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## Order PELECANIFORMES

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

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

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

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Family **PHAETHONTIDAE** tropicbirds

Medium-sized, highly aerial seabirds. Three species in one genus *Phaethon*, so similar and closely related that they may be regarded as a superspecies. Body elongate; neck short; wings long and narrow, with 11 primaries (p10 longest, p11 minute); secondaries diastatic; tail with 12–14 feathers, central pair elongated into streamers; bill, powerful and decurved with serrated edges but not hooked at tip; nostrils, well-developed slits; no bare gular skin; very short tarsus, totipalmate toes; claws not with comb. Crouching stance; shuffling gait and unable to walk easily. Oil-gland, feathered. Sexes, similar. Plumage, white with black markings on head and upperparts. Golden and pink-washed plumages of some species have been taken as reason for separating into subspecies but probably best regarded as morphs because they occur in different proportions in different colonies.

Distributed throughout Tropics and Subtropics. Essentially pelagic and can be seen far from land; rarely wander outside tropical and subtropical waters but occasionally blown far inland during storms. Usually do not fly low over water; flight sustained with strong wing-beats, equally efficient in calms or in winds. Mostly feed by plunge-diving for fish and squids, from fairly high but not entering water deeply. Attracted by ships but usually do not follow them persistently. Mostly solitary at sea or in pairs; loosely gregarious at breeding stations. Nest in loose groups where terrain is suitable; indulge in communal display flights at colonies. Pair-bond monogamous, often long-term in successful pairs, which are more likely to reunite than those that fail. Pairs may maintain contact at sea unlike most other seabirds. Defend nest-site territories and re-use same site from year to year. Probably roost on water when not breeding. No specialized visual displays ashore, being almost unable to walk and because nest-sites not convenient or suitable for displays. Calls also seem unspecialized, mostly given on wing near colony and at sea and sometimes from nest-site.

Breeding season often prolonged; individuals may lay at intervals of 9–12 months. Nests are scrapes without any or much material; usually in cavities under rocks or bushes. Eggs vary in shape and colour, fawn to rich purple-brown and quite unlike those of other Pelecaniformes. Clutch-size, one. Replacement laying after loss. Incubation by both sexes in spells lasting from 3 to 16 days. Single median brood-patch. Incubation period, 40–46 days. Young, semi-altricial, nidicolous, downy at hatching. Cared for and fed by both parents by regurgitation. In *P. rubricauda*, at least, adult inserts bill into gullet of chick and disgorges, unlike any other Pelecaniformes. Nestling period, 65–90 days, varying greatly according to food supply. Independent of parents at fledging and no period of desertion before fledging.

*Phaethon rubricauda* Red-tailed Tropicbird

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*Phaeton* [sic] *rubricauda* Boddaert, 1783, *Tabl. Planches enlum.*: 57, based on *Paille-en queue de l'Isle de France* of Daubenton, *Planches enlum.*: Pl. 979 — Mauritius.

In Greek mythology, Phaethon (the shining) was an epithet or surname of Helios (the sun) but more commonly the name of a son of Helios by Clymene. Zeus slew him for driving the chariot of the sun too near the earth. His sisters (Phaethontides), who had yoked the horses to the chariot, were metamorphosed into poplars and their tears into amber. The specific name is a compound of the Latin *ruber*, *rubri* — (red) and *cauda* (f) tail.

OTHER ENGLISH NAMES Red-tailed Bos'nbird, Silver Bos'nbird, Strawtail.

The name **bos'nbird** was given by sailors because the projecting middle tail-feathers of the birds were generally likened to the marlin spike of the boatswain and the birds' call is like his whistle. However **tropicbird** has prevailed over it and was given to the bird earlier because as Dampier (Voy 1: 53) said, 'it was never seen far without either Tropic' and hence Linnaeus 'bestowed upon it the generic term *Phaethon* in allusion to its attempt to follow the path of the sun' (Newton & Gadow, *Dict. Birds*, 1896).

## MONOTYPIC

**FIELD IDENTIFICATION** Length 95–104 cm (includes central rectrices projection c. 35 cm); wingspan 111–119 cm; weight c. 800 g. Medium-sized, mainly white sea-bird with bright-red bill and very long central rectrices, thick-set body and unusual style of flight. Sexes similar. No seasonal plumage changes. Juveniles and immature separable.

**DESCRIPTION ADULT.** Above, white except for varying pink suffusion, black chevron-markings on tertials and black shaft-streaks on outer primaries. Wings long and tips rather rounded. Tail tapering and mainly white; central pair of rectrices very elongated as flexible points and entirely red but often surprisingly difficult to see; one or both points liable to be broken or missing. Below, white with more or less pink suffusion; flanks and axillaries streaked with dark greyish. Comma-like black facial stripe from lores through eye to ear-coverts. Bill pointed, slightly decurved and mainly bright red; legs, bluish grey, feet, blackish. **JUVENILE, IMMATURE.** Crown, nape, mantle, back, rump and upper wing-coverts heavily barred and scaled blackish on white, no central tail projections; bill, grey or black. Transition to adult plumage involves progressive decrease in barring on upper body and wings, probably over 2–3 years (Stokes in press).

**SIMILAR SPECIES** Longer winged and heavier bodied than *Silver Gull* *Larus novaehollandiae*; proportions and flight may suggest Caspian Tern *Hydroprogne caspia*. Distinguished from large terns Sternidae by heavier build and flight, lack of grey on upperparts and wedge-shaped or pointed tail. Adults distinguished from *White-tailed Tropicbird* *P. lepturus* by red bill, much less black on outer primaries and inner wing-coverts and red central tail-projections. Juveniles and immatures more similar but Red-tailed Tropicbird has bill dark grey or part red (not yellow), only a little black on outer primaries and is larger and more heavily built.

Fly mostly well above waves with regular, rather mechanical wing-beats alternating with horizontal glides. Wings appear to be set far back, usually held well angled at carpals and weight of body forward. Plunge-dive for food; rest on water with tail raised. At sea, usually solitary; rarely in coastal waters. Loosely gregarious at breeding grounds, with much activity, displays and calling. Calls given round breeding site include loud harsh growling notes given in circling flight; usually silent at sea. On land, crawl balancing on breast, pushing and pulling with wings and bill until reaching suitable take-off point.

**HABITAT** Pelagic, tropical and subtropical, aerial. In Indian Ocean, prefer waters with salinities <35‰ and surface-temperatures of 24–30 °C (Pocklington 1979; Dunlop *et al.* 1988a). In Pacific Ocean, boundary of range parallels summer surface isotherm of 22 °C; avoids waters of <33.5‰ in n. hemisphere and <35‰ in s. hemisphere (Gould *et al.* 1974); casual visitor over colder waters perhaps penetrating Tasman Sea as far S as Latitude 38°S (Falla *et al.* 1978). Distribution off WA appears to reflect presence of warm intermediate-salinity waters of Leeuwin Current, which have allowed recent southward expansion of breeding range (Dunlop *et al.* 1988b; Dunlop & Wooller 1986). In Pacific Ocean, may be dependent on cooler nutrient-rich waters for feeding, especially when breeding; decline in numbers and breeding failure on Christmas I. (Pac.) during El Niño Southern Oscillation, when sea surface-temperature high and food supply poor (Schreiber & Schreiber 1984). Highly pelagic; may be seen hundreds of km from land. On Christmas I. (Ind.), forage well out at sea in early morning, closer to shore in late afternoon (Gibson-Hill 1947a). Stay closer to land during breeding season (Gould *et al.* 1974); Tarburton (1979) assumes birds flying within 100 m of shore are breeding or about to breed.

Breed in Tropical and Subtropical Zones; on volcanic and other islands, stacks, atolls, cays; usually far from main-

land but in WA on coastal stack and has nested unsuccessfully on beach at Busselton (HASB). Often inaccessibly; in rugged terrain, on coastal cliffs (caves, fissures and ledges) and slopes (Merton 1970; Tarburton 1979; Stokes 1988); but also on low-lying cays and atolls, on vegetated sand-flats, beaches and coral rubble. From sea-level to 250 m (Philip I., Norfolk I.).

In central Pacific, follows ships at estimated mean height of 40 m (3–250; 307); dives from mean height of 25 m (10–50; 17; Gould *et al.* 1974); 6–12 m (Gibson-Hill 1947a). Probably roost on water (Gould *et al.* 1974).

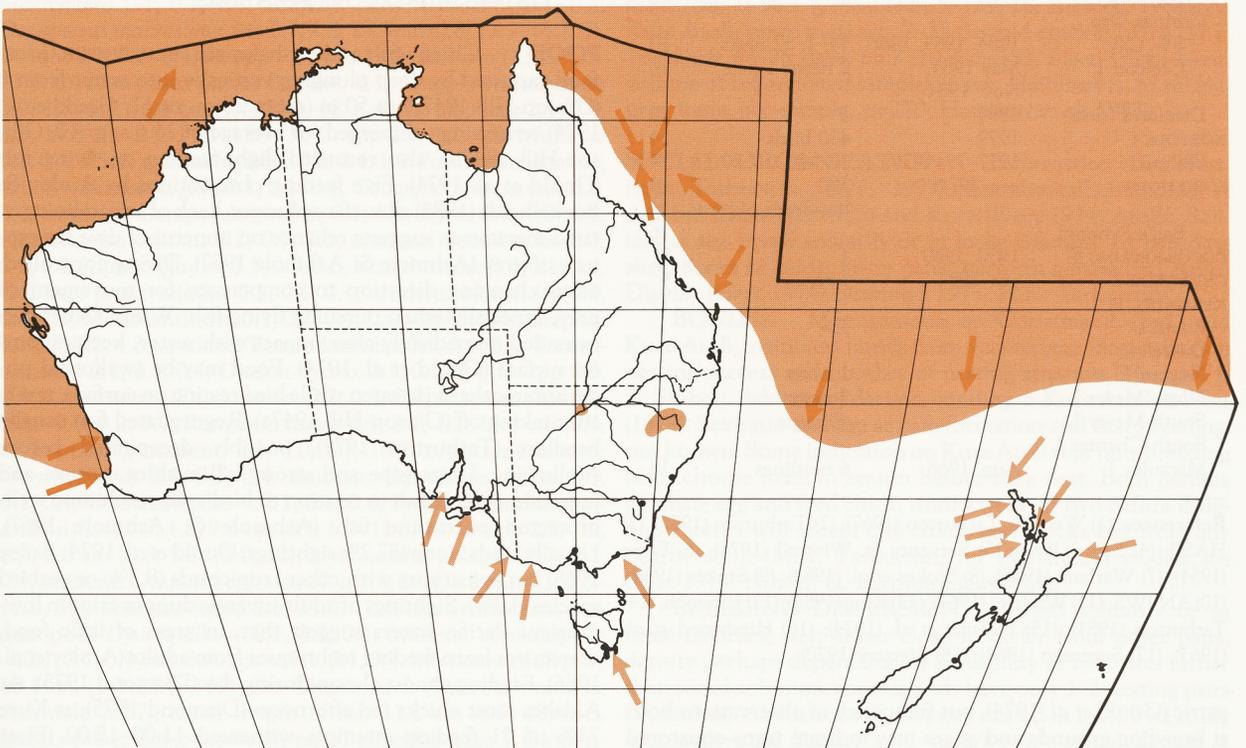
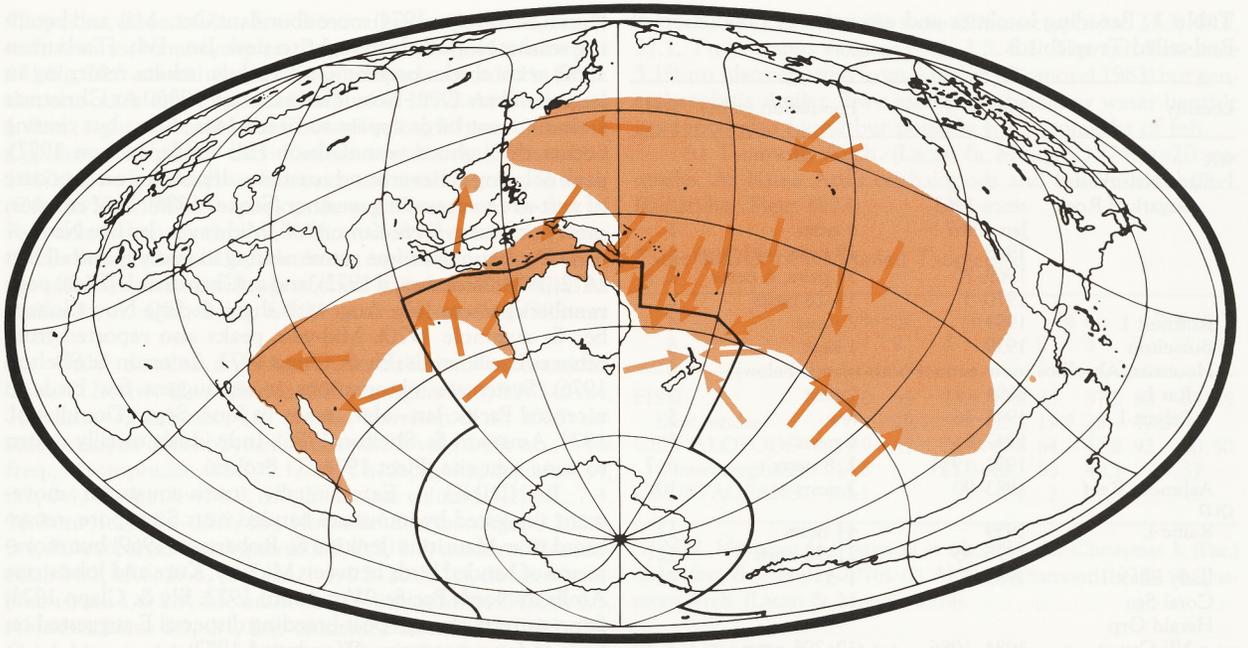
On Christmas I. (Ind.), clearing for settlement and mining has destroyed some nesting areas (Stokes 1988). Very tame when nesting (Warham 1956); will build near camps and roads (Serventy & Whittell 1976). Lack of protection after desertion of tourist camp may have led to extermination on Pelsart I. (HASB) but introduction of rats and cats, human interference, with consequent increase of gulls, cause losses. Interference by humans on WA mainland probably caused failure (Tarburton 1977).

**DISTRIBUTION AND POPULATION** Solitary, pelagic species of Tropical Indian and Pacific Oceans ranging to nearly 40°N and S. Occasional records far inland.

**AUST.** Discontinuous distribution; recorded all States. Most records from n. Aust. Nov.–Mar. with wind-blown birds sighted far inland. **Qld.** Recent reports only from Raine I. **Coral Sea** area, widespread. **NSW.** Fifteen records up to 1977, Nov.–July, most during summer and most of adults, mostly also in coastal waters along their whole length; one inland, Tamworth, June 1945 (Hindwood 1947; Morris 1979). On 20–23 Mar. 1978, storm-wrecked birds blown inland to Baradine, Coonabarabran (Warrumbungle NP), Gosford, Barraba, Dubbo, Parramatta, Bourke, Armidale, Tamworth (Morris 1979). Three records, Montagu I., 4 Apr. 1976, 29 Apr. 1980 (2 birds), 30 Mar. 1981 (Fullagar 1989). **Vic.** Storm-driven bird, Guildford, Jan. 1945 (Morrison 1945); at sea off Port Fairy, Mar. 1958 (Wheeler 1958); single, sighted, S of Lakes Entrance, 22 Mar. 1978 (Vic. Atlas). **Tas.** One, Derwent Estuary, 25 Feb. 1917 (Hall 1917). Two seen at sea, E of Tas., Mar. 1967 (Harper 1972). **SA.** Robe, Beachport (Aust. Atlas). Recorded from Pearson I, 1923; Flinders I., 1960; North Shields, N of Port Lincoln, 1919; C. Spencer, 1926; Gypsum L., Kangaroo I., 1967; Encounter Bay, 1969 (twice) (Parker *et al.* 1979). **WA.** Regular coastal isolated records N from C. Naturaliste to King Sound, NT. **NT.** Records Timor Sea to Gulf of Carpentaria (Aust. Atlas). Regular Cocos-Keeling, Christmas (Ind.), islets of Ashmore Reef, Lord Howe and Norfolk Is (where breeding).

**NZ** Straggler. Several dead or exhausted, off Three Kings Is, 1877 (Buller 1888); Taupo, Feb. 1936 (NZCL); Muriwai, May 1942 (NZCL); two, Rangitoto Channel, Hauraki Gulf, Feb. 1945 (CSN 8). Singles: W of Taranaki, 11 Feb. 1951 (Sibson 1951), 18 Apr. 1961 (Kinsky 1961); E of Cuvier I. (Stein 1955); Toreparu Beach, N of Aotea Harbour, Oct. 1963 (Sibson 1965; NZCL); East Cape, Feb. 1971 (CSN 19); S of Wanganui, Jan. 1976 (NZ Atlas); and near L. Okaitina; four sightings, far n. NZ, summer 1977–78, including singles at Puhiki, Ahipara and Rangaunu Harbour, thought to be same individual (CSN 25; V. Hensley); Taupo, 14 May 1978 (CSN 25); SW Cape Reinga, 11 Feb. 1980 (CSN 28); N of Three Kings I., Mar. 1984 (A. McBride); w. coast Northland, Apr. 1984 (Miller & Miller 1986); Ninety Mile Beach, Feb. 1987 (R.G. Powlesland).

**BREEDING** Breeding localities in our area and esti-



mates of populations are listed in Table 1. Extralimittally breeds Seychelles, Mauritius and Madagascar, Indonesia, Cook Is, Fiji, New Caledonia, French Polynesia, off Japan, islands of w. and central Pacific Ocean, Pitcairn I. and off Chile, (de Korte 1984; Burland 1964; Gould *et al.* 1974; Garnett 1984; Cooper *et al.* 1984; Diamond 1975; Feare 1984).

Status, stable but always endangered by human interference. Taken for food in w. Indian and Pacific Ocean islands and formerly on Christmas I.(Ind.) but population now stable

there following enforcement of wildlife laws since 1977 (Stokes 1988). Maori valued long red tail feathers for ornamental purposes and said to search North Cape coast for beachcast birds after storms (Buller 1888).

**MOVEMENTS** Dispersive or migratory. Pattern of movements away from breeding site not known but adults and juveniles appear to disperse widely. May remain within same latitudinal range all year, with subspecies rarely allo-

**Table 1.** Breeding localities and estimates of population of Red-tailed Tropicbirds

Locality	Year	Population (pairs)	Ref.
<b>WA</b>			
Cape Naturaliste			
Sugarloaf Rock	since 1963		
	Jan. 1967	4 nests	1
	1968	19 nests with eggs	2
	1969-70	34 pairs, 6 nests	2, 3
	1970-5	14-26 nests	2
Rottneest I.	1959	2 nests	4
Busselton	1939	1 nest	5
Houtman Abrolhos	(now extinct both islands below)		3
Rat I.	1894	1 nest	5
Pelsart I.	1943-46	few	5
	1947/8	6 nests	5
	1952, 1954	2, 8 nests	6, 7
Ashmore Reef	1983-90	3 nests	10
<b>QLD</b>			
Raine I.	1959	44 nests	11
	1975-85	21-98 nests	12
Lady Elliot I.	1985-8	1-5	13
Coral Sea			
Herald Grp			
NE Cay	1984, 1986	10; 205 nests	3, 10
SW Cay	1984	5	10
Coringa Grp			
SW Cay	1984, 1985, 1986	54; 2; 52 nests	10
Chilcott I.	May 1984, Nov. 1984	2 nests; 1 pair	10
Diamond Islets	1984	3	10
<b>NORFOLK I.</b>			
Philip I.	1977-79, 1979,	30-100; 10-20	14
<b>LORD HOWE I.</b>			
	pre-1974	200	15
		hundreds of birds	16
Ball's Pyramid			16
COCOS-KEELING IS	1950, 1980	1	8
CHRISTMAS I.	pre-1984	1400	9
<b>KERMADEC IS</b>			
Raoul I.		few	17
Dayrell I.			
Nugent I.		2 nests	
North Meyer I.		9 nests	
South Meyer I.		40 nests	
South Chanter I.			
Macaulay I.	Aug. 1966	6 nestlings	18

**References:** (1) Watts & Tarburton (1967); (2) Tarburton (1977); (3) HASB; (4) Storr (1964); (5) Serventy & Whittell (1976); (6) Ealey (1954); (7) Warham (1956); (8) Stokes *et al.* (1984); (9) Stokes (1988); (10) ANPWS; (11) Warham (1961); (12) King (1986); (13) J. French; (14) Tarburton (1981); (15) Fullagar *et al.* (1974); (16) Hindwood *et al.* (1963); (17) Sorensen (1964); (18) Merton (1970).

patric (Gould *et al.* 1974), but frequency of observations both at breeding grounds and at sea may indicate trans-equatorial movement, possibly following warm currents along e. coast of s. continents (D.W. Eades). Most birds recorded s. Aust. (Morris 1979; Aust. Atlas) and s. Africa (Batchelor 1979) during summer and breeding sites at Lord Howe I. (Hindwood 1940) and Sugarloaf, WA (Tarburton 1977) almost deserted during winter. Nearer equator breeding more aseasonal but at Aldabra, Indian Ocean, peaks Dec.-Mar. with fewest during Sept. (Diamond 1975; Prys-Jones & Peet 1980). At Mauritius (Temple 1976), Kermadec Is (Iredale 1910; Sorensen 1964; Merton 1970; Oliver) and Tuamotu Arch.

(Lacan & Mougin 1974) more abundant Oct.-May and breeding season Norfolk I. thought to peak Jan.-Feb. (Tarburton 1980) with chicks present until 15 July, adults returning in large numbers Oct.-Nov. (Hermes *et al.* 1986). At Christmas I. (Ind.), most birds appear to breed Mar.-Oct., but nesting occurs throughout year (Gibson-Hill 1947a; Nelson 1972); peak of laying varies around coastline, depending on exposure of nest-site to prevailing weather (Stokes 1988). N of equator, most immatures leave Kure Atoll, Midway Is, by late Nov. — early Dec., though some active nesting in every month (Fleet 1972, 1974; Woodward 1972), and at Christmas I. (Pac.), peak numbers present July-Aug. with sharp decline Nov. (Schreiber & Ashmole 1970). Mid-year peaks also reported from other n. Pacific atolls (Ely & Clapp 1973; Amerson & Shelton 1976). Systematic observations at sea suggest few birds in n. central Pacific Jan.-Mar., many in June-Sept. (Gould *et al.* 1974; Amerson & Shelton 1976). Individuals usually return to same nest-site (Fleet 1974; T. Stokes).

**BANDING** Extraliminally, trans-equatorial movement suggested by immature banded near Singapore, recaptured near Mauritius (Jenkins & Robertson 1969) but movements of banded birds between Midway, Kure and Johnstone Atolls in North Pacific (Woodward 1972; Ely & Clapp 1973) fit no pattern, though post-breeding dispersal E suggested on basis of four recoveries (Woodward 1972).

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**FOOD** Chiefly fish and cephalopods. **BEHAVIOUR.** Most food captured by deep plunging vertically into water from 6 (Gibson-Hill 1947b) to 50 m (mean 25 m, n=17; Gould *et al.* 1974) remaining submerged for average of 26.6 s (n=10; Gibson-Hill 1947b); also recorded flight-feeding on flying fish (Gould *et al.* 1974). Five feeding observations by Ainley & Boekelheide (1983) all surface plunges. Lack of streamlining of tarso-metatarsus suggests reliance on impetus of dive for capture of prey (Ashmole & Ashmole 1967). Diving controlled, often changing direction to compensate for movement of prey, especially when pursuing flying-fish. Wings sometimes extended immediately after impact with water, keeping bird on surface (Gould *et al.* 1974). Food may be swallowed underwater, otherwise eaten while bird resting on surface, rarely after taking off (Gibson-Hill 1947a). Regurgitated fish usually headless (Tarburton 1977), possibly decapitated before swallowing. Large gape and strong bill enables capture and ingestion of large fish in relation to bird's size, including well-protected porcupine fish (Ashmole & Ashmole 1967). Usually feeds alone (87.2% sightings; Gould *et al.* 1974; Bailey 1968) but sometimes with other tropicbirds (8.3%) or seabird species (4.3%). Sightings of adult-juvenile duos or trios in low-nutrient Pacific waters suggest that, in areas of little food, immatures learn feeding techniques from adults (Ainley *et al.* 1986). Feeding almost always during day (Diamond 1975). At Aldabra most chicks fed afternoon (Diamond 1975); at Kure 73% of 51 feeding attempts witnessed 11:00-15:00 (Fleet 1974). Probably feeds hundreds of kms from nest (Dunlop *et al.* 1988b); Diamond (1975) suggests mucus round food bolus fed to chicks retards digestion during travelling time; White-tailed Tropicbird, which feeds closer to breeding island (Dunlop *et al.* 1988b), does not have mucus coated regurgitations. Unusually for seabirds, adult regurgitates directly into chick's bill rather than chick taking food from adult's gullet (Fleet 1974). Follows ships 10-15 min at a time, mean height above water 40 m (3-250; 307; Gould *et al.* 1974).

**BREEDING** At Sugarloaf, WA, principal diet fish:

Clupeidae, Exocoetidae, *Scomberesox forsteri* frequent, *Sardinella lemura*, *Hemirhamphus*, Belonidae infrequent; fish up to 141.8 g, 20.5 cm without head; cephalopods recorded in chick diet one out of three seasons (Tarburton 1977). At **Christmas I.** (Ind.; eight stomachs) and **Cocos-Keeling Is** (two) immature *Cypsilurus bahiensis* and *Exocoetus volitans* (Gibson-Hill 1947b) as well as small cephalopods and small herring-like fish (Gibson-Hill 1947a); cephalopods more important in diet of Red-tailed than in that of White-tailed Tropicbird, young chicks being fed cephalopods almost exclusively with percentage of fish increasing with age of chick (Gibson-Hill 1947b). At **Raine I., n. Qld.**, flying fish (15 cm x 4 cm; MacGillivray 1918).

Only detailed information extralimital: summarized Table 2. In **nw. Hawaiian Is** (270 regurgitations, 1073 items; 76 adults, 32 sub-ads., 162 chicks; Harrison *et al.* 1983) detailed analysis of fish: Synodontidae 0.1% vol., 1.0% no., 0.4% freq., Myctophidae <0.1, 0.1, 0.4, *Cheilopogon spilopterus* 0.4, 0.1, 0.4, *C. spp.* 3, 4, 1.9, 5.9, *Exocoetus volitans* 3.2, 2.1, 7.4, 14.0 cm (1.2; 12.4–15.9; 16), *Hirundichthys speculiger* 0.3, 0.1, 0.4, *Parexocoetus brachypterus* 0.5, 0.3, 0.7, unident. Exocoetidae 24.1, 15.6, 39.6, 13.3 cm (1.4; 1.3–20.1; 11), *Euleptorhamphus viridis* 1.6, 0.9, 2.6, unident. Hemiramphidae 0.4, 0.5, 1.5, *Ablennes hians* 0.1, 0.1, 0.4, unident. Belonidae 0.2, 0.1, 0.4, *Cololabis saire* 4.1, 1.7, 4.1, *Priacanthus* <0.1, 0.1, 0.4, *Remora brachyptera* 0.1, 0.1, 0.4, unident. Echeeneidae 0.1, 0.1, 0.4, *Decapterus macrosoma* 3.6, 2.7, 4.8, 15.3 cm (0.8; 13.1–18.1; 5), *D. tabl.* 0.1, 0.1, 0.4, *D. spp.* 9.5, 4.9, 15.9, 16.8 cm (1.3; 14.0–21.6; 6), *Naucrates ductor* 0.4, 0.4, 0.1, *Coryphaena equiselis* 3.9, 1.7, 6.7, 16.3 cm (1.1; 13.4–18.3; 4), *C. hippurus* 2.4, 0.8, 3.3, 14.8 cm (2.3; 11.1–18.9; 3), *C. spp.* 2.9, 1.2, 4.8, Mullidae 0.3, 0.5, 1.5, *Kyphosus bigibbus* 0.6, 0.4, 1.1, Pomacentridae 0.1, 0.1, 0.4, *Bleekeria gillii* 0.1, 0.1, 0.4, *Gempylus serpens* 0.3, 0.7, 3.0, unident. Gempylidae <0.1, 0.1, 0.4, *Auxis* 0.5, 0.2, 0.7, *Katsuwonus pelamis* 2.2, 0.7, 2.6, unident. Scombridae 0.7, 0.3, 1.1, *Xiphias gladius* 1.5, 0.7, 2.6, Istiophoridae 0.4, 0.1, 0.4, *Cubiceps pauciradiatus* 0.1, 0.1, 0.4, unident. Nomeidae 0.2, 0.4, 1.5, Monacanthidae 0.1, 0.2, 0.4, *Lagocephalus lagocephalus* 3.2, 1.2, 4.8, unident. Tetraodontidae 0.6, 0.4, 1.1, Tetraodontoidei 0.1, 0.1, 0.4, *Diodon hystrix* 0.1, 0.1, 0.4, *D. spp.* 0.3, 0.3, 1.1, unident. Diodontidae 0.2, 0.2, 0.7, *Masturus lanceolatus* 0.5, 0.2, 0.7, *Ranzania laevis* 4.3, 2.1, 5.2, 13.0 cm (0.4; 12.3–14.0; 5), unident. fish 4.0, 4.7, 16.7; cephalopods were *Onychoteuthis* 0.4, 0.2, 0.4, unident. Onychoteuthidae 0.1, 0.1, 0.4, *Ommastrephes* <0.1, 0.1, 0.4, *Symplectoteuthis oualaniensis* 2.4, 1.5, 4.8, 9.0 cm (0.4; 6.0–11.3; 14), *S. spp.* 2.2, 1.9, 6.3, 8.0 cm (0.6; 5.2–12.0; 10), *Hyaloteuthis pelagica* 0.1, 0.1, 0.4, unident. Ommastrephidae 10.1, 1.3, 24.4, 8.2 cm (0.3; 2.3–12.8; 58), unident. squid 2.6, 33.0, 17.4; the crustaceans stomatopods *Lysiosquilla* <0.1, 0.2, 0.4, unident. stomatopods <0.1, 0.1, 0.4 and shrimps <0.1, 0.1, 0.4. Mean size of all prey 10.1 cm (1.0–23.7; 169). On Christmas I. (Pac.; Ashmole & Ashmole 1967), mean length of fish 11.2 cm (6.9; 60) incl. Exocoetidae, *Coryphaena* 4% no., Tetraodontidae 3, Diodontidae 6; cephalopods were 6.5 cm (2.2; 110) incl. Histiototeuthidae 1% no., Ommastrephidae (largely *Symplectoteuthis*); crustaceans were isopods and may have been taken accidentally.

On **Aldabra Atoll** (27 adults, 35 chicks regurgitations; Diamond 1975) fish were *Exocoetus volitans* 8.8% wt., 2.5% no., 4.8% freq., 10–25 cm; *Cypsilurus furcatus* 37.0, 10.9, 21.0, 10–25 cm; *Oxyporhamphus micropterus* <0.1, 0.8, 1.6, other Hemiramphidae 1.5, 0.8, 1.6, Belonidae 5.7, 4.1, 8.0, Carangidae <0.1, 2.5, 4.8, Scombridae <0.1, 2.1, 4.6, Stromateidae

3.1, 0.8, 1.6; cephalopods were Ommastrephidae 21.3, 40.3, 37.1, *Tremoctopus violaceus* 5.1, 2.5, 3.2. The fish Zanclidae 3.1% no. also reported from Aldabra (Diamond 1983) but general analysis similar. Two examples of shallow water benthic gastropod also found but possibly from stomachs of fish.

At **Tuamotu Arch.** (Lacan & Mougin 1974) n=20 stomachs. At **Kure Atoll** cephalopods and fish 95% no. (incl. Ballistidae; Fleet 1974).

Table 2. Diet of Red-tailed Tropicbird

	% vol.		% wt.		% no.		% freq.		
	1	2	1	2	3	2	3	4	
FISH	82.0	53	73.4	49.8	33	57.2	80	89	55
Exocoetidae		29.7		63.1	19.9	20	47.0		
CEPHALOPODS	17.9	47	26.4	49.8	64	42.8	92	40	50
Ommastrephidae	14.8		21.3	16.5	53	40.3		37	
CRUSTACEANS	<0.1			0.4	2			5	

(1) NW. Hawaiian Is (Harrison *et al.* 1983). (2) Christmas I. (Pac.) (Schreiber & Hensley 1976). (3) Aldabra (Diamond 1975). (4) Tuamotu Arch. (Lacan & Mougin 1974).

**INTAKE** At Midway I., nestling feeding rate, 0.98 meals/day at 96.1 g/meal (4.6; 5–125; 26; Ricklefs 1984). At Kure Atoll, mean meal wt., 2–33 day-old chicks, 28.0 g (17.7; 1–112); at 44–76 days, 65.7 (10.7; 2–183; Fleet 1974). Mean volume of regurgitated samples in nw. Hawaiian Is, 57 ml (4.0 prey items per sample, n=270; Harrison *et al.* 1983).

**SOCIAL ORGANIZATION** Information for Aust. from Tarburton (1977, 1979). Extraliminally, studied at Aldabra (Diamond 1975) and Kure (Fleet 1974) Atolls. Solitary at sea; breed solitarily or in loose colonies. At breeding sites, flocks of birds, many pairs, perform generalized Aerial Display (Fleet 1974; Diamond 1975; M.K. Tarburton).

**BONDS** Monogamous; on Christmas I. (Ind.) and Kure Atoll, maintains bonds from year to year, depending on nesting success and number of nesting attempts (Fleet 1974; T. Stokes). Additional data on bonding at Kure Atoll in Fleet (1974). Sex ratio and age at pair-formation and first breeding, not known. Some indication on Kure Atoll that non-breeding birds choose mate in season before they nest. Both parents incubate egg and feed chick, until a week or two before fledging. Parents will accept any chick, and chicks beg from any nearby adult (M.K. Tarburton; for extralimital studies see Fleet 1974; Howell & Bartholomew 1969).

**BREEDING DISPERSION** Breed solitarily or in loose colonies; nest either close to or far from other pairs, density perhaps depending on availability of nest-sites rather than social cohesion; some islands have only 1–2 nesting pairs (T. Stokes). At Kure Atoll, 90 pairs nested in c. 0.57 ha study area with total density of 1 nest/64 m<sup>2</sup>; actual density 1 nest/24 m<sup>2</sup> because distribution was clumped. Territorial, defending nest-site and pecking distance round it (Fleet 1974) from conspecific and interspecific intruders (M.K. Tarburton). At Kure Atoll, territory established and defended up to 3 months before laying; time between first recorded presence at nest site and onset of laying 41.3 days (2.3; 0–91; 90 pairs); non-breeding birds probably choose nest-site in breeding season before occupation (Fleet 1974). On Sugarloaf Rock and Norfolk I., birds defend area of av. diameter, c. 0.8 m (M.K. Tarburton). On Norfolk I. and Christmas I. (Ind.), up to

70–80 m between nests (M.K. Tarburton; T. Stokes); on Kure Atoll, mean distance between nests, 1.5 m (Fleet 1974).

**ROOSTING** At sea, only incubating or brooding adult remains on land at night (Fleet 1974; M.K. Tarburton). Birds may be present at breeding site all year. At Kure Atoll during breeding season, non-breeding birds may rest on ground during day, return to sea at night. At Sugarloaf and Norfolk Is, both birds may be at nest resting (for 1–35 min at Sugarloaf), mostly in late morning or early afternoon (M.K. Tarburton).

**SOCIAL BEHAVIOUR** Studied in detail at Kure Atoll by Fleet (1974) and at Aldabra Atoll by Diamond (1975). Also information from Midway I., Hawaiian Is (Howell & Bartholomew 1969). Information provided by M.K. Tarburton. Behaviour similar to White-tailed Tropicbird (Diamond 1975). Aerial Displays easily observed; displays at nest little known.

**AGONISTIC BEHAVIOUR** Birds defend nest-site against conspecifics and interspecific intruders (M.K. Tarburton). **THREAT. Defence Posture:** bird raises humeri and holds wrists close together, neck pulled into body, feathers of head ruffed to appear larger, tail-feathers spread and tilted upwards; posture often accompanied by guttural screech and head shaken rapidly from side to side; increases size and startles intruder. Illustrated in Tarburton (1984). Used as threat and anti-predator display (M.K. Tarburton); generally given by adults, and by chicks >40 days old (Fleet 1974). Agonistic interactions rare at Kure Atoll; more common at French Frigate Shoals, where birds crowded and suitable nest-sites few (Pettit 1983); at Norfolk I., Bill-jabbing and Defence Posture if observer forces one bird into territory of another (M.K. Tarburton). Intraspecific **FIGHTING** seen at nest-sites, and at entrances and approaches to nest through vegetation. Observation of one fight at French Frigate Shoals: birds lunged with bills at each other for few minutes, then interlocked bills and twisted, forcing each other into contorted positions, wings providing leverage. Fight lasted 90 minutes, bills remaining interlocked throughout but birds occasionally resting; both bled from wounds to eyes, mouths and throats. Guttural screams given intermittently (Pettit 1983). No **SUBMISSION** or **APPEASEMENT** displays observed. Fight described above ended when birds separated and flew out to sea (Pettit 1983).

**SEXUAL BEHAVIOUR** At Kure Atoll, male tends to initiate **COURTSHIP** and select nest-site (Fleet 1974); some non-breeding birds may select mate and nest-site during pre-breeding and breeding periods. **AERIAL DISPLAYS. Pre-breeding Aerial Display:** groups of 7–20 (Fleet 1974), 2–20 (Diamond 1975) or 2–15 (M.K. Tarburton) birds fly in large vertical circles, up to 100 m, over likely nesting places, one bird flying above and slightly behind another (Fleet 1974) and calling rapidly. Birds perform with three distinct flight actions, changing between normal slow flight, hovering with much wing movement, and stiff-winged glides, in which they drop below the group to few metres above surface then fly back up to group; birds give bark-like *eek* and cackling calls. Displays last a few seconds to 5 min; pairs drop out to prospective nest-site (Diamond 1975; Tarburton 1977; M.K. Tarburton). **Complete Aerial Display:** performed by single pair with upper bird watching lower; pair follow each other through three vertical circles, one bird above other; lower bird flies in long shallow glide while upper bird at first maintains itself perpendicular to ground, then flies backwards

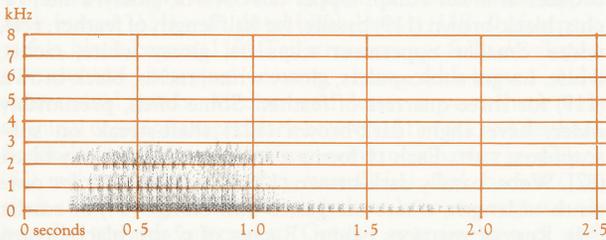
and up, being rapidly blown backwards by wind; as lower bird moves from glide to vertical stall that precedes backward flight, upper bird turns forward and begins glide; red central rectrices usually held straight behind during gliding portion and switched from side-to-side during backward flight at intervals of 1–6 s (Tarburton 1977). At Sugarloaf Rock, WA, and Christmas I. (Ind.), display usually finishes with pair dipping in close to nest-site and trying to land (T. Stokes); at Kure Atoll, ends with long glide with one bird just over other (Fleet 1974). Both birds emit guttural croaking calls (Fleet 1974) or bark-like *eek* and cackling calls (M.K. Tarburton). At Kure Atoll, display activity greatest before nesting starts and in early part of breeding season; however, at Aldabra Atoll, peak activity after peak of laying (Diamond 1975); individuals start to display again if nest fails and, in large colonies and bad years, non-breeders and failed nesters may lead to more Aerial Displays later in season at Aldabra (Diamond 1975); not so at Sugarloaf (M.K. Tarburton). Birds with active nests do not display (Fleet 1974). Function of Aerial Display probably social attraction, bringing birds to colony, and social stimulation to synchronize breeding activities (Fleet 1974). **COPULATION** not observed, but assumed to be at nest (Fleet 1974; Diamond 1975; M.K. Tarburton); probably infrequent. **MUTUAL PREENING** and **COURTSHIP FEEDING** not recorded (Fleet 1974; M.K. Tarburton). **GREETING** consists of shortened cackle or *eek*.

**RELATIONS WITHIN FAMILY GROUP** From Fleet (1974) unless stated. Pairs may make several scrapes before laying; probably prepared by male alone. In one observed instance, scraping bird kicked sand backwards using each leg alternately for 10–20 strokes per leg, rotating continuously for complete circle, turning on breast; stopped kicking to pick up then discard twig; then dragged bill through scrape, found and discarded another twig, then proceeded to kick out sand. Adults maintain scrape while incubating; also maintained by chicks older than 50 days who often add twigs and leaves to rim. When sitting on nest, adults and young hold wings folded against body; in wet weather, pull head and neck back into body feathers tilted c. 60° to encourage run-off. Young older than 40 days capable of Defence Posture (see above) and display and jab at threatening objects (Tarburton 1977). After laying, females usually leave on same day and male incubates. Adults share incubation about equally. After hatching, adult broods young, which typically remain inactive beneath adult; later, more active and sit beside adult or under its wing; (Howell & Bartholomew 1969; Fleet 1974). Eventually adults come to nest only to feed chick. Both adults feed young; chick starts Begging Call as soon as adult lands and continues till its departure; nestlings will beg from any adult. Chick gapes in response to stimulation by parent caressing black area at base of its bill (Howell & Bartholomew 1969); adult places bill into gullet of chick, regurgitating food directly; when feeding completed, chicks will often hold or strike adult's bill. Chicks begin exercising wings after about 75 days and, a week before fledging, begin to wander more widely, often to beach for several hours where they exercise wings before returning to nest. At this stage some may be separated from parents and starve. Once airborne, fledgelings fly directly out to sea and do not return to island.

**VOICE** No detailed studies; behaviour studied at Sugarloaf Rock, WA (Tarburton 1977), Kure Atoll (Fleet 1974) and Aldabra (Diamond 1975). Silent at sea; reports of call like boatswain's whistle possibly confused with calls of Red-billed

Tropicbird *P. aethereus* (M.K. Tarburton). At breeding sites, Aerial Displays and calls obvious; calls at nest-site not well known. At Kure Atoll and Sugarloaf Rock most aerial calling before laying (Fleet 1974; Tarburton 1977); at Aldabra, display and calling continues throughout breeding season, possibly by non-breeders (Diamond 1975). Most Aerial Displays and aerial calls about midday; few birds in air during morning and evening (Fleet 1974). Calls only given during aerial displays, on contact with mate and when threatened at nest (M.K. Tarburton). Give a series of harsh Rattles, Cackles or Croaks; generally of similar form to those of congeners. No sexual differences known. Individual differences, geographical variation not known.

**ADULT Aerial Call.** Loud *cackling* (Tarburton 1977; M.K. Tarburton) or guttural *croaks* (Fleet 1974) given periodically during Aerial Display. Bark-like *eek* also reported during display (M.K. Tarburton). **Greeting Call:** shortened *cackle*, *eek* or *squawk* may be given as Greeting Call between mates when one bird returns to occupied nest-site (M.K. Tarburton). **Contact Call:** reported between mates on nest as soft *urk-trill-urk*. **Defence Call:** long, loud growling ratchet-like *aaarh* (M.K. Tarburton) (sonagram A) or guttural screech



A P.J. Fullagar; Lord Howe I., Feb. 1971; P26

with head shaken rapidly from side to side (Fleet 1974). Begins suddenly and at full volume (M.K. Tarburton) as part of Defence Posture. Given in response to threats at nest-site or on ground. No vocalizations associated with feeding of young (Howell & Bartholomew 1969).

**YOUNG** Hatchlings usually call constantly when adult nearby (Fleet 1974); beg with shrill, persistent rattling (Aldabra; Diamond 1975) or guttural *chatter* (Fleet 1974; Tarburton 1977), with bill partly opened; resembles sound of fisherman's reel (Diamond 1975). Begging begins as soon as adult lands and continues while adult present for average 4.4 min (0.55; 1-10; 18; Fleet 1974; Diamond 1975; Tarburton 1977). Juveniles reported to make low-pitched Trilling or Purring when begging from adult (Howell & Bartholomew 1969). **Defence Call.** Identical to that of adult though quieter (M.K. Tarburton); chicks gave harsh snarling cries when approached or touched (Howell & Bartholomew 1969).

**BREEDING** Aust. information from Tarburton (1977, 1979, 1984). Extralimital: at Aldabra (Diamond 1975), Kure Atoll (Fleet 1974). Breeds in simple pairs, solitarily or in loose colonies on islands, cliffs and rarely on mainland.

**SEASON** SW. Aust., laying late Oct.-Apr., young Dec.-June. Abrolhos, Raine I., breed in all months, peak in mid-year (King 1986). Christmas I. (Ind.) and Aldabra, eggs and young throughout year; on Christmas I., peak of laying varies around coastline, depending on exposure of nest-site to prevailing weather (Stokes 1988); in Aldabra, slight peaks of eggs and young in nests, Dec.-Feb. and Apr.-May (Diamond

1975). Kermadec Is, mainly mid-Dec. to mid-Jan. occasionally as late as Apr.; young mainly mid-Jan. to early May (Oliver; Sorenson 1964); six well grown nestlings, Aug. (Merton 1970); no eggs seen by 4 Dec. 1988 (A.J.D. Tennyson; G. Taylor; P. Scofield).



a) Kermadec I.



b) Norfolk I.

**SITE** On rugged coasts in cavities, fissures and ledges of cliffs facing sea but also up to 40 m back from edge (Merton 1970; Tarburton 1979; Stokes 1988); often inaccessible; between 2 and 250 m asl on Philip I. (Norfolk I.). On Christmas I., availability of cliffs may determine occurrence of nests, birds perhaps being reluctant to fly among trees (Gibson-Hill 1947a). At Aldabra on limestone islets (mushrooms). On low flat islets, cays and atolls, scrapes under shrub or rock, against rock or tree. Site usually shaded, often well hidden but sometimes quite open; sheltered by overhangs, rocks, trees, bushes, low sand-cliffs or coral blocks (Warham 1956; Hindwood *et al.* 1963; Merton 1970; Tarburton 1979; Stokes *et al.* 1984; King 1986). At Sugarloaf Rock, at least half nests on seaward, windward face; some protected, others exposed; all but one in shade for most of day (Tarburton 1977). One or two sites may be tested, occupied before final choice. Same sites used for at least six seasons, often by same pair (M.K. Tarburton). Density: nests 1-12 m apart in small defined colony or up to 70 m apart elsewhere (Tarburton 1977).

**NEST, MATERIALS** Usually nil, except that stones, shells, twigs, leaves, grasses may be put round edge of scrape; at Norfolk I., some birds had full bowl of grass (M.K. Tarburton). Scrape dug with feet, excavating backwards; stones, etc., placed by bill at edge of scrape by sitting bird. Sites thus attended for up to 3 months before laying; activity at sites mostly mid-morning to mid-afternoon (M.K. Tarburton).

**EGGS** Broadly ovoid; porous shell, mat; light-fawn ground-colour, finely spotted with mulberry and brown, larger denser flecks at larger end.

**MEASUREMENTS:**

Norfolk I.: 67.7 (62.7-74.2; 23) x 47.7 (42.2-49.9) (M.K. Tarburton)

Norfolk I.: 67.3 (59.9-73.6; 16) x 48.1 (45.8-50.1) (B.R. King)

Lord Howe I.: 65.4 (3.1; 3) x 47.6 (1.7) (Tarburton 1989)

WA: 64.7 (61.1-71.0; 7) x 47.1 (45-50) (M.K. Tarburton)

Christmas I. (Ind.): 64.9 (54.8-72.2; 113) x 45.7 (41.1-48.8) (T. Stokes & G.B. Baker)

Kermadec Is: 67.2 (2.2; 6) x 47.4 (1.7) (Tarburton 1989)

Raine I.: 63.9 (54.0-77.0; 97) x 44.9 (40.6-49.9) (B.R. King)

**WEIGHTS:**

Raine I.: 68.2 (50-88; 97) (B.R. King)

Norfolk I.: 80.1 (67-93; 16) (B.R. King)

Christmas I. (Ind.): weight within two days of laying, 75.0 (62.5-88; 29) (T. Stokes & G.B. Baker)

**CLUTCH-SIZE** One. No sure evidence of C/2; reported occurrences probably from laying by two females or

accidental acquisition from nearby nest. Replacement laying after loss of egg or chick, at probably 1–2 month interval (Schreiber & Ashmole 1970) and after 40–71 days at Aldabra (Diamond 1975). Only one brood per season.

**LAYING** No information.

**INCUBATION** By both sexes alternately in shifts of 2–7 days (M.K. Tarburton), but at Kure, average of 8 days (0.07; 4–16; Fleet 1974) and at Christmas I. (Pac.), c. 6 days (Ashmole & Ashmole 1967); probably same at Aldabra. **INCUBATION PERIOD:** WA: 41–48 days (n=3); Hawaii: 42–46 days (n=45; Fleet 1974); at Aldabra one egg hatched after 51 days incubation (Diamond 1975) probably anomalously; Christmas I.: 44+ days (Gibson-Hill 1947b); estimates of 35 days (Falla *et al.* 1978; Oliver) certainly too low. Birds have no brood patch; heat generated from feathered abdomen (Howell & Bartholomew 1969). Shells usually disappear within a day of hatching.

**YOUNG** Altricial, nidicolous. Hatched blind with grey or white down 10–15 mm long; eyes open in 2–3 days; for first week only opens beak when touched. Fed by both parents by incomplete regurgitation and for first week parents have to stimulate chick to beg by caressing base of its bill. Fed once or twice a day but no feeds for 3 days have been recorded; at Aldabra, on average 1.4 feeds per day (n=59; Diamond 1975). Mostly fed during mid-day. After about one week, chick starts to beg and gape at any nearby bird. Brooded under body continuously by parents for first week then shielded under parent's wing or merely guarded alongside. Attendance by parents decreases as chick grows, and apparently ceases after about 6 weeks (Diamond 1975). Chick defecates round scrape. **NESTLING PERIOD:** WA: estimates doubtful because hard to know if young had died or fledged successfully; 68–91 ± 1–4 days in all examples; Kure Atoll: 84.2 days (0.76; 67–105; 41; Fleet 1974); Aldabra, c. 90 days (Diamond 1975); Christmas I. (Ind.), c. 90 days (T. Stokes; *contra* Gibson-Hill 1947a); Christmas I. (Pac.), c. 86 days (Schreiber & Ashmole 1970).

**GROWTH** Feet and legs grow quickly at first, to adult size at fledging, perhaps thus aiding thermoregulation (Howell & Bartholomew 1969); culmen grows more slowly to two-thirds adult-size; wing, growth slow at first, then faster to 20 mm less than adult size at fledging; weight increases varying to av. maximum of 69 g more than adult and then decreases for last 4 days in nest (Fleet 1974); at Aldabra, max. wt. 115% of mean adult weight, fledging at approximately adult weight (Diamond 1975). First feathers (scapulars) appear at 16–20 days old (Tarburton 1977), at end second week (Christmas I. [Ind.]; Gibson-Hill 1947b). Chicks start to lunge at intruder, give defence call at 7–8 days (M.K. Tarburton).

**SUCCESS** WA, for six seasons: proved losses, 20–54%; maximum possible total success (eggs laid-chicks fledged) 46–50%. Kure Atoll, for two seasons (Fleet 1974): total success, 38 and 17%. Aldabra, for two seasons (Diamond 1975): total success 4.4 and 44% (av. 22%). On Christmas I. (Pac.), breeding failed during El Niño Southern Oscillation; increased sea surface-temperature, deepened thermocline and high sea-level preceded failure of food supply and heavy rainfall may have flooded nests and inhibited breeding activity (Schreiber & Schreiber 1984). **PREDATORS.** In WA, Ospreys *Pandion haliaetus*, White-bellied Sea-Eagles *Haliaeetus leucogaster* kill brooding birds, large chicks; Silver Gulls *Larus novaehollandiae*, ravens *Corvus* spp may take eggs and chicks. Interference by humans probably greater risk. On Norfolk I., feral cats are menace. On Christmas I. (Ind.), chicks and adults

taken by poachers, feral cats and dogs (Stokes 1988). On Aldabra, land crabs *Birgus latro* suspected of predation; heat-stress probably major cause of losses (Diamond 1975).

## PLUMAGES

**ADULT HEAD AND NECK.** Crown, glossy white; concealed feather bases, dark brown (121); outline of bases of feathers, visible through somewhat transparent feathers. Moderately broad line of black-brown (119) feathers extends from ear-coverts, through eye, to distal lores; at distal lores, line extends downwards to gape; line forms incomplete, inclined U-shape. Rest of head and neck, glossy white. Interramal space feathered. At nape, concealed bases of feathers, dark brown (119A); rachis, black-brown (119) basally, white distally. **UPPERPARTS.** Mantle, glossy white with very pale dull-pink (5) shade on webs and slightly paler fringes; rachis on upper mantle, black-brown (119) basally, white distally. Back, glossy white. Outer rump feathers, glossy white; concealed faint dark-brown (119A) outlines visible; these are basal dark-brown (121) shaft-streaks; rachis, dark brown (119A) basally, white distally. Basal dark-brown (119A) shaft-streaks also on lower back and central rump, becoming broader at lower rump. Upper tail-coverts, glossy white; rachis, black-brown (119) basally, for half length of feather; rest, white. Smaller uppermost scapulars, glossy white; rachis, white. Larger subscapulars, glossy white; rachis, black-brown (119) for three-quarters of feather. Some birds, presumably older, have slight dark-brown (121) shaft-streak on subscapulars. **TAIL.** Each t1 forms a streamer; rachis, grey-black (82). Webs, basally dark-brown (119A), edged white for one-tenth of length, where merges to dull orange (94) or scarlet (14). Rest of rectrices, white. Rachis of t2–t4, black-brown (119); rachis of rest of rectrices, three-quarters black-brown (119), with distal quarter, white. **UPPERWING.** Remiges, white with strong dull-pink (5) shade. Rachis of p10, broad and grey-black (82); streaked on rachis near tip. Rachis is three-quarters grey-black (82), rest white. Similarly, greater primary coverts. S1–6 have grey-black (82) rachis-streak for one-quarter of length, rest white. All-white secondaries; tertials have broad dark-brown (121) shaft-streaks. In some birds, presumably older, subterminal dark-brown (121) shaft streak on tertials. Humeral, white; rachis, black-brown (119) for half feather length. S17–s19 have basal rachis, dark brown (121). **UNDERPARTS,** glossy white. Feathers on mid-lower flanks, long, almost lanceolate; these have broad subterminal dark brown (119A) shaft-streaks, with light grey (85) shade; corresponding with length of shaft-streak; rachis, dark brown (121). Under tail-coverts and axillaries, white. In some birds, presumably older, long broad subterminal dark-brown (121) shaft-streaks on lateral under tail-coverts. **UNDERWING,** entirely white; outer web of p10 narrow.

**DOWNY YOUNG** Down thin, long, white or grey, and erect on crown; thicker and whiter on forehead; becomes grey by time feathers erupt (M.K. Tarburton). Down on lores, sparse. Scapulars and upper wing-coverts appear first. Down retained on rump last. At Christmas I., first contour feathers appear at end of third week. At fifth week, primaries, rectrices and scapulars visible. At sixth week, some down still remains on axillary region, on underparts and anterior edge of wing. At c. eleventh week, down disappears except for patches among coverts on lower breast, belly and flanks (Gibson-Hill 1947a). No reddish colour on new feathers visible (Gibson-Hill 1947a).

**JUVENILE HEAD AND NECK.** Forehead, white and

glossy. Crown, glossy white; dark brown (121) bases of feathers more exposed. Moderately broad line of black-brown (119) feathers extends from ear-coverts, through eye, to distal lores; at distal lores, line extends downwards to gape, forming incomplete inclined U-shape. Rest of head and neck, glossy white with broad subterminal dark-brown (121) shaft-streaks. At nape shaft-streak separates halfway along feather to produce subterminal spot on either edge, becoming subterminal bar towards lower hindneck. Interramal space feathered. Chin and throat white. **UPPERPARTS.** Mantle horizontally barred dark-brown (121) and white. Back and rump similarly barred. Upper tail-coverts, predominantly white; some oblique dark-brown (121) bars to mid-feather length on outer web. Humeral short with few subterminal dark-brown (121) patches. Scapulars, basally white, rest barred dark brown (121). Longest scapulars irregularly barred, almost heavily blotched. Smallest tertial, dark brown (121) narrowly fringed white. Tertial coverts have broad dark-brown (121) shaft-streaks, shaped like pea-pod, fringed white. **TAIL.** Outer rectrices, white with a few subterminal dark-brown (121) spots on inner web. Rachis, grey-black (82) basally for half feather length; rest, white. Other rectrices, except streamers, white, tipped dark brown (121). Both t1, short, white, tipped dark brown (121) with distal black-brown (119) shaft-streak; rachis, black-brown (119). Tail streamers not fully-developed. **UPPERWING.** Marginal coverts have dark-brown (121) subterminal patch. Median and lesser coverts have subterminal crescent-shaped dark brown (121) marks on feathers. Secondaries, all white apart from outermost having grey-black (82) rachis. Outer secondary (tertial) has dark brown (121) shaft-streaks shaped like pea-pod; these become progressively broader towards outermost. Greater primary coverts with dark brown (121) shaft-streak, broadening distally towards innermost. Outer primary, white with grey-black (82) rachis. Dark-brown (121) shaft-streak broadening on p7; reduced to distal subterminal spots on p5 and p4. **UNDERPARTS,** mostly white. Feathers on outer breast varyingly barred, or with dark-brown (121) shaft-streaks. Flank feathers with broad dark-brown (121) shaft-streaks, shaped like pea-pod. **UNDERWING,** white.

**BARE PARTS** Sources: except where stated, photos in Lindsey (1986).

**ADULT** Iris, dark brown (219). Bill, red (210), paler at base, grey-black round nostril (82). Feet and proximal third of toes, pale blue-mauve or bluish white; distal two-thirds and web, black (Gibson-Hill 1947a).

**DOWNY YOUNG** Iris, black-brown (119). Skin on supra-orbital area, dark blue-grey (78). Bill, grey-black (82). Tarsus, pinkish with distal two-thirds of toes and webs, black. At sixth week, bill paler at base and crimson-grey, darkening to almost black at tip; tarsus, pale madder-blue (Gibson-Hill 1947a).

**JUVENILE** Iris, dark brown (c. 121). Bill, grey-black (82); base, light blue-grey (88). Legs and feet, grey (84).

**MOULTS** Breeding season protracted (e.g. Hindwood *et al.* 1963); timing of moult varies.

**ADULT** Staffelmauser; duration and onset of moult series undescribed in A'asia. Details given here for moult in *P.r. melanorhynchos*, based on Schreiber & Ashmole (1970) and Fleet (1974). Further details of moults are given in Gould *et al.* (1974): moult of adults suspended during breeding (Fleet 1974). Schreiber & Ashmole (1970) state that birds undergo

complete moult annually. Streamers replaced constantly; usually one streamer fully grown while other being replaced. During latter part of breeding season (Aug.), shed streamers often found on ground near nest-sites (Fleet 1974; M.K. Tarburton). Moult of streamers precedes general body moult. Schreiber & Ashmole (1970) found most tropicbirds on Christmas I.(Pac.) had one growing streamer; concluded that at least one streamer moulted while birds still feeding chicks, and that growth of other one normally nears completion at time of laying; similar on Christmas I. (Ind.) (T. Stokes). Moulting of streamers unrelated to moulting of rest of plumage in two species of tropicbirds on Ascension I. (Stonehouse 1962). Species probably has alternate moult of streamers.

**POST-JUVENILE** Observations of one bird at Christmas I. (Ind): last juvenile feathers lost on median wing-coverts, rump and upper tail-coverts. Worn tail-feathers and very worn outer five primaries present; inner five primaries less worn (Stokes in press). Post-juvenile moult said to occur at about three years old (BWP). Further study needed.

**MEASUREMENTS** (1) Norfolk I., adults, live; methods unknown (Tarburton 1981). (2) Norfolk I., adults, live; BILL = exposed culmen, other methods unknown (ABBBS; bander B.R. King). (3) Raine I., Qld, adults, live; BILL(NT) = nares to bill tip, other methods unknown (ABBBS; bander B.R. King). (4) Raine I., Qld, juveniles, live; BILL(NT) = nares to bill tip, other methods unknown (ABBBS; bander B.R. King). (5) Kermadec Is, adults, live; methods as in Baldwin *et al.* (1931), WING = flattened chord, TAIL = tail excluding streamers, TAIL(S) = tail including streamers (A.J.D. Tennyson). (6) Lord Howe I., NSW, adults, skins; TAIL = tail excluding streamers, TAIL(S) = tail including streamers (MV, WAM, SAM, ANWC).

UNSEXED	
WING	(1) 353.0 (9.0; 335-375; 30) (2) 335.9 (10.43; 315-355; 20) (3) 329.0 (17.11; 230-420; 99) (4) 249.0 (42.2; 170-326; 21) (5) 343.6 (8.57; 333-354; 3)
TAIL	(3) 103.5 (6.34; 82-116; 83) (4) 104.8 (21.66; 62-138; 19) (5) 102.8 (1.08; 101.3-103.7; 3)
TAIL(S)	(5) 404.0 (11.86; 389-418; 3)
BILL	(1) 67.0 (2.1; 61.8-70.5; 30) (2) 66.1 (2.20; 62.6-71; 20) (5) 70.0 (1.94; 67.5-72.2; 3)
BILL(NT)	(3) 49.9 (2.11; 43.8-54.6; 84) (4) 41.9 (3.25; 36.1-48.1; 20)
BILL W	(1) 26.8 (1.2; 24.8-29.7; 30)
TARSUS	(2) 36.9 (1.85; 31.6-39.1; 20) (5) 31.6 (0.84; 30.5-32.5; 3)
TOE	(5) 53.6 (2.05; 51-56; 3)
MALES	
FEMALES	
WING	(6) 345.0 (5.40; 338-353; 5) 338.4 (13.10; 320-356; 5)
TAIL	(6) 107.6 (5.85; 96-112; 5) 107.2 (5.84; 100-117; 5)
TAIL(S)	(6) 395.8 (61.6; 280-457; 5) 404.0 (23.31; 380-443; 5)
BILL	(6) 66.9 (1.69; 65-70; 5) 65.9 (2.11; 63-69; 5)
TARSUS	(6) 30.7 (2.14; 29-35; 5) 29.6 (0.91; 28.6-31; 5)
TOE	(6) 52.4 (1.52; 49.7-54; 5) 53.9 (2.73; 51-58.9; 5)

Further measurements in Gibson-Hill (1950) and Tarburton (1981); review of measurements of all subspecies and discussion of measurements in Tarburton (1989).

**WEIGHTS** (1) Raine I., Qld, adults, live; methods unknown (ABBBS; bander B.R. King). (2) Raine I., Qld, juveniles, live; methods unknown (ABBBS; bander B.R. King). (3) Kermadec Is, NZ, adults, live (A.J.D. Tennyson). (4) Sugarloaf Rock, WA, adults, live (Tarburton 1977).

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UNSEXED

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- (1) 600,695  
 (2) 832.6 (116.21; 590-1095; 19)  
 (3) 835.0 (24.83; 815-870; 3)  
 (4) 782 (675-940; 14)
- 

No data on seasonal changes of weight.

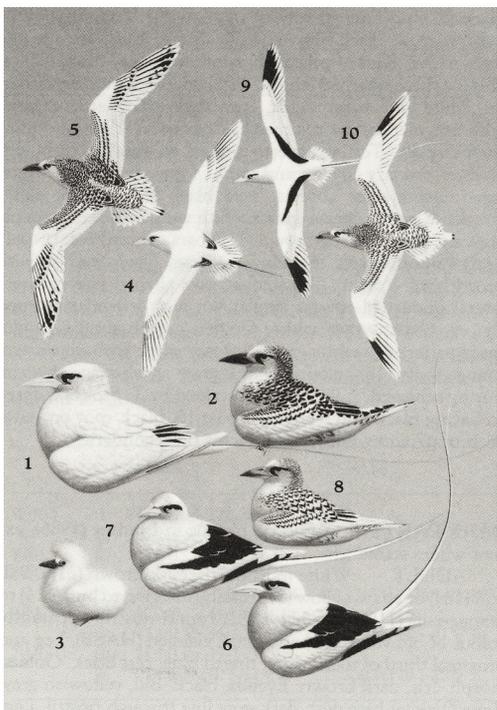
**STRUCTURE** Wing, long and pointed. Eleven primaries: p10 longest, p9 1-8 mm shorter, p8 9-25, p7 31-45, p6 51-71, p5 76-92, p4 105-123, p3 128-151, p2 159-204, p1 176-212, p11 minute. No emarginations. Twenty-four secondaries, 5 of tertial form. Tail, wedge-shaped with long pair of central streamers; 14-16 rectrices, usually 14; t1=streamer, longest, t7 252-373 mm shorter; where t=8, 210-435. Streamers often worn when breeding or lost in moult; t2 longest, t7 30-40 mm shorter; where t=8, 29-40. Bill, deep at base, slightly compressed, decurved and pointed; backward serrations on cutting edges. Nostril, elongate-oval in shape, situated near base of upper mandible. Tarsus short. Feet totipalmate. Claws are narrow and strongly curved. Outer toe c. 95% of middle, inner c. 80, hind c. 34.

**GEOGRAPHICAL VARIATION** Subspecies separated on measurements of wing and bill and intensity of pink suffusion on plumage. Tarburton (1989) recognized no subspecies, regarding variations in size and intensity of pink suffusion as clinal from N to S.

RMO

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**Volume 1 (Part B), Plate 68**

Red-tailed Tropicbird *Phaethon rubricauda*

1. Adult
2. Juvenile
3. Downy young
4. Adult
5. Juvenile

White-tailed Tropicbird *Phaethon lepturus*

6. Adult, white morph
7. Adult, golden morph
8. Juvenile, white morph
9. Adult, white morph
10. Juvenile, white morph

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