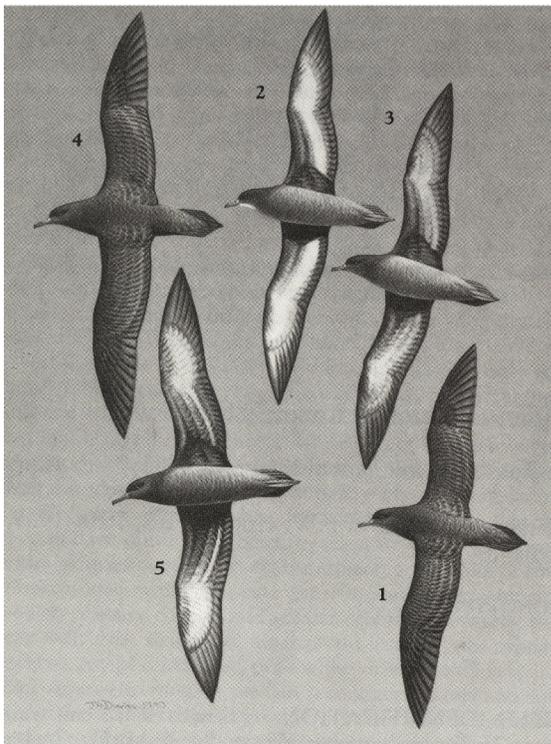
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Short-tailed Shearwater *Puffinus tenuirostris*

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

Sooty Shearwater *Puffinus griseus*

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

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