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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 Pelecaniformes. 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 fedges 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: Diomedeidae 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 Diomedeidae. 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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Procellaria grisea Gmelin, 1789, Syst. Nat. 1:564; based on 'Grey Petrel' of Latham, 1785, Gen. Syn. Birds 3: 399 — southern hemisphere between 35° and 50°S = New Zealand, restricted by Mathews, 1912, Birds Aust. 2: 95.

The specific name is medieval Latin for 'grey', referring to the colour of the plumage.

OTHER ENGLISH NAMES King or New Zealand Muttonbird, Sombre Petrel or Shearwater.

MONOTYPIC

FIELD IDENTIFICATION Length 40–46 cm; wing-span 94–105 cm; weight 650–950 g. Large solid-bodied shearwater, closely resembling slightly smaller Short-tailed Shearwater *Puffinus tenuirostris*. Long slender bill, slender flat-crowned head and longish neck. Slim wings, not so long or broad as other large shearwaters. Tail, short and rounded; feet extend slightly beyond tip of tail in flight. Cruciform shape in flight; faintly recalls large fluttering-type shearwater distinct from other large shearwaters that soar and flap wings less (except for *P. tenuirostris*). Entirely dark brown-grey except broad pale streak down centre of underwing. Sexes alike. Seasonal variation in colour, rapidly wearing from dark brown-grey to brown. Fledgelings generally inseparable; in Apr. and May, distinguished by fresh blackish plumage (when adults worn, brown) and larger, more silvery (not white) underwing panel.

DESCRIPTION ADULT. Head, upperbody, upwing and tail, uniform dark brown-grey; browner when plumage worn. Underbody, slightly paler than upperparts but still mid- to dark-grey. Often appears all dark at sea apart from underwing. Underwing varies but always has dark grey-brown leading-edge to inner wing and slightly darker subhumerals. Primary coverts, apart from leading-edge, vary: all-white; white streaked with blackish shafts; white in centre, very heavily streaked blackish; rarely, all-grey, sometimes streaked blackish. Most have more white in area of primary coverts than do Short-tailed Shearwaters. Secondary coverts, generally grey except for median coverts, which usually white centrally, often streaked blackish. Often appears all black to brownish in field with paler, often whitish central underwing. In strong sunlight, reflection can make underwing appear paler, silvery. Bill, long and slender; nostrils raised only slightly over base of upper mandible; culminicorn and nostrils, black; rest, dark brownish grey; usually appears blackish at sea; in strong light, can appear paler, but never as pale as Flesh-footed Shearwater *P. carneipes*, or Wedge-tailed Shearwater *P. pacificus*. Iris, dark brown. Legs and feet, blackish on outside of tarsus and outer toe; inside of tarsus and rest of toes and webs, flesh-pink.

SIMILAR SPECIES **Short-tailed Shearwater**, always smaller though not always apparent; bill, shorter, (one of the most reliable features). Underwing pattern: often have pale feathers restricted to centre, appearing as white streak (Sooty generally has larger area of white in area of primary coverts) but some can have as much white on underwing as average Sooty; in close views, most do not have streaks through whiter parts of underwings. Identification should not be made solely on underwing pattern, but often useful when flocks of either species seen, as individual variation can be assessed. In close views, more abrupt profile of head (Sooty tend to have flatter-crowned appearance and less of a forehead). Harrison (1987) suggested that Short-tailed Shearwaters have paler throats and darker caps, imparting more hooded appearance. However, throat-colour varies, not all having paler throats, and should not be relied on. In Bass Str., Jan.–Aug., Short-tailed Shearwaters never show moult of remiges (Sooty Shearwaters, assumed to be non-breeding, often in heavy moult, especially of remiges). **Wedge-tailed Shearwater** *P. pacificus* has very different structure with smaller head and body, long slender wedge-shaped tail and long broad wings, held well forward and bowed with pronounced carpal bend. Also all-dark underwing and pale feet that do not extend past tip of tail. Flight, lazy and buoyant, without bursts of rapid stiff-winged fluttering of Sooty. **Flesh-footed Shearwater** *P. carneipes*, with heavier paler bill and broader wings. Underwing, dark but can appear silvery in bright sunlight. Pale feet do not protrude beyond tip of tail. Flight, more leisurely with less flapping. **Christmas Shearwater** *P. nativitatis*, markedly smaller, with broader wings and longer tail. Under wing-coverts, dark; feet, dark, not extending beyond tip of tail. **Great-winged Petrel** *Pterodroma macroptera* appears large-headed and bull-necked, with stubby black bill and high forehead. Face, usually grey; underwing, dark. Long slender wings held well forward and swept back from carpal joint.

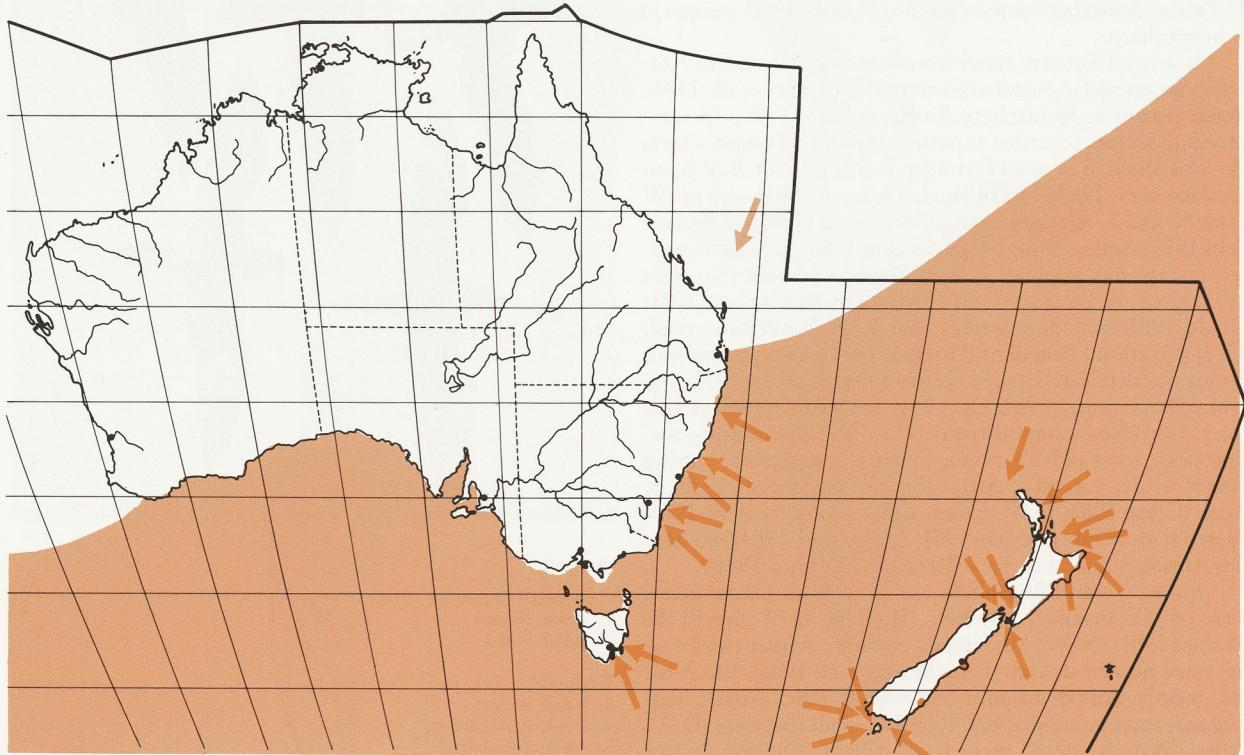
Abundant in s. oceans in summer, especially round s. NZ. Singly or in small flocks but usually highly gregarious, often feeding in huge flocks or gathering in rafts of thousands off

major breeding colonies in late afternoon. Flocks have no apparent structure, although small groups may fly in an oblique line. Flight very similar to Short-tailed Shearwater; wings held straight, not bowed downwards or swept back at carpal joint; fast and direct, with bursts of 2–8 rapid stiff-winged beats interspersed with low arcs and long glides with one wing-tip near surface. In higher winds, flap less, arc higher and flex wing more at carpal joint. On land, waddle with head low to ground and back hunched; often sit back to raise head and look round. If panicked, run quickly with wings extended and slightly raised. Swim well, not as high in water as other large shearwaters. Dive for food from surface or from low flight, using partially open wings for propulsion under water. Obtain most food by diving from less than 1 m; low horizontal glide turns into stall-dive, then head-first plunge into sea with wings partly folded. Flocks often feed along a front with surfacing birds patterning along surface before flying to front of flock and plunging in again. Large flocks can blacken sea, with band of white water where hundreds of birds splashing into sea. Sometimes feed in association with other seabirds e.g. penguins, albatrosses, Cape Petrels *Daption capense*, prions, terns and gulls. Usually ignore ships, though may (especially juveniles) attend trawlers. Breed in dense colonies on islands and headlands; under tussock, herbs, scrub and forest, wherever soil deep enough for burrowing. Strictly nocturnal at most colonies but, at Snares Is., birds come ashore before dark, circling higher above sea, then moving over island en masse in largely silent, unstructured swarm, each bird circling overhead, then heading out to sea again. As dusk approaches, more and more birds land; each landing preceded by repeated circling and half-stalling over eventual landing site, then bird stalls and crashes through vegetation to ground. Usually silent at sea; occasionally call in flight over colonies; highly vocal on ground and in burrows. Main call, loud

rhythmic repeated *der-rer-ah* or higher-pitched *coo-roo-ah*; two calls often given by duetting birds and may be given by opposite sexes. Calls deeper, slower and less hysterical than Short-tailed Shearwater. Soft crooning often heard from burrows during day.

HABITAT Marine, pelagic; in subtropical, subantarctic and Antarctic waters, migrating to n. Pacific and Atlantic Oceans in non-breeding season. Pre-breeders range S in open Antarctic waters to edge of iceberg-belt in s. summer; abundant in region of Polar Front overlying 2.5 °C isotherm (Ainley et al. 1984). Mainly in offshore and pelagic waters, but occasionally inshore, especially during rough weather (Bailey & Sorensen 1962; Bartle 1974; Milledge 1977). In NZ, observed feeding on edge of fish shoals, especially on downcurrent side of strong tidal streams (Jenkins 1974). Preferences for sea surface-temperature poorly recorded in A'asian waters; in s. South America, occupy waters of 0–19 °C (Brown et al. 1975a); in n. Pacific, prefers narrower range of temperature, and birds found over cool waters of 8–14 °C (Kuroda 1955; Ogi 1984; Briggs & Chu 1986). In both n. and s. hemispheres, feeding concentrations observed over thermal fronts at edges of upwellings and at boundaries of cool and warm water-masses (Cooke & Mills 1972; Brown et al. 1975a; Wahl 1978; Briggs & Chu 1986).

In A'asian region, breed mainly on subtropical and subantarctic islands; also on mainland NZ. Nest in burrows or rock crevices on coastal slopes, ridges and cliff tops, in herb-field, tussock grassland or forest; waterlogged or shallow soils and dense vegetation avoided. On Snares Is., birds excluded from areas occupied by Snares Penguins *Eudyptes robustus* (Jackson 1957; Warham 1967; Warham & Wilson 1982; Brothers 1984). Nesting birds affect vegetation by undermining trees, trampling seedlings and removing litter and ground



vegetation for nest lining (Warham *et al.* 1982). In Aust., often select higher and more secluded parts of islands for nesting (Lane & White 1983) though may burrow at base of cliffs or along shoreline (<10 m asl) (Keast & McGill 1958; Lane & White 1983). Exposed rocks, slopes and cliff edges near colonies used for take-off (McGill 1954; Warham 1967).

Usually fly low over sea, but may cross coast at 80–100 m height on return to breeding colonies (Guao, Chile; Clark *et al.* 1984). Dive from surface or plunge from 3–5 m height, swimming underwater to depths of up to 10 m (Brown *et al.* 1978; Brown *et al.* 1981).

Breeding range on mainland NZ has contracted, probably because habitat has been altered and introduced predators have become menace; colony at Twelve Mile Bluff declined after clearing, and birds did not use new growth of gorse, blackberry and bracken (Jackson 1957). On Macquarie I., areas of tussock grassland grazed by rabbits hold fewer burrows than ungrazed areas; where grassland denuded, greater risk of predation by feral cats and skuas, but some protection from Wekas *Gallirallus australis* and Black Rats *Rattus rattus*, which prefer vegetational cover (Brothers 1984). Former colony on Tasman I., Tas., may have been destroyed by establishment of gardens, sheep-grazing or predation by feral cats (Brothers 1979).

Commercial muttonbirding takes place round Stewart I., NZ; Maori permitted to harvest chicks on a few islands during a controlled season. Sooty Shearwater only species allowed to be sold commercially; most preserved and eaten but some used for making soap and lubrication oil; feathers may also be sold. Up to 250 000 young taken each year (Oliver; Robertson & Bell 1984).

DISTRIBUTION AND POPULATION Found s. hemisphere in s. summer where breeds round NZ, s. Aust. and s. South America; in non-breeding season, most move to N. Pacific Ocean but some move into N. Atlantic or remain in s. hemisphere.

In austral summer, range from breeding islands S to Antarctic waters as far as iceberg-belt (67°S) (Ainley *et al.* 1984). Some remain n. hemisphere (Briggs & Chu 1986). In non-breeding season, recorded as passage visitor to Tongan waters (Jenkins 1980), E of main Hawaiian Is (King 1970), E of Japan (Watabe *et al.* 1987), Sea of Japan (Guzman 1981), and off W coast N. and S. America e.g. California and Golfo de Aruaco (Jehl 1973; Ainley 1976; Briggs & Chu 1986). In austral winter, mainly concentrated E from Sea of Okhotsk (Shuntov 1972) across N. Pacific to Gulf of Alaska in W (Guzman 1981; Gould 1982) including waters near Kuril Is (Watabe *et al.* 1987) and round Aleutians (Guzman 1981). Less common in Bering Sea than Short-tailed Shearwaters (Shuntov 1972; Ogi *et al.* 1980; Guzman 1981; Ogi 1984). In Atlantic, passage visitor e. Canadian waters (Brown *et al.* 1975b) wintering nw. European coast (BWP). Some found s. hemisphere during austral winter e.g. off s. Africa (Brooke & Sinclair 1978), s. Aust. (Close 1982; D.W. Eades) and S. America (Jehl 1973; Brown *et al.* 1975b; Guzman 1981; Ainley *et al.* 1984) and near Iles Amsterdam and St Paul (Roux & Martinez 1987).

AUST. Breeding NSW and Tas. Qld. Uncommon; seen off SE in small numbers (Roberts 1979; Smyth & Corben 1984). NSW. Moderately common migrant and visitor, most numerous Oct.–Feb. (Morris *et al.* 1981). Vic. Visitor, mainly during autumn and winter (Vic. Atlas). Tas. Regular, small numbers. SA. Regular, small numbers (D.W. Eades). WA. Scattered records off Albany (Fullagar & van

Tets 1976; Aust. Atlas).

NZ During Nov.–Dec., common along e. coast (Norris 1965). On mainland, breed on headlands e.g. Banks and Otago Pens. and islands as far N as Three Kings Is (34°S), more common Cook Str. (41°S) but centre of abundance Foveaux Str. and on islands round Stewart I. e.g. Whero I. (Richdale 1963; Warham & Wilson 1982). Further offshore breed Snares (Horning & Horning 1974), Chatham, Antipodes, Auckland and Campbell Is.

BREEDING Known breeding sites and populations (pairs unless stated).

AUST. (from *Seabird Islands Series* in *Aust. Bird Bander* and *Corella* unless stated). NSW: Broughton I. (10); Little Broughton I. (5); Cabbage Tree I. (before 1976, 50–100); Boondelbah I. (10); Bird I. (5); Lion I. (8–10); Bowen I. (10); Montagu I. (1967–72, 150); Muttonbird I. (possible; Lane & White 1983); Tollgate Is (1976, 5). Tas.: Tasman I. (1978, 1000); Hippolyte Rocks (1980, few); Courts I. (regular; Lane & White 1983); Flat Witch I.; Flat I.; Breaksea I.; Green I.

NZ (from Warham & Wilson [1982] unless stated). Three Kings I.; Caval I.; Hen I.; Mokohinau I.; Alderman I.; White I.; Rurima I.; Motuhora I.; Kapiti I.; Mana I.; Stephens I.; The Trios; Open Bay I.; Green I.; Teirei I.; Cook Str.; Stewart I.; Cuvier I. (1976, small numbers); Foveaux Str. islands.

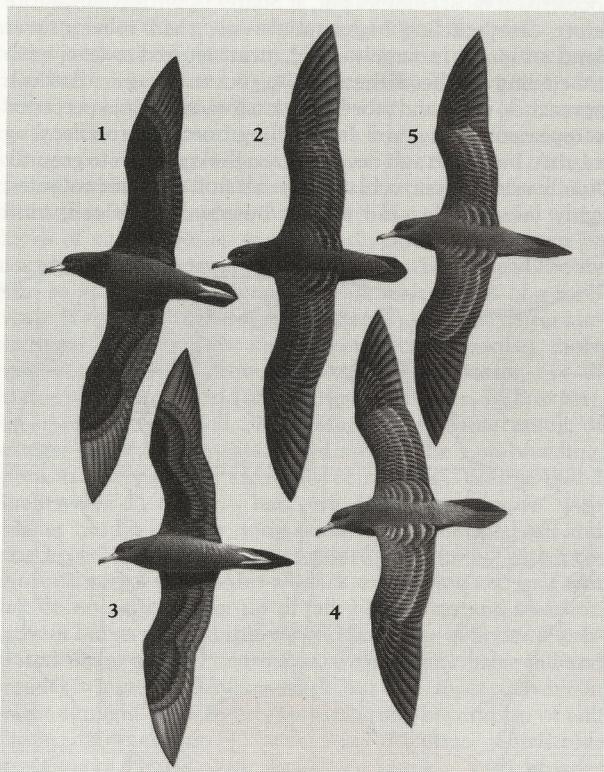


Plate 45

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

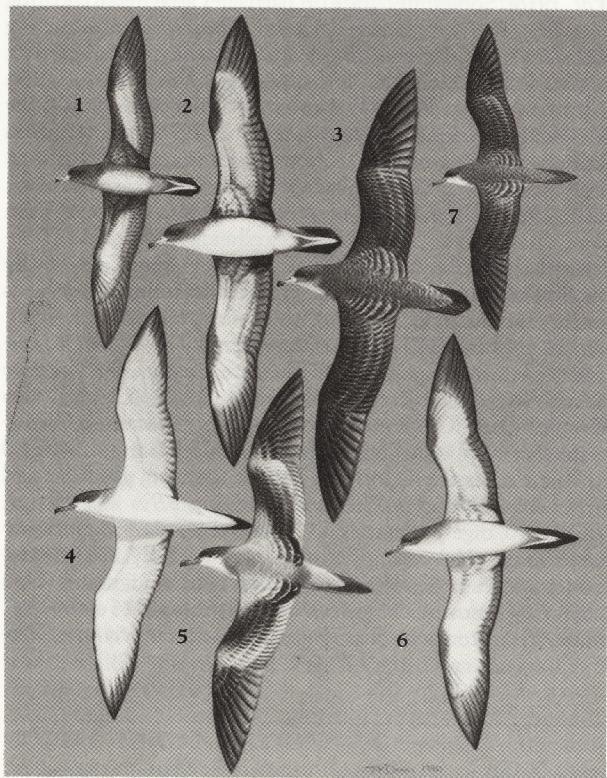
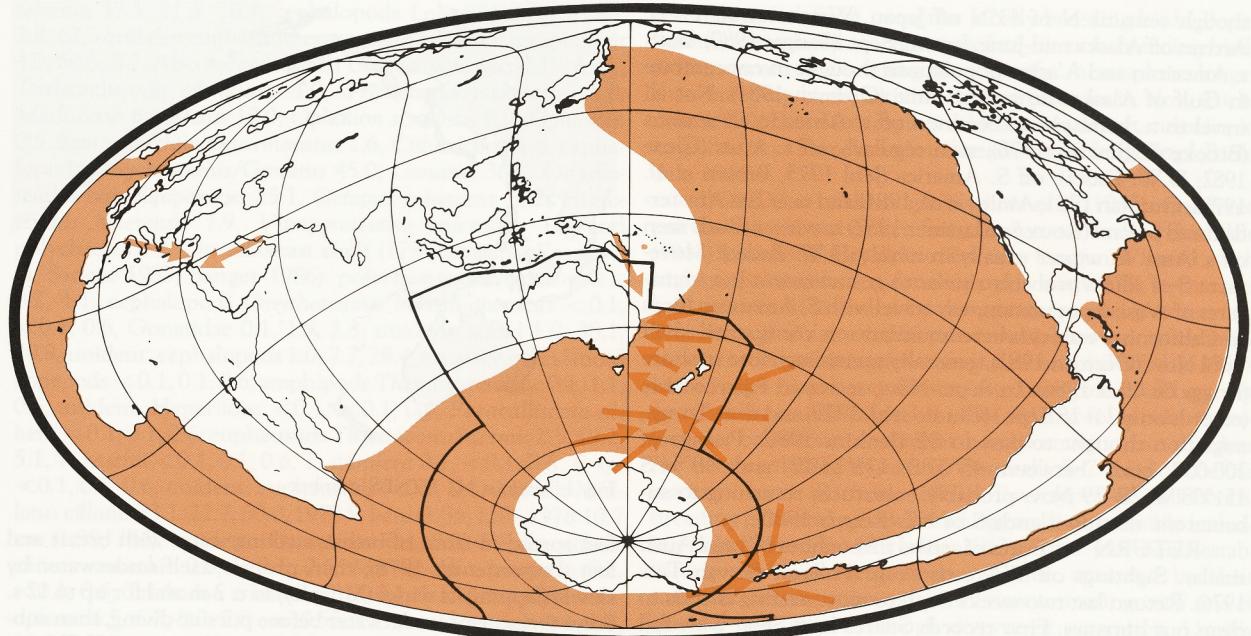


Plate 46

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

MACQUARIE I. (35 colonies, 1777 nests; Jones 1980; Brothers 1984).

SOLANDER IS (Cooper & Morrison 1984).

SNARES IS (1970-71, 2 750 000).

ANTIPODES IS (small colonies; Warham & Bell 1979).

AUCKLAND IS (small colonies; Warham & Bell 1979).

CAMPBELL I. (Warham *et al.* 1982).

CHATHAM IS (large colonies).

Extralimitally, breed Chile (Clark *et al.* 1984) and Falkland Is (very small numbers; Croxall *et al.* 1984).

MOVEMENTS Trans-equatorial migrant from breeding grounds round NZ, s. Aust. and s. S. America to Bering Sea and N. Atlantic. Timetable of movements similar throughout range (Warham *et al.* 1982).

DEPARTURE Most adults depart breeding islands by second week Apr. with a few remaining until May. Chicks remain for up to a month later before leaving (Richdale 1963) though not necessarily on first flight (Warham *et al.* 1982). Last adult at Snares Is, 1 May (Anon. 1974); last chick, 29 May (Horning & Horning 1974).

NON-BREEDING Flight-path through Pacific of A'asian population probably directly N on broad front towards Aleutian and Kuril Is (Guzman 1981) rather than any form of circular passage (Bourne 1956; Phillips 1963). Seen in Tongan waters in large numbers during May and n. migration thought to pass E of Samoan islands (Jenkins 1980) and reaches seas E of n. Japan late May (Watabe *et al.* 1987). S. American population probably travels up Humboldt current as far as Peru then either cuts across tropical Pacific towards Arctic waters (Guzman 1981) or continues up American coast. Present off California mid-May-Sept. (Ainley 1976) with peaks in numbers occurring May off s. California, May-July off central California and as late as Sept. N of C. Mendocino (Briggs *et al.* 1987); peaks off Oregon Apr.-May and Aug.-Sept. corresponding with birds on passage (Wiens & Scott 1975). Does not penetrate as far N in Bering Sea as Short-tailed Shearwaters (Shuntov 1972; Ogi *et al.* 1980; Ogi 1984)

though remains N of 43°N off Japan (Watabe *et al.* 1987). Arrives off Alaska mid-June, leaving Sept. (Sanger 1980). Both s. American and A'asian populations thought to concentrate in Gulf of Alaska during this time (Guzman 1981). Not all travel to n. hemisphere: common off s. Africa in all seasons (Brooke & Sinclair 1978); seen regularly off s. Aust. (Close 1982; D.W. Eades), off S. America (Jehl 1973; Brown *et al.* 1975a; Guzman 1981; Ainley *et al.* 1984) and near Iles Amsterdam and St Paul (Roux & Martinez 1987) in winter. Birds seen off s. Aust. in winter usually in moult (D.W. Eades). Movement S of adults probably similar to n. movement but immatures of A'asian population may travel with S. American birds to Californian waters where abundant on continental shelf until Nov. (Guzman 1981), generally remaining close to shore (Briggs & Chu 1986). In Sept.-Nov., scarce in Fijian waters (records only 21-28 Sept.) (Clunie *et al.* 1978) and near Tonga; migration thought to pass to SE (Jenkins 1980). Passage of 200 000 birds between 45°07'S 175°23'W and 48°54'S 151°08'W 28-29 Nov. probably immatures returning to subantarctic nesting islands S of NZ (Rogers 1980).

RETURN Dates of arrival throughout NZ and Aust. similar. Sightings off WA early Aug. (Fullagar & van Tets 1976). Return last two weeks Sept. to most nesting islands to clean out burrows. First records Snares Is, 8 Sept. with full occupation by first week in Oct. (Horning & Horning 1974). Possibly later at Macquarie I. where first evidence, 7 Oct. (Warham *et al.* 1982) and 10 Oct. (Brothers 1984). Population at Whero I. (Richdale 1963) may have nested later (Warham *et al.* 1982).

BREEDING Suggested by Warham *et al.* (1982) that Sooty Shearwater travels less distance to forage while breeding than Short-tailed Shearwater but, during summer, Sooty Shearwater most abundant species along Polar Front N of Ross Sea, occurring S to 67°00'S, where first icebergs appear (Ainley *et al.* 1984) and abundant between 60° and 65°S at 120° and 150°E when all Short-tailed Shearwaters N of 60°S (Mochizuki & Kasuga 1985).

BANDING Returns from NZ summarized Fig. 1. Other records (ABBBS).

33S151E 02 1+ U 30 12509 61
33S151E 12 1+ U 10 274 202
33S151E 12 1+ U 48 2007 106
33S151E 12 1+ U 5 8645 352

FOOD Wide variety of pelagic animals including cephalopods, fish and crustaceans. **BEHAVIOUR**. Most food taken by pursuit-plunging, pursuit-diving and surface-diving, also shallow plunging, surface-seizing (Harper *et al.* 1985) and hydroplaning (Sealy 1973). In pursuit plunging, dives from 3-5 m at c. 45° with wings one-third extended from body, and

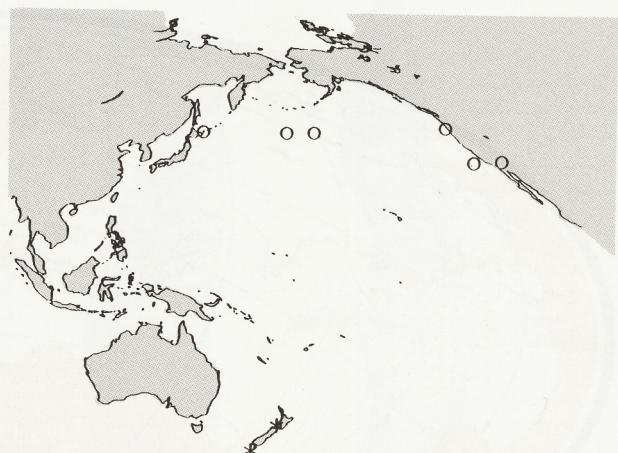


Fig. 1. Various NZ NZNBS number

feet spread in front of breast, striking water with breast and feet (Brown *et al.* 1978), then propels itself underwater by slowly flapping its wings (Murphy) to c. 2 m and for up to 12 s. Sometimes peers underwater before pursuit-diving, then submerges smoothly, descending and ascending at c. 45° (Brown *et al.* 1978). Sometimes graze on barnacles attached to floating logs (Ogi 1984). Quantified observations: pursuit-plunging 60%, shallow plunging 29%, surface-seizing 11% (n=383; Ainley & Boekelheide 1983). Sometimes feed in association with whales (Anon 1912; Best *et al.* 1984), including Grey Whales *Eschrichtius robustus* (Harrison 1979) and dolphins (Enticott 1986); and in association with Black Petrel *Procellaria parkinsoni*, White-headed Petrel *Pterodroma lessonii*, Black Storm-Petrel *Oceanodroma Melania*, Arctic Tern *Sterna paradisaea* (Ainley & Boekelheide 1983) and White-fronted Tern *S. striata* (Oliver). Probably attracted to prey by smell of oil (Hutchinson *et al.* 1984) or by seeing other birds feeding (Hoffman *et al.* 1981).

NON-BREEDING Summarized Table 1. In n. Pacific (173 stomachs; Ogi 1984), fish were mostly *Cololabis saire* (69.7% wt., 23.7% freq., fork length 16.0-26.2 cm), also Myctophidae, *Gasterosteus aculeatus*, *Helecolenus/Neosebastes*, *Scomber japonicus*; cephalopods (72.8% freq., 3.0-25.0 cm mantle length) incl. *Berryteuthis anonymus*, *Japetella* and *Argonauta*; barnacles *Cirripedia* made up 2.9% wt., jellyfish *Velella* 1.0, digested matter 5.4. Off California fish predominated: young *Helecolenus/Neosebastes* May-July and *Engraulis mordax* Aug.-Sept. while fattening before migration (Chu 1984). *E. mordax* made up 46.3% wt., 4.8% no. (116 stomachs), 38.8% freq. (stomachs plus 75 gizzards) with *Helecolenus/Neosebastes*.

Table 1. Non-breeding diet of the Sooty Shearwater.

	%dry wt.		%wet wt.		%vol.		% no.		%freq.	
	1	2	3	4	2	3	4	5	2	4
fish	97.0	83.1	89.3	95.1	31.8	69.6	30.9	13.3	97	50
cephalopods	<0.1	7.3	5.3	2.1	3.5	21.5	47.7	60.0	91	41
crustaceans	3.0	0.4	4.8	2.8	64.8	4.0	21.3	26.7	18	5
euphausiids	2.7	0.3	4.0	<0.1	60.5	<0.1	19.9	6	5	
amphipods	0.1	<0.1		<0.1		0.1	1.3	0	1	

(1) Jackson (1988); (2) Ogi (1984); (3) Chu (1984); (4) Krasnow & Sanger (1982), Sanger (1986); (5) Baltz & Morejohn (1977).

sebastes 37.3, 21.3, 30.4, cephalopods *Loligo opalescens* 5.3, 2.8, 62.3 and the euphausiid crustacean *Thysanoessa spinifera* 4.0, 60.5, 5.7. Also recorded, fish *Clupea harengus* 0.5% freq., *Tarletonbeania crenularis* 1.0, *Triphoturus mexicanus* 1.0, *Merluccius productus* 10.0, *Ophidion scrippsae* 0.5, *Ophiodon* 0.5, *Scorpaenichthys marmoratus* 1.6, *Citharichthys* 1.6; cephalopods *Onychoteuthis/Gonatus* 45.0, *Gonatus* 36.2, *Onychoteuthis borealijaponicus* 25.1, *Octopus rubescens* 16.2, *Histioteuthis heteropsis* 7.9, *Vampyroteuthis infernalis* 1.0 and polychaetes 4.2. On Alaskan shelf (178 stomachs; Krasnow & Sanger 1982; Sanger 1986): polychaetes *Nereidae* <0.1, 0.2, 1.1; cephalopods *Onychoteuthis borealijaponicus* <0.1, <0.1, 0.6, *Gonatidae* 0.1, 1.9, 2.3, unident. squid 1.0, 38.1, 40.9, unident. cephalopods 1.0, 7.7, 28.4; crustaceans calanoid copepods <0.1, 0.1, 0.6, amphipods *Themisto pacifica* 0.1, 1.1, 0.6, unident. Hyperiidae <0.1, <0.1, 0.6, *Paracallisoma alberti* <0.1, 0.1, 0.6, euphausiids *Thysanoessa inermis* 2.5, 19.2, 5.1, *T. raschii* <0.1, 0.1, 0.6, *T. spinifera* 0.1, <0.1, 0.6, *T. sp.* <0.1, 0.5, 0.6, unident. euphausiids <0.1, 0.1, 0.6; fish *Mallotus villosus* 83.1, 22.7, 50.0, 1977 9.1 cm (1.86; 130), 1978 10.7 cm (1.98; 244), unident. Osmeridae 0.4, 0.3, 3.4, *Sternobrachius nannochir* 0.6, <0.1, 0.6, *Microgradus proximus* 0.2, <0.1, 0.6, *Trichodon trichodon* 0.2, 0.1, 1.1, *Ammodytes hexapterus* 6.5, 6.0, 8.0, 7.8 cm (0.55; 135), unident. fish 4.1, 1.8, 18.8. In Monterey Bay, California (21 stomachs, 872 items; Baltz & Morejohn 1977) fish, *Clupea harengus* 0.3% no., 9.5% freq., *Engraulis mordax* 8.6, 61.9, *Porichthys notatus* 0.2, 4.8, *Merluccius productus* 0.3, 4.8, *Helecanenus/Neosebastes* 8.8, 9.5; cephalopods *Loligo opalescens* 36.6, 42.9, unident. sp. A. 8.6, 71.4, sp. B. 0.2, 4.8; crustaceans *Thysanoessa spinifera* 36.3, 4.8, unident. 0.2, 4.8. In Benguela Region, S. Africa (42 stomachs, 48 gizzards; Jackson 1988) fish *Engraulis capensis* stomach: 33.3% dry wt., 32.2% no., 29.2% freq., gizzard: 2.0% no., 8.9% freq., *Maurolicus muelleri* 30.3, 24.0, 29.2, 27.4, 41.7, *Lampanyctodes hectoris* 30.3, 30.7, 31.1, 21.2, 29.0, unident. self-caught fish 0.1, 1.1, 7.7, 0.1, 0.7, offal from trawlers *Coelorinchus fasciatus* 3.0, 2.4, 8.3, 0.7, 15.3; crustaceans stomatopods *Squilla armata* 3.0, 7.4, 8.3, 0.2, 4.2, amphipods <0.1, 0.2, 0.7, -, -, euphausiids *Euphausia lucens* <0.1, 0.1, 3.3, -, -, crab megalopa <0.1, 0.6, 2.1, -, -, cephalopod beaks -, 0.2, 0.7, 40.2, 60.7. Other records: fish *Engraulis mordax* 80% vol., other 12, cephalopods 8 (Wiens & Scott 1975); anchovies, cephalopods, and crab larv. *Cancer polydon*, *Pinnixa transversalis* (off Peru; Murphy). In N. Atlantic takes mostly euphausiid crustaceans with some soft-bodied fish such as herring (Brown et al. 1981).

BREEDING At Snares Is, one regurgitation contained euphausiids *Nyctiphantes australis* and *N. capensis* (Fenwick 1978); also recorded taking *N. australis* by Cheah & Hansen (1970) and seen feeding on crustaceans in Cook Str. (Walter 1903). Stomach oil of chicks mostly wax esters (Carter & Malcolm 1927).

SOCIAL ORGANIZATION Gregarious. Migrate in huge continuous flocks: continuous passage of 200 000 birds recorded (Rogers 1980; CSN 33); estimated migrating birds pass at 3000 birds/h at Foxton Bay, NI (CSN 34); single flock of c. 500 000 recorded at sea (CSN 4). Occur in large numbers in wintering grounds (Richdale 1944), in flocks of 'millions' at estimated densities of 2560/km² at sea off California (Peakall 1960). At any time of year, flocks may contain other shearwaters e.g. Short-tailed, Wedge-tailed and Buller's (Vooren 1972; Milledge 1977). Feeding flocks of 8000–10 000 birds may form over shoals (CSN 23). Flocks arriving at breeding

colonies in late Sept. comprise mostly breeding birds. Populations, considered to be mainly late- or non-breeding birds (66%), remain at wintering grounds of n. hemisphere longer than breeding birds, arriving back at colonies in Nov. (Richdale 1963); these unemployed birds also depart colonies in large flocks c. 7 weeks before breeders and fledglings (Richdale 1944).

BONDS Although Warham et al. (1982) considered pair-bonds remain intact from season to season, Richdale (1963) found that they did not last very long on Whero I., with high proportion lasting for only one season: 23% were intact next season, 61% ended by disappearance of a partner, and 16% through divorce (n=83 pair-bonds). However, pair-bonds also recorded as lasting for at least 11 seasons (Richdale 1963). Mated pairs have lower divorce rate than pairs that have not successfully mated. Birds 3–4 years old first form pairs as preliminary behaviour to true pair-bond formation, but this does not necessarily lead to mating. Generally 5–7 years old before mating occurs (Richdale 1963). Two types of pair-bonds: breeding pairs and pairs without egg or chick (possibly including failed breeders) (Richdale 1963). After pair-bond established, trio may form when outsider, attracted by their activities, accompanies pair with view to mating with one of original pair, either through divorce or separation. Usually unsuccessful in splitting pair, but, if successful, ousted bird may remain nearby (Richdale 1963).

PARENTAL CARE Both sexes incubate and feed young. After first week, chick unattended for significantly longer periods than attended. Parents rarely visit chick simultaneously (Richdale 1945) and, as a whole, visit on only 24–50% of nights that chick spends in burrow. Chick deserted, regardless of age, after early May, age having no influence over parents' attentiveness (Richdale 1963). No post-fledging care.

BREEDING DISPERSION Nest colonially; highly sociable breeders. Usually densely packed. Highest densities: on Snares Is, 1.9 burrows/m² under *Poa* meadows and 1.2/m² under *Olearia* forest (Warham & Wilson 1982); on Whero I., 0.7/m² (Richdale 1963). However, on Whero I., 33% of burrows not used by breeders and 27% contained no birds at all; possibly 'play burrows' excavated by young birds (Richdale 1963). TERRITORIES. Occupants defend burrow entrance (therefore avoiding collapse through others excavating close by) (Warham & Wilson 1982). When on surface, tend to remain near particular burrow. Mated pairs intolerant of intruders in burrow; intruder of same sex ejected (Richdale 1963). Once observed sharing burrow with great-winged Petrel *Pterodroma macroptera* (Merton 1967). At Whero I., birds tend to shift burrows annually and often within season. Frequently more than two birds, and up to ten, can be found in a burrow. Seven percent of birds occupy more than two burrows and some occupy up to five. Birds with more than one burrow remain in same neighbourhood (shifting from 15 cm to 9 m). Each season, return to same neighbourhood, but not necessarily same burrow. Of birds found within burrows, those breeding for two successive seasons shift least (av. 0.78 m; 2.55; 0–18.79; 274); those breeding for one season and not for next, shift farther (av. 7.1 m; 2.33; 0–19.10; 603); birds not breeding in both seasons, shift most (av. 3.10 m; 3.18; 0–27.88; 358) (Richdale 1963). Mating, laying, chick rearing and roosting occur in territory. In evening, may land farther than 27 m away from burrow and scurry overland to burrow (Merton 1967). Birds feeding young may travel hundreds of kilometres from colony in search of food (Oliver).

ROOSTING Sleep with head tucked under wing (Fleming 1948). Breeding birds roost solitarily at night either in burrow or on ground near burrow's entrance, often after feeding young. Unemployed birds usually roost on ground, but sometimes in burrows (Fleming 1948; Richdale 1963). Sometimes roost in burrows during day (Oliver); 46% of unemployed birds caught were found in burrows during day (Richdale 1963). Often roost and loaf offshore during day, except when weather rough (CSN 1; Warham 1967); usually in afternoon, with numbers increasing later in day (Warham 1967), possibly awaiting onset of darkness (HASB). Arrive to roost at colonies late afternoon and evening, generally before other petrels. On Whero I., arrive between 20:30 and 22:00 (Richdale 1943–44, 1944, 1963). Fly noisily over colony before landing. By 21:20 birds have begun to land, and by 21:40 most have landed. Generally quiet by midnight, although unemployed birds may call well into night (Richdale 1963). On Solander I., birds call overhead between 22:45 and 06:10 (Cooper 1984). At Snares Is birds generally arrive during daylight hours, between 16:30 and 18:00, land within a few minutes, and become quiet by 22:00 (Fleming 1948; Richdale 1963). Leave roost at dawn. Departure preceded by noisy pre-dawn chorus, with unemployed birds leaving burrows 2 h before take-off, and wandering round colonies (Richdale 1940, 1963; Warham 1967; Warham & Bell 1979).

SOCIAL BEHAVIOUR Partly known; no detailed behavioural studies but other studies by Richdale (1945, 1954, 1963) and Warham (1964, 1967) and Warham & Wilson (1982). Information compiled by J.M. Peter. Observation at nest-site difficult as much activity occurs at night and in burrows.

AGONISTIC BEHAVIOUR When handled fight fiercely. Adults capable of defending themselves and nests from predators (Fleming 1939) by making strenuous efforts to bite (Bassett Hull 1911). Single birds that enter burrow of mated pair may be evicted (Richdale 1963). Chicks cough up oil when disturbed (Richdale 1944; 1949).

SEXUAL BEHAVIOUR COURTSHIP. Birds probably paired when they arrive at colony, and subsequent courtship behaviour possibly to maintain pair-bond; pre-breeding birds may form pairs at colonies in previous year, when unemployed birds nocturnally wander round colony, often in pairs or trios, indulging in courtship actions and calling (Richdale 1944). On arrival at colonies, 3–4 year olds settle at permanent site and become acquainted with residents by wandering in and out of burrows. Eventually trios formed: preliminary behaviour to pair-formation (Richdale 1963). Duetting, apparently with arched napes and down-turned bills. COPULATION. Before copulation, pairs sit on ground calling loudly, rubbing heads together, with one sometimes placing head beneath other's chin (CSN 1); male occasionally thrusts bill violently at head and neck of partner (Warham 1967). During copulation, male waves outstretched and dangling wings, and thrusts open bill into feathers of mate's neck. Female turns bill upwards to probe male's throat (Warham 1967). Coition may last for a few seconds (CSN 1) or several minutes (Warham 1967); then female moves away and stands erect with flapping wings for 2–3 s, before resuming calling and head rubbing. Birds then return to burrow (CSN 1). Those observed copulating on ground outside burrows generally pre-breeders (Warham 1967).

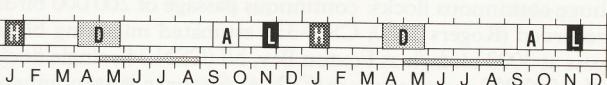
RELATIONS WITHIN FAMILY GROUP Parent may incubate for up to 16 days without relief (Richdale 1963).

During incubation, sensitive to disturbance and will readily desert eggs (Warham & Wilson 1982). Chick guarded by parent for at least first day after hatching, though attendance at nest decreases markedly after this (Richdale 1945). Both parents feed chicks and collect food simultaneously, leaving chick unattended (Richdale 1954). Young fed in burrows, where begging behaviour unobservable but probably feed with cross-bill style (Richdale 1963). Frequency of feeding decreases with age, and by fifth week chick will have undergone long periods (up to 25 days) without food, interspersed with short intervals of heavy meals, sometimes from both parents on same night (Richdale 1945, 1963). After mid-Apr., parents only spasmodically return to feed chicks (Richdale 1954), and after early May parents cease to feed chicks and desert them, regardless of age.

VOICE Poorly known and no studies. Usually silent at sea; occasionally call in flight over colonies; highly vocal on ground and in burrows. Main call, loud rhythmically repeated *der-rer-ah* or higher-pitched *coo-roo-ah*; the two calls often given by duetting birds and may be by opposite sexes. First two notes, exhaled and the last inhaled. Calls deeper, slower and less hysterical than Short-tailed Shearwater. Soft crooning often heard from burrows during day. No further information.

BREEDING Fairly well known. Studies by Richdale (1942, 1945, 1954, 1963) at Whero I., NZ and by Warham (1964, 1967), Warham & Wilson (1982) and Warham et al. (1982). Information compiled by J.M. Peter. Breed colonially in burrows, often associated with other seabirds (shearwaters, penguins, prions, storm-petrels and diving-petrels) but on Tasman I., Tas., segregated from Short-tailed Shearwaters (Wood Jones 1936; Sharland 1946; Brothers & Skira 1983), and on Snares Is., avoid colonies of Snares Penguins (Warham & Wilson 1982).

SEASON Summer breeder in A'asia, but season may appear longer because unemployed birds active longer (Richdale 1944). In s. NZ colonies, breeding birds arrive 1 Sept., when large numbers of unemployed birds (possibly both late and non-breeders) still in n. hemisphere; latter arrive in mid-Nov. (Richdale 1944; Warham et al. 1982). At Bird I., NSW, arrive Sept. (Lane 1973). Come ashore to colonies in Oct. and immediately begin cleaning out burrows (Oliver). Breeders undertake pre-laying exodus of c. 14 days, from 1 Oct. until mid-Nov. (Warham et al. 1982). Eggs laid immediately on return. Most eggs on Whero I. laid between mid-Nov. and early Dec., although earliest egg noted on 7 Nov. On Snares Is., from 1968–70, 66% laid between 20–24 Nov. Recorded in late Nov. on Macquarie I. (Campbell). Unemployed birds (failed and pre-breeders) leave colonies from early Feb., but remain offshore until migration begins in mid-late Mar. Adults and fledglings leave in late Apr. and early May (Richdale 1963; Warham et al. 1982).



SITE Nest on offshore islands, but sometimes on headlands on NZ mainland (Warham et al. 1982; Blackburn 1968). At Snares Is., high density (see Social Organization) in tussock meadows dominated by *Poa* spp, where roots in soil few, even if soil thin; also high density in *Olearia* forest, where

no leaf-litter, it having mostly been removed by the birds for building; lowest density in *Hebe* and *Senecio* scrub. At Whero and Snares Is., prefer to dig burrows in peat more than 45 cm thick and generally avoid thin, waterlogged and eroded soils. On Solander I., most nests in thickets and scrub of *Hebe elliptica* and *Senecio stewartiae*; favour bases of tree-ferns (Cooper 1984; Cooper et al. 1986; Wilson 1973). On Motuara I., recorded nesting among blackberries, ivy and other introduced plants and under remains of houses (CSN 19) but at Twelve Mile Bluff avoid areas of introduced plants like gorse and blackberries, even bracken (Jackson 1957). Generally, few burrows in shallow hard stony soils (Richdale 1963; Hicks et al. 1975); recorded burrowing in sandy soils (Keast & McGill 1948). Burrows often overgrown and inconspicuous but those of non-breeders often have freshly dug soil at entrance (Richdale 1944). Burrows not always used by same pair each year but same pair usually nests in same small area each year (Richdale 1963).

NEST, MATERIALS In chamber at end of burrow, which may be winding in friable soils (Richdale 1963) or straight elsewhere. Nest roughly constructed with leaves, twigs, seedlings, grass, leaf-litter (Bassett Hull 1911; Richdale 1944; Warham 1967; Warham et al. 1982). Several burrows may have common entrance (Richdale 1944). Burrows, 30 cm-3 m long (Richdale 1944), generally longer than those of Short-tailed or Wedge-tailed Shearwaters (Keast & McGill 1948); 0.5-1 m below ground (Warham & Wilson 1982). Sometimes nest in shallow scrapes (>12 cm; Hicks et al. 1975) under bushes or huts (Richdale 1963), or in rock crevices (Brothers & Skira 1983; Kinsky & Sibson 1959; Warham 1967); under Manuka roots overlain with fallen debris (Hicks et al. 1975). Although nests usually in total darkness, recorded incubating eggs at entrance to burrow in daylight (Richdale 1944). On arrival at colonies, old burrows scratched out; if entrance blocked by collapse or plant growth, new entrance dug nearby, with new tunnel possibly running into and ruining several other burrows, forcing occupants to go elsewhere (Richdale 1963). Probably dug at night. Ground round colonies in *Olearia* forests bare, as leaf-litter etc. gathered for inclusion into nest. Material carried in bill (Warham et al. 1982). Grass may be clipped with bill (Horning & Horning 1974). Addled eggs brought to mouth of burrow before excavating site, usually burying egg in the process (Richdale 1943-44). Eggs laid on surface usually abandoned (Warham & Wilson 1982).

EGGS Round, oval or elongate; coarse or chalky texture, minutely pitted, with slight gloss; white, may become stained (Campbell; Richdale 1944; Murphy).

MEASUREMENTS: Aust. Tasman I. av. 72.3 x 45.7 (40 eggs; Wood Jones 1936). NZ. Whero I., 77.4 (2.9; 72-88; 72) x 48.26 (1.8; 44-52) (Richdale 1944); Mangere I., Chatham Is., 74.8 (2.52; 70.6-78.3; 9) x 48.5 (1.57; 46.4-50.5) (A.J.D. Tennyson).

WEIGHTS: Whero I., av. 92.93 (70-115; 65) (Richdale 1944, 1963).

CLUTCH-SIZE One. No replacement laying. (Richdale 1949).

LAYING Well synchronized (see Season).

INCUBATION By both sexes, for up to 16 days at a stretch, during which sitting bird fasts (Richdale 1963). **INCUBATION PERIOD.** On Snares Is., mean 52.7 days (n=9). Mean hatching dates: in 1971, 14 Jan. (n=7); 1967-72, 13 Jan. (7-18; 28) (Warham et al. 1982). Earliest hatching on Snares Is probably 6 Jan. (CSN 24). On Whero I., incubation period esti-

mated as 56 days, with hatching between 16 Jan. and 4 Feb. (peak 24 Jan.) (Richdale 1963). Change-over at night (Warham et al. 1982).

YOUNG Semi-altricial, nidicolous. Hatched with dark-grey down on upperparts, lighter underneath. Down shorter than other petrels: 20 mm on back, 8 mm on head. Forehead covered to base of bill, over which down falls. Bill, light blue-grey; ramicorn, violet-grey; egg-tooth, white; tarsi: front, light grey, back, darker; toes, light grey, webs, pinkish (Richdale 1945, 1963). Eyes fully open at hatching. **NESTLING PERIOD.** From hatching to departure, 96.79 (4.71; 86-106; 35) (Richdale 1954).

GROWTH On Whero I., by second week, head noticeably elongated, upperparts appear lighter, egg-tooth still present and sheaths of mesoptile just visible on scapulars. Egg-tooth disappears between 11-22 days. By fifth week, body elongated appreciably. Between 31 and 35 days, feathers appear on scapulars and quickly spread all over body; by 49 to 50 days, tail feathers appear. Primaries first protrude on Day 52. By eighth week, down loosened by growing feathers. Wing measurements: 1 day old, 26 mm; 8 days, 30.1; 15 days, 34.5; 22 days, 45.4; 29 days, 55.5; 36 days, 72.9; 43 days, 92.5; 50 days, 115 mm. Weight at hatching, 60-80 g. Maximum weight, 1070 g at 47 days old. On Snares Is., 91% of adult weight at fledging. During one night chick may gain up to 300 g in weight, and in 3 days may increase body weight by 133% (Richdale 1945). A parent always present during daylight just after hatching. On Whero I., fed within 12 h of hatching, and then often throughout first week, although on second day attendance by parents decreases to 60%, on third day to 30% and rarely present after third day; from hatching to desertion, chicks attended on 24-50% of days (average 36.9%; 56) (Richdale 1945, 1954). On Snares Is., mostly fed at night for first 5 nights and on at least eight of their first 14 days; parents more attentive than on Whero I. because usually a parent remains with chick from 4-5 days and up to 16-21 days. As chicks grow, period between feeding visits increases; on Whero I., left for up to 25 days, but on Snares, longest recorded was 7 days. Before fasting, chicks fed on few nights in succession; extended fasting early in life can result in death. Meals after fasts generally increase in size in proportion to length of fast (Richdale 1945). Fed by both parents, rarely simultaneously (Richdale 1945; Warham et al. 1982). Probably fed in 'cross-bill' style (Richdale 1963). Richdale (1945) found 70.3% of meals weighed <100 g, although largest weighed 300 g. Parents only spasmodically return to feed chicks after mid-Apr. and, regardless of chick's age, cease by early May. Richdale (1954) considered chicks must weigh at least 455 g to survive and begin migration; heavier chicks leave 11.98 days (5.59; 0-27; 58) after desertion, and lighter ones leave 20.64 (6.66; 10-36); thus late hatching (lighter) chicks may be less likely to survive than those hatched earlier. On Whero I., leave burrows between 19 Apr.-12 May. Usually leave at night, with birds lining up on slopes, beating wings and jostling for position; departure orderly, and some birds observed landing, indicating that not all chicks successful on first flight (Warham et al. 1982).

FLEDGING TO MATURITY First pairing may occur at 3-4 years, but do not breed until possibly between 5 and 7 years and certainly by 9 years (Richdale 1963).

SUCCESS On Snares, rainfall only major cause of mortality; when burrows flooded, chicks forced to leave and sit, exposed to wet and cold, on surface causing many to die. Some of these fall prey to skuas. Silver Gulls *Larus novaeh*

hollandiae take some eggs and small chicks from shallow burrows (Warham *et al.* 1982).

PLUMAGES

ADULT In fresh plumage: **HEAD AND NECK**. Crown, hindneck, sides of neck and most of foreneck, black-brown (c119); short white filoplumes on crown and nape; chin, brown-grey (79), feathers narrowly tipped pale grey (86); malar region and lores, brown-grey (79). **UPPERPARTS**. Mantle, black-brown (c119) with broad dark-brown (121) open pennaceous tips. Back, rump and scapulars similar, but tips narrower; when worn, tips, light grey-brown (119C). Upper tail-coverts, similar to mantle-feathers. **TAIL**, black-brown (119); rachis, dull white at base, merging to black-brown (119) distally. **UPPERWING**. All coverts, including alula, dark brown (121), with slightly paler open pennaceous tips. When worn, tips dark brown (119A). Remiges, black-brown (119). **UNDERPARTS**, dark brown-grey (79); feathers from breast to vent, narrowly tipped brown-grey (80); concealed bases, very pale brown-grey (80). Under tail-coverts, pale dark-brown (121), tipped light grey-brown (119D). When worn, tips on underparts dark brown (119A) to brown (119B). Axillaries, dark brown (121); rachis, black-brown (119). **UNDERWING**. Varies; coverts may appear dark, or light, depending on extent of white. Inner web of remiges, light grey-brown (119C). Outermost greater primary covert, glossy brown-grey (79); rest, white with distal glossy brown-grey (79) mottling on webs. Median primary coverts, white with basal dark-brown (121) shaft-streak, extending to three-quarters of length and mainly confined to outer webs. Marginal and lesser primary coverts, dark brown (121), tipped white. Greater coverts, white at base, with subterminal mottled brown-grey (79) gloss on webs, narrowly tipped white. Median coverts, white with distal quarter tipped grey-brown (91); lesser coverts similar, but with narrower tips. Marginal coverts, dark brown (121), tipped white.

DOWNTY YOUNG Based on Richdale (1945) who used another colour guide, see Richdale (1945) for details. **HEAD AND NECK**. At hatching, prototile 8 mm long on head. **UPPERPARTS**, dark carmine-grey; down 20 mm long on back. **UNDERPARTS**, medium neutral-grey with traces of lighter shade. At second week, down slightly lighter in colour. At 8 days, mesoptile present; sheaths of scapulars visible. Mesoptile well grown in third week. Little external change by fifth week. At 31–35 days, feathers appear on scapulars and spread over body. Tail appears at 49–50 days. Primaries appear at 52 days.

JUVENILE Similar to adult. Differs in having broader tips of feathers of upperparts, giving greyer appearance; according to Watson (1975) also have darker underwings and weaker bill.

ABERRANT PLUMAGES Partial albino reported by Poppelwell (1918). Albino, off Campbell I., showed a few dark feathers on wings (Bailey & Sorensen 1962). Further details of albinism given in Loomis (1918) and Oliver. Details of a supposed hybrid with Short-tailed Shearwater, showing intermediate characters given in Kuroda (1967).

BARE PARTS

ADULT, JUVENILE Iris, dark brown (219). Bill, grey-black (82); may appear brown when dirty from burrows. Tarsus, black-brown (119) on outer side, dark brown (121) with mauve (75) shade on inner, dirty pink (4) to dull pink (5).

DOWNTY YOUNG Except where stated, based on photographs in NZRD and NZDOC library. Iris, no data. Richdale (1945) states: at hatching, bill uniform light blue-grey. Ramicorn, light violet-grey; lower mandible, light blue-grey with lighter shade at mandibular unguis. Bill darkens by third week. Egg-tooth, white. Tarsus, light violet-grey, outer side darker. Top of toe, light violet-grey, underneath, darker. Webs, pinkish. Tips of claws, whitish, ridges with bluish tinge. At second week, tarsi and feet darken in colour. Egg-tooth disappears between 11–22 days (n=9) (Richdale 1945); lost at 16 days (5–23; n=10) after hatching (Warham *et al.* 1982).

MOULTS

ADULT POST-BREEDING Complete; primaries moult outwards, May–Aug.; occurs in nw. Pacific. All birds collected Monterey Bay, off California from May–July had old and newly growing flight-feathers; by Aug., quarter of birds had new plumage; by Sept., over half completed moult. Number of wing- and tail-feathers in moult greatest during July; see Chu (1984) for details. Secondaries moult outwards in both directions from s4–6; moult of remiges progresses faster and completed earlier than body-moult (Chu 1984). Ogi *et al.* (1981) observed similar pattern.

POST-JUVENILE Complete; occurs Feb. onwards; may include unsuccessful breeders. Some birds moult as late as Nov. (Mayaud 1949, 1950). Sequence of secondary moult as in Manx Shearwater *P. puffinus*. Secondaries moulted in four groups, s1–s4, s5–s12, 13 or 14, and 3 innermost moult inwards, s18 or s19–s14, 13 or 12 moult outwards (BWP).

MEASUREMENTS (1) Macquarie I. (MV). (2) Macquarie I., adults, skins; methods unknown (Falla 1937). (3) Campbell I., adults, skins (NMNZ). (4) Unknown status; methods unknown (Loomis 1918).

	MALES	FEMALES
WING	(1) 296.6 (4.78; 290–301; 3) (2) 299.2 (1.78; 297–301; 4) (3) 298.0 (12.02; 281–307; 3) (4) 301.0 (282–314; 78)	293.0 (7.82; 284–305; 5) 294.5 (9.17; 283–304; 4) 288.8 (20.75; 260–308; 3) 209.0 (281–318; 87)
8TH P	(1) 170.6 (5.24; 166–178; 3)	162.0 (4.73; 155–169; 5)
TAIL	(1) 85.6 (1.69; 84–88; 3) (2) 86.2 (4.02; 82–92; 4) (3) 87.5 (1.47; 85.5–89.0; 3) (4) 88.0 (80–94; 78)	87.4 (3.61; 83–93; 5) 88.7 (3.56; 85–94; 4) 89.3 (0.94; 88–90; 3) 89.0 (81–97; 87)
BILL	(1) 42.0 (0.65; 41.2–42.8; 3) (2) 42.2 (0.43; 42–43; 4) (3) 41.3 (0.99; 40.5–42.7; 3) (4) 43.0 (40–47; 78)	42.2 (1.03; 41.4–44.2; 5) 42.8 (0.73; 42–44; 4) 42.2 (0.72; 41.5–43.2; 3) 41.8 (38–45; 87)
TARSUS	(1) 56.4 (1.04; 55–57.4; 3) (2) 55.2 (1.08; 54–57; 4) (3) 59.1 (1.20; 57.3–60.3; 3) (4) 53.3 (50–57; 78)	56.9 (1.21; 55.5–58.5; 5) 54.7 (1.29; 53–56; 4) 59.4 (0.94; 58.5–60.7; 3) 53.0 (50–56; 87)
TOE	(1) 65.1 (1.26; 63.5–66.6; 3) (2) 66.0 (0.70; 65–67; 4) (3) 67.0 (1.78; 65.1–69.4; 3) (4) 65.2 (60–69; 78)	66.4 (0.60; 65.6–67.3; 5) 66.2 (3.03; 62–70; 4) 64.8 (0.87; 63.6–65.5; 3) 64.2 (60–68; 87)

Unsexed birds: (5) Whero I., NZ, adults, live (Richdale 1963). (6) Macquarie I., adults, live birds; minimum chord (Brothers 1984). (7) Snares Is, adults, live birds >11 years old; (Miskelly 1987).

	UNSEXED
WING	(5) 304.0 (6.9; 287-322) (6) 293.4 (7.83; 270-313; 68) (7) 304.0 (5.80; 293-315; 30)
TAIL	(5) 89.6 (2.7; 84-89) (6) 87.0 (3.05; 83-95; 68) (7) 91.0 (3.50; 86-101; 30)
BILL	(5) 41.9 (1.6; 38.5-45.5) (6) 41.2 (1.56; 38.7-45.6; 68) (7) 40.8 (1.61; 37.6-43.7; 30)
BILL D	(5) 14.8 (0.6; 13.5-16.2) (6) 15.1 (0.69; 13.8-16.5; 30)
BILL W	(5) 13.9 (0.6; 12.5-15.2) (6) 14.8 (0.79; 12.1-16.1; 30)
TARSUS	(6) 56.6 (1.97; 54.4-66.5; 68) (7) 57.3 (1.34; 54.4-59.8; 30)
TOE	(5) 67.6 (2.2; 62-74) (6) 67.4 (1.97; 65-72.1; 68) (7) 71.3 (1.82; 67.4-76.6; 30)

SEXING, AGEING Adults sexed on cloaca (Warham *et al.* 1982).

RMO

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Before departure, juveniles have wing measurement c. 8 mm shorter than adult (Richdale 1963); unknown when fully adult length attained; measurements of juveniles, given in Stonehouse (1964), overlap those of adults. Additional measurements in Murphy (1930), Palmer (1962), Stonehouse (1964), Mougin (1975), Warham & Bell (1979), Murphy and BWP. For full details of rates of growth of chicks, see Richdale (1945, 1963).

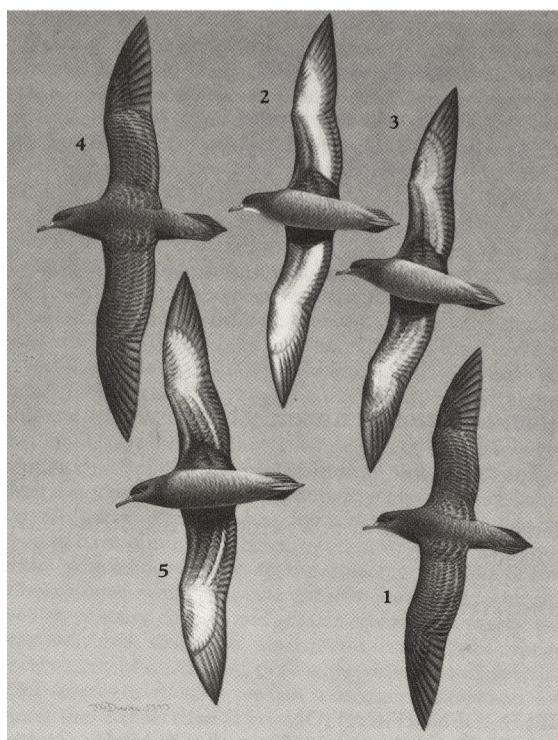
WEIGHTS Unsexed adults, Dec.-Jan., Whero I., NZ, 787 (16.0; 666-978; 100) (Richdale 1963). At Snares Is, unsexed adults >11 years old, 884 (62.4; 760-975) (Miskelly 1987). Label data from adult skins at NMNZ, Campbell I., Dec., no fat to very fat, males 613 (205; 327-793; 3), females 708 (26.4; 671-729; 3). Birds lean when arriving off California on migration in May; birds complete moult May-Aug. (see Moults) and fatten before departure again to s. hemisphere. Heavy moult coincides with 12% loss of weight and stored fat, which suggests that moult substantially affects energy balance. Fatten rapidly once moult complete; higher fat-content in Aug. and in Sept. Heaviest specimen collected in Sept. had extracted fat-weight, 542.9, or 41% of body-weight. Except for 12% decrease in July, mean body-weight (weight at collection minus gut-contents) increased from May to Sept. (Chu 1984). Additional weights in Richdale (1944, 1945), Stonehouse (1964), Mougin (1975) and Brown *et al.* (1981). Full details of changes of weight in chicks in Richdale (1945, 1963) and Warham *et al.* (1982). At Snares Is, in Apr., fledging weight 746 (176; 500), c. 91% of mean adult weight of 819 g (Warham *et al.* 1982).

STRUCTURE Wing long and narrow. Eleven primaries: p10 longest, p9 4-8 shorter, p8 18-23, p7 40-45, p6 61-71, p5 85-91, p4 110-121, p3 132-143, p2 151-163, p1 169-176, p11 minute. No emarginations. Twenty secondaries (Mayaud 1949, 1950); four of tertial form. Seven short humerals. Tail, short and rounded; 12 feathers; t1 longest, t6 15-30 mm shorter. Bill, slender with rounded maxillary unguis; nostril tubes, c. 25% of bill length; septum, subterminal; nostrils, directed obliquely upwards at tip. Tarsus, laterally compressed. Feet, webbed. Outer and middle toes, about equal in length.

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Volume 1 (Part A), Plate 47

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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