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A. O. Gross[1], J. M. Moulton[1,2], and C. E. Huntington[1,3]

Introduction

During three weeks of the southern summer, December 10, 1960 to January 1, 1961, two of us (Gross and Moulton) had an opportunity to study the behavior and early nesting activities of the Wedge-tailed Shearwater Puffinus pacificus chlororhynchus Lesson, locally known as the Mutton Bird, on Heron Island in the Capricorn Group at the southern end of the Great Barrier Reef. Facilities of the Heron Island Research Station of the Great Barrier Reef Committee are gratefully acknowledged.

Moulton was conducting a research program on Heron Island at the Marine Research Station during October and November, 1960, during which he observed the annual arrival of the birds, their mating and nesting, and recorded their calls. Thus the period of observation extended through three months of the bird's breeding season of 1960-1961, and in December Gross and Moulton worked together. The topography and vegetation of Heron Island have been described by Fosberg, Thorne, and Moulton (1961).

The Wedge-tailed Shearwater is one of the most common and widespread shearwaters of the tropical and semi-tropical parts of the Pacific. Its breeding range extends from the Revilla Gigedo Islands off Baja California to the Seychelles and Mascarene Islands off Madagascar and from the Pescadores Islands in Formosa Straits to Henderson Island in the southeastern Tuamotus. Its southernmost breeding stations are off the southeast coast of Australia and its northernmost in the Leeward Hawaiian and Bonin Archipelagoes. Its distribution and systematics have been discussed by Murphy (1951) who recognized two subspecies, Puffinus pacificus pacificus of the Kermadecs, Fijis, and Norfolk Island, and P. p. chlororhynchus, occupying the rest of the range. Oliver (1955) believes that these birds do not migrate, but remain in the seas adjacent to the breeding islands outside the nesting season; their great powers of

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[1] Department of Biology, Bowdoin College, Brunswick, Maine.

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flight allow them to range widely, however, asindicated by Murphy's report of specimens taken hundreds of miles from any possible breeding station.

The Wedge-tailed Shearwater is known by several common names in different areas of its distribution, such as Wedge-tailed Puffin, Wedge-tailed Petrel, Mourning Bird, Moaning Bird, or Ghost Bird because of its call, Black Burrowers and the usual name, Mutton Bird. The latter name is applied to several other species such as P. tenuirostris, P. griseus, P. carneipes, and P. bulleri. The name Mutton Bird arose from the taste of the flesh.

Description

The plumage of the Wedge-tailed Shearwater shows two color phases. The dark phase has the upper surface of the plumage a sooty brown, the primaries and tail are black, the chin, throat, and forehead brownish gray, and the remainder of the under surface a dusky brown. In the light phase the birds are brown above, but the under parts are white with gray along the borders between the two colors. The under tail coverts are black in both forms. The bill is slate or lead color, the iris dark brown, the tarsus, foot, and nails flesh color, and the outer edge of the outer toes darkly pigmented. The outer toes are stronger, thickened, and calloused, probably due to the greater use of these toes in digging.

Only the dark forms are found on Heron Island. The Wedge-tailed Shearwater is polymorphic, the light and dark phases occurring together in some colonies, while a third intermediate form is sometimes found (Murphy, 1951). Although the proportion of light phase birds is higher in the northern part of the range, these color phases do not constitute geographical subspecies, as was formerly maintained (Loomis, 1923). Geographical variation, both in size and in color phase proportions, occurs within the subspecies Puffinus pacificus chlororhynchus. A number of albinistic and semi-albinistic forms of the Wedge-tailed Shearwater have also been reported (Munro, 1944).

Measurements in millimeters and weights in grams of five specimens of Wedge-tailed Shearwaters from Heron Island are given in Table I. The measurements and weights are of living birds, sexes not determined. The nostril-bill measurements were from the anterior edge of the nostril opening to the tip of the bill. The eye-bill measurement was the distance from the anterior edge of the eye to the tip of the bill. (The other measurements are standard.)

Table I

Measurements in millimeters and weights in grams of five adult Heron Island Wedge-tailed Shearwaters

	1	2	3	4	5	Mean
Length	423	436	438	441	449	437
Extent	995	1025	1000	1016	1036	1014
Wing	294	295	298	292	289	294
Tarsus	51	52	50	43	48	49
Foot	50	53	55	53	58	54
Bill(culmen)	30	36	30	38	33	33
Nostril-bill	30	36	29	33	33	32
Eye-bill	50	55	50	55	53	53
Weight	396	410	407	—	--	404

Some measurements of 5 birds, 2 males and 3 females, from the Tonga Islands were made by Davidson (1931) on January 6, 1921:

	Wing	Tail	Culmen	Tarsus
Average 2 males	289.0	135.5	41.25	46
Average 3 females	289.0	135.0	39.0	39.0

Arrival at Heron Island

No Wedge-tailed Shearwaters were observed on Heron Island when Moulton arrived on the island for the first time on October 4, 1960. He captured and photographed one of the first arrivals of 1960 near the Marine Station on October 8, 1960, and the first call notes of the year were heard later that night. By October 11 large numbers had arrived and were present from then on until our departure. Many of the shearwaters fed at sea during the day, often with Noddy Terns, Anous sp. None of them were seen on the island during the day, except in burrows, but thousands of them poured onto the island at dusk and departed the next morning. By November many fresh burrows had been excavated in the sand and apparently old ones were renovated and lengthened.

The Nest Burrow

The openings of the tunnels leading to the nesting cavity are usually wider than high and large enough to admit the birds with room to spare. Five representative openings were 10 x 15, 9 x 15, 13 x 13, 10 x 18, and 20 x 25 centimeters in size. The length of tunnel varies with repeated use, the character of the soil, and obstructions encountered in digging. In some cases in which the tunnel was less than half a meter long we could see the egg or the incubating bird; a few tunnels were as long as 3 meters. The majority of the nests could be easily reached by inserting the arm and required no excavation to obtain the adult bird or its egg. The nests had only a scant lining of grasses and twigs and it was not unusual to find the egg on the sandy bottom of the nesting bowl without any nesting material. The excavated tunnels started down usually at a slight angle and then paralleled the surface of the ground. The burrows of former years were renovated and were dug much longer than the freshly dug tunnels.

Several of the birds were seen digging their nesting holes at the start, in which the legs and feet play an important role. The bird would rest on its side and by extremely rapid strokes of the leg would make the sand spray upwards for as much as a meter. Presently the bird would turn to its other side and continue digging with the opposite foot. The tarsi of the Wedge-tailed Shearwater are long and strong and well adapted to digging. The beak, contrary to what one might expect, was not used to any great extent in digging. The burrows on Heron Island were very close together, sometimes 3 or 4 to the square meter, so that the ground was almost completely undermined. In walking across a nesting area, one was constantly breaking through into the burrows even in places where the surface of the ground seemed to be firm and solid. Many of the nesting burrows on Heron Island were under and among the tangled roots of Pisonia and other trees. In a section of the nesting area near the guest houses of the hotel the birds tunneled under the buildings and other structures. A large water tank resting on the ground was so completely undermined with tunnels made by the birds that it sank deeply on one side and had to be reset. The custom is to lay chicken wire (wire netting) around buildings to prevent burrowing underneath.

The cabin which the senior author occupied was in the midst of a heavily populated section of the shearwater colony. An area of 20 x 25 meters had been cleared of vegetation and leveled directly in front of our cabin. Approximately 50 pairs of birds continued to use the area in spite of the radical changes made by man's intrusion. Banding of birds elsewhere has revealed that other shearwaters and petrels persist in occupying the traditional grounds, even returning to the same burrow if it remains intact from one nesting season to the next.

The Egg

The onset of egg-laying occurred with surprising uniformity. Although more than twenty burrows in different sections of the island

were examined almost daily, the first eggs were not found until 15 December. On that date we suddenly found eggs commonly, the majority of nests examined contained an egg where before there had been none, and several eggs were found freshly laid on the surface of the ground.

The occurrence of a large number of eggs on the open ground is difficult to explain, but it is possible deposition on the ground occurred when a burrow had not yet been excavated or when a burrow had been filled in.

A nesting area near the hotel buildings was very much dug up by the birds. The area was smoothed over by a tractor scraper, filling up all of the nesting tunnels. It was at the beginning of the egg-laying season, and as a result the birds seemed bewildered when they appeared in the evening. Many eggs were deposited on the ground during the night, but such eggs were never incubated, although according to Howell and Bartholomew (1961) on Midway Island "the Wedge-tailed Shearwater commonly nest in shallow depressions of the sand. The nest is usually in at least partial shade, but in rare instances nests were placed completely in the open." In 1910 on Raoul Island of the Kermadec group many eggs of the Wedge-tailed Shearwater were laid on the surface of the ground; in the previous year a storm filled many of the burrows with sand and rocks, which set so hard the birds could not burrow (Oliver, 1955).

The single egg of the Wedge-tailed Shearwater is elongate, ovate in shape and pure white in color with a matte surface. Ten eggs measured by us varied in length from 60.3 to 68.2 mm. (mean 62.7), in width from 40.7 to 43.0 mm. (mean 41.8), and in weight from 53.7 to 64.1 grams (mean 59.0). These means are close to those given by Bent (1922). Other data have been published by Oliver (1955) and Willett (1919) for other islands.

When boiled, the egg was fully as palatable as a hen's egg and did not have the fishy odor or taste that are associated with the eggs of many other sea birds. The yolk was a pale yellow. The white of the Mutton Bird's egg is like that of the hen's egg. It is not surprising that the Maoris of New Zealand prize the eggs as well as the flesh of other shearwaters as food.

Sex Determination

Since theshearwaters exhibit no external sexual dimorphism we used the method used by Serventy (1956a) in sexing petrels and shearwaters by an examination of the cloaca. This method is applicable during the period of sexual activity. The difference between the sexes lies in the great dilation of the cloaca associated with the swelling of the oviduct of the female, to allow for the passage of the large egg. We examined a series of birds and found the method easy and apparently accurate. To check the sexing, an incubating bird determined to be a male by the cloacal examination was collected; dissection proved the diagnosis to be correct. We examined six birds

from nests soon after the egg was deposited; all six were males. This was evidence that the male takes part in incubation and probably initiates it. Three males were banded which were incubating eggs, and in one case a female replaced the male after six days. Unfortunately, the other two nests were accidentally destroyed. It is certain that both male and female normally take part in incubation. The male may be the one of the pair to excavate the burrow, but no sex determination was made of the few birds seen digging burrows. More observations are needed to determine the time spent on the nest by each sex and the number of times changes are made during the entire period of incubation.

Behavior

The door and a window of our cabin faced the cleared area, giving us an unexcelled opportunity to observe, by means of flashlights and electric lights, the activities of the birds at all hours of the night. Here we could repeatedly record the time of their arrival and departure and note the details of their behavior.

During the day the shearwaters were not in evidence on the island; all but those incubating in their burrows were scattered, feeding out at sea. Some were seen by various observers more than a hundred miles from the colony. They seem to be widely dispersed in small groups but have been seen concentrated in very large numbers, sometimes with Noddy Terns, in places where food was abundant. The Wedge-tailed Shearwaters do not feed on fish to any great extent. The food, judging from stomach examinations, is chiefly cephalopods such as squids, shrimps, and other small crustaceans which are caught near the surface of the water. Far out at sea single individuals or small groups of 2 to 5 may be seen seeking food and occasionally sitting on the water. The shearwaters are expert fliers and with their long narrow wings maneuver expertly as they skim closely over the waves with little movement of their wings; their flight resembles that of the albatrosses, but with more flapping.

On a typical evening in December the Noddy Terns were the first to return; a few of them would be seen going to or from the island at any hour of the day, but by 6:30 p.m. the vanguard of the great masses of terns coming to the Heron Island rookery for the night had arrived. Some of the birds came in as single individuals, but most of them were in groups of ten or more. By 7:00 p.m. the terns were arriving by the thousands all along the eastern side of the island -- as many as 350 per minute within 30 meters of the beach.

At 7:45 p.m. the light was growing dim and suddenly there was an awe-inspiring roar of wings: the shearwaters had arrived off shore. Thousands of them were circling and flying about before venturing inland. A few minutes later they would fly over like a swarm of huge bats. They continued to fly back and forth over the entire nesting area of the island.

At the clearing near the camp a few minutes after 8:00 p.m. a dozen or more shearwaters circled high above the tree tops. It was too dark to see the details of the nesting area without lights, but the birds were darkly silhouetted against the starlit sky above. The birds uttered no calls. As they circled and came nearer and nearer to the ground they seemed to be searching for a proper place to land near their burrows. Around 8:30 p.m. the first bird would literally drop to the ground with a distinct thump in a resounding pancake landing, withdrawing the feet and folding the wings at about 1½ meters above ground. It did not land on its feet nor did it break its downward speed by using its tail and wings effectively. (Odd birds crashed into lighted windows.) The birds were not stunned but, lingering long enough to get their bearings, they scooted towards the entrance of a burrow where they might be met by their mates. At the proper burrow the two birds seemed to exchange subdued calls of recognition. One newly-arrived bird appeared to be feeding its mate by regurgitation, but we were unable to observe the transfer of the food. The two birds came close together and one of them repeatedly ran its beak through the feathers of the neck and head of its mate. This behavior may have been a part of the courtship performance. At such times a pungent oil was emitted from the nostrils as occurs in other petrels. Soon other birds made similar landings in quick succession, and the majority of them joined their mates, not in the burrows as might be expected but on the open ground where they remained for the night. Courtship including copulation usually took place not in the burrows but on open ground. The birds do not stand upright on their feet but rest their bodies flat on the sand. A bird entering a wrong burrow was vigorously ousted by the tenant which obviously was not its mate. This ousting was accompanied by loud yowls and violent flappings of wings. At this time the calls and weird sounds of the birds made the night hideous and ghostly. They came from thousands of birds in every part of the nesting area of the whole island. The calls were not bird-like and not musical but were high-pitched cat-like squalls mingled with low-pitched murmurs. At times their calls resembled those of cows and their calves, and again it was like a lively and spirited cat serenade. The silence of day was rudely broken, as darkness descended, by their weird dolorous wails.

The chorus of thousands of shearwaters mingled with the high-pitched calls of the noddy terns in their wooded rookery was kept up throughout the night without any marked intermission. The birds were still going strong at 5:00 a.m., but soon thereafter the volume of sounds began tapering off. There was much activity among the shearwaters, the birds running rapidly and awkwardly, scooting over the ground with their wings upheld to balance themselves. Evidently with their heavy bodies and wing spread of a meter it was difficult to take off in a restricted area. Instead there would be a stampede of birds rushing along the ground to the shore along well-defined paths. Some of the birds in their confusion banged against our camp with such force that it was surprising that no dead or stunned birds were found on Heron Island. The exodus was rapid and by 5:30 a.m. no birds were seen on the breeding grounds. The thousands of shearwaters were off for another day on their hunting grounds at sea.

Calls

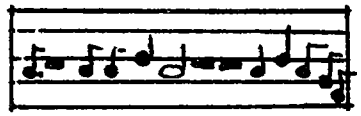
We were particularly interested in the Mutton Bird because of the extent to which its breeding and nesting behavior parallel that of Leach's Petrel, Oceanodroma leucorhoa (Vieillot), which has been studied for many years at the Bowdoin Scientific Station at Kent Island in Canada's Bay of Fundy (W.A.O. Gross, 1935; Griffin, 1940; A.O. Gross, 1947; Huntington, 1962.) Actually, although members of the same order (Procellariiformes), the two birds are in different families (Procellariidae - Shearwaters and Fulmars, and Hydrobatidae-Storm Petrels) which share many characteristics, including nesting underground on offshore islands, laying a single egg, going and coming by night, feeding at sea, calling on the breeding grounds, the sexes being alike externally, and ejecting a stomach oil of characteristic odor.

The calls of Leach's Petrel have been recorded by Huntington, Philip D. Walls, Lowry C. Stephenson, and D. Barry May. This petrel makes a "flight call" heard at night over the nesting grounds and occasionally at sea, and a "burrow call" or "purring call" produced in the burrow. The purring call may be rarely produced on the wing, and the flight call is commonly produced in the burrow. While the flight call is produced somewhat irregularly, the purring call is produced over and over again by an undisturbed bird. When it is heard from a burrow, usually two birds are present, and the call is often heard as a duet (Palmer, 1962, p. 228). The flight call consists of two distinctive staccato phrases, separated by a brief pause (Table II); it varies greatly in pitch and pattern details.

The Mutton Bird, on the other hand, produces a moan-like call which varies in pitch from one individual to another, but is too simple to allow variation in pattern. It is made by birds lying on the ground and by birds in the burrow. It may sound like a caterwauling, a howl, a low moan, and during fighting like a snarl. The birds are quiet whenever they enter a lighted area, and we never heard them calling at sea or on the wing.

Recordings were made of Heron Island Mutton Birds in the vicinity of the laboratory building of the Great Barrier Reef Committee on October 14, 1960, with a Magnecorder PT6-BN and a PT6BA2HZ tape recorder and an Electro-Voice 630 microphone around 10:00 p.m. at 3 3/4 inches/second. Recordings of Leach's Petrels were made on Kent Island, Grand Manan, on May 25, 1962, around 10:45 p.m. with a Magnemite Recorder 610-EV, and Electro-Voice 630 microphone and a 30-inch parabolic reflector at 15 inches/second; other recordings were made on Gull Island, 20 miles south of St. John's Newfoundland, at 1:45 a.m. on August 14, 1962. Sound spectrograms were prepared on a Kay Vibralyzer vibration frequency analyzer, and time-frequency data are taken from those preparations. Characteristics of Mutton Bird and Leach's Petrel calls are shown in Table II.

TABLE II

Call	Duration	Frequency Span	General description
Mutton Bird	1.29 seconds (Range 1.13 - 1.47) Mean of 5 calls	Measurements of fundamental:- Mean of 5 starts 279 cps (225 - 315) Mean of 5 peaks 419 cps (270 - 500) Mean of 5 ends 297 cps (180 - 360) There are usually 2 harmonics	Call varies from a low moan to a harsh snarl
Leach's Petrel Flight call	1.02 seconds (Range .8 - 1.2) Mean of 5 calls	88 to over 8800 cps with most sound energy between 615 and 4100 cps	A series of 10 or 11 rapidly emitted notes, usually in the following pattern:- 
Leach's Petrel Burrow call	2.5 seconds between clucks (1 call measured)	Purring: up to 6500 cps with most sound energy below 2200 cps in a harmonic pattern. Ascending sound: 250-570 cps. Cluck: 88 to over 8800 cps in a harmonic pattern	A prolonged purring interrupted periodically (after 56 notes in one case) by the ascending sound of indrawn breath and a sharp cluck

Nesting

The nesting season of the Wedge-tailed Shearwater varies in the different parts of its extensive latitudinal range. In the northern colonies the time is in the northern spring, while in the southern Pacific it is in the southern spring (Murphy, 1951).

At Heron Island the first bird was seen on October 8th and the first egg on December 15th. Egg-laying was at its height at the end of December. The incubation period of the Wedge-tailed Shearwater is somewhat less than two months, while fledging requires at least three months, according to Oliver (1955).

We are indebted to Mr. H. F. Manning for information concerning the status of the shearwaters on Heron Island after our departure. A few of the adult birds left in March, 1961, but most of the adults do not usually leave until May. The birds are extremely noisy before their departure, and on the following day all is deathly quiet. The young are deserted in their burrows, where they remain until they are able to shift for themselves.

The Short-tailed Shearwater does not acquire sexual maturity until six or more years of age (Serventy, 1956b). As a similar period may exist for the Wedge-tailed Shearwater, a large portion of the birds present on Heron Island may be non-breeding individuals.

Summary

Wedge-tailed Shearwaters nesting at Heron Island were observed from their arrival on October 8, 1960, until January 1, 1961. Measurements of five unsexed living specimens and ten eggs were obtained. Widespread egg-laying began abruptly on December 15th. Many eggs were laid on the ground, but were not incubated. Nest-building, nightly arrivals and departures, courtship, copulation, and calls were observed and described. Sound spectrograms of the calls were compared with those of another tube-nose, Leach's Petrel, and found to be much simpler and less variable.

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Captions of Photos

Upper left-- A characteristic pose of the Wedge-tailed Shearwater with its body resting flat on the ground. The crossed wing tips extend to near the end of the tail.

Upper right-- The Wedge-tailed Shearwater at left approaching its mate, which has just emerged from the nesting burrow.

Lower Left-- The shearwater at the left has approached its mate which has come out of the nesting burrow. The birds are billing each other and running their beaks through the feathers of the neck, a part of the courtship performance.

Lower right-- Three eggs of the Wedge-tailed Shearwater (Numbers 1-3 of Table II) with an Australian sixpence, showing the relative size of the large eggs.