OBSERVATIONS ON THE BREEDING BEHAVIOUR OF THE DIVING PETREL Pelecanoides u. urinatrix (Gmelin)

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ABSTRACT

Observations on the Diving Petrel (**Pelecanoides u. urinatrix**) were made on Green Island, Mercury Group, and other small islands in New Zealand in 1966 and 1967. The various calls and communications are described and weights and measurements given of adults and of growing chicks. Various behaviour patterns are briefly compared with the Northern Alcid, the Cassin Auklet (**Ptychoramphus aleutica**).

Incubation was recorded by assistants for one egg at 53 days. Chicks reach the adult weight by 30 days of age and attain the average at rest body temperature of the adult about the same time. Daily growth rates of the various body parts, total length, closed wing, tarsus, toe, culmen and tail are given for developing chicks. Fluctuations in incubation temperature of two eggs are given. Other eggs showed considerable tolerance to lowered temperatures. The difference between at rest and active body temperatures of adults is indicated at approximately 2°C.

The adults arrive at the breeding site early in April with a peak of actviity by the end of May. The egg-laying period is calculated to begin early in August and last for about one month. Average body weights of 20 adults in April were about 18 grams more than in June and October.

Apart from the morphological comparisons by Loomis (1918: 66-67), the general accounts of Murphy and Harper (1921. 495-554), and Murphy (1936: 771-792), studies by Richdale (1943, 1945) have been the only contribution to our knowledge of the biology of the Diving Petrel. Richdale made his observations mainly on Whero Islet near Oban, and Stewart Island, New Zealand. Falla (1934: 246) mentions some early seasonal activity on islands in the North of New Zealand, but no extensive studies have previously been reported in the northern part of the range. Storer (1945: 439) gives anatomical comparisons of the alcids with *Pelecanoides* and states that there is no doubt anatomically that *Pelecanoides* is related to the petrels.

METHODS

The present data was collected on Green Island, Mercury Group, New Zealand, from 10 October, 1966, to 16 July, 1967. During the period 10 October to 20 December, while the young were being reared, I remained camped on Green Island taking only a week-end break every other week. Visits were made to the island every second week during the early premating stages from 10 April to 16 July when my study had to be terminated.

Some observations were also made on The Brothers, islands in Cook Strait, and a brief visit was made to Whero, near Stewart Island, on 12 January, 1967, to record the progress of the colony that Richdale studied. It was noted that the ecological situation on Whero had changed radically since Richdale's reports and that there is now little evidence that the Diving Petrel nests there. This small islet is now largely taken over by a colony of Stewart Island Shags *(Phalacrocorax carunculatus chalconotus)*, a race which was previously only an occasional visitor on Whero (Richdale, 1942: 87).

On Green Island, 10 October, 1966, many Diving Petrel's eggs were hatching. Some chicks, ten to twelve days old (age calculated later when accurate weights and measurements were available), were found in burrows at this time. Fifty nests were located that were suitable for study and daily records kept until the chicks had grown and left their burrows permanently. Descriptions of the area and population figures were presented in a previous paper on the ecology

of the island (Thoresen, 1967: 182-200), and Atkinson (1964: 325-402) has described the vegetation of Green Island. Measurements were made in the field with a millimeter steel rule and vernier calipers. Weights were recorded on a Ohaus triple beam balance and temperatures were recorded with an Atkin thermistor instrument with an accuracy of ± 1% of the scale. Different probes suitable for humidity readings, soil, air, and body temperatures were used. Rectal temperatures were recorded immediately upon capture with a polyethylene covered medical probe inserted 1 inch through the cloaca for 60 seconds. Incubation temperatures were recorded with the same type of probe inserted into and left in the air space of the egg. The probes were held in position with paraffin wax and adhesive tape.

Nocturnal activity of the adults was observed in several ways. A small portable generator was tried to provide light with low wattage bulbs suspended in the trees above the study area. The noise of the generator was disturbing so I resorted to hanging several kerosene hurricane lamps in convenient positions and left them burning all night. The lights seemed to make the birds wary and they sought out the shaded areas beneath clumps of fern or hid in their burrows. However, some braver pairs co-operated well. By using flash photography and a bright 6 volt head lamp observation of the activity of the birds in dark areas was possible.

Adults were captured at night and their temperatures recorded within one minute of capture. Records of weights and measurements were also made at the same time.

Comparative data on the Cassin Auklet *(Ptychoramphus aleutica)* mentioned here were collected on the Farallon Islands, California, during a study reported earlier (Thoresen, 1964).

CALLS AND COMMUNICATION

The Maori name for the Diving Petrel is " Kuaka." It quickly became obvious that this name is derived from a common sound that the birds make. That is, they utter their Maori name, " Kuaka." But this is only one of the common sounds. It is produced alone or with several differing intonations following. The rather resonant sounds would come from dozens of birds in chorus. Often one would imagine that every individual of the colony was contributing to the noise at the same time. Because of this and the darkness it was practically impossible to interpret the meaning of each individual sound. The variations noted are as follows:

1. " Kuaka," uttered frequently and sometimes during flight early in the season.
2. " Kuaka-did-a-did." This is perhaps the most common call of all especially when the birds first arrived in numbers in the evening. This sound was also occasionally heard from burrows in the daytime during the incubation period. Sometimes the third syllable was more clipped than usual, sounding more like " Kuaka-kit-a-did "; or more rarely a syllable was added to the end such as " Kuaka-did-a-did-a."
3. " Kuaka-ku-ku " or just an abbreviated " Kuaka-ku."
4. Sometimes a syllable was completely omitted. From one burrow during the feeding period, I noted " Kua-kit-a-did, Kua-kit-a-did." In another burrow a bird skipped the usual fourth syllable as " Kuaka-did-did."

5. " Ku-ku-did-did " was another variation noted occasionally on Green Island and I was interested to find that this variation was predominant at The Brothers colony and only rarely was the distinct resonant " Kuaka " heard at the latter colony.
6. A " Ku-ku-ku " was uttered while in flight and from a burrow early in April.
7. Other variations noted only at The Brothers colony include: " Ku-ku-ka-did," " Ku-ku-meow," " Ku-ku-did," and " Ku-ku-did-a-did-a-did."
8. In the evening hours but predominantly nearer dawn during departure ceremonies at both colonies a clear, ascending " Meow " was uttered in chorus. It almost sounded as if many guitarists were sliding their fingers up the strings.
9. During feeding and as soon as the adults entered the burrow the chicks kept up a constant, rasping " Squeer."

PRE-EGG-LAYING STAGE

No accurate data is available as to the earliest date and occupation of the breeding territory in North New Zealand by Northern Diving Petrels. According to Sladden (1924: 184) possession of the shallow burrows takes place about July on Karewa Island. Falla *et al.*, (1966: 67) gives the breeding season from August to December; however, Falla (1934) indicates that they are active in April and that the annual moult is completed in March. Chittleborough and Ealey (1950: 103) found the South Georgian Diving Petrel in burrows late March and early April.

I made my first winter trip to Green Island on 10 April, 1967, and found a limited number of birds already active cleaning their burrows. Later visits to the colony approximately every other week indicated a build-up of a number of active individuals at the nesting site. In order to establish the relative numbers a frequency index was established by counting the number of birds seen between the hour 19:00 and 20:00 each night (see Figure 1). In handling many birds on 25 April for measurements, weights, and banding, John Jenkins and I noted that several were still moulting the contour feathers as indicated by the fact that feathers readily dropped out in normal handling. By May, all contour feathers were fresh and firm. On the same date in April we saw many pairs sitting together billing and nebbing. From a burrow near my tent I heard one of a pair using the " Meow " call while its mate made a " Ku-ku-ku " - " Ku-ku-ku " sound. While banding birds in the evening several were heard to utter " Kuaka " sounds while in flight. At midnight heavy rain and thunder set in during which the divers engaged in considerable noise making. Between showers at 03:00 hours I inspected the study area and counted only 5 birds above ground. Most of the noise was coming from the shelter of the burrows.

Two birds were seen to skirmish in front of a burrow on a steep slope. They held each other by the bill and flapped their wings in a pushing-pulling action until one lost the grip and fluttered down the bank. Later, a similar incident was witnessed involving another pair. By 05:30 the " Meow " chorus reached its climax and began to wane as the birds gradually made their way towards the sea.

On 26 April we located one Diving Petrel in its burrow at 14:00 hours and during the month of May birds were found more frequently in the burrows during the daylight hours. My notes for 10 May read, "One adult was found in a burrow and released to observe its behaviour in flight from the top of the cliff. It dived straight down toward the water and flew rapidly out to sea along the surface of the water in zig-zag flight, tilting to the right and left, until it splashed into the water when almost out of sight. Another adult in a burrow near my tent has been making 'meow' and 'kuaka' sounds periodically all day."

All night long Diving Petrels flew in circles and criss-crossed the island uttering loud "Kuakas" which reminded me very much of the "Kreekier" sound of the Cassin Auklet, but these flights were distinctly petrel-like in character. From their underground retreats I could hear "Kuaka-did-a-dids" and "Meows" all through the night. One bird close to my observation point sat and peered into a burrow entrance from which came "Meow" calls. It peered this way, then that, responding to the subterranean sounds with "Kuaka-did-a-dids." As usual the whole island seemed to resound with "Meow" crescendos about an hour before sunrise and by 06:00 the area was peaceful and quiet once again.

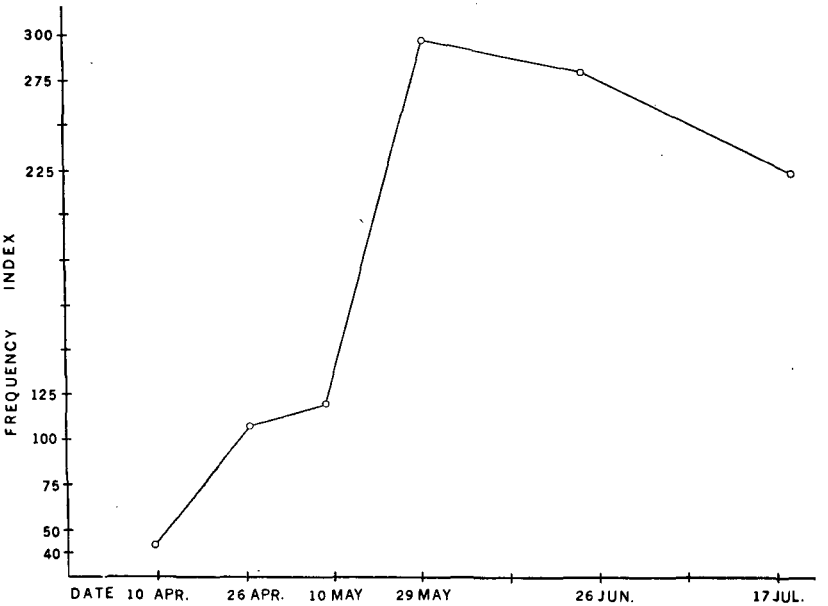


FIGURE 1 — Frequency index of adult birds counted in the study area during one hour, recorded on the various dates, show that most birds returned to the island to begin breeding activities during the month of May, 1967.

At sea, not far from Mercury Bay headlands, we saw many 'Divers' during most of the winter excursions. They were usually in groups of four to six. As the boat approached they would fly short distances close to the water, splash into the sea and immediately dive under. When emerging they would take to wing as soon as they surfaced. One bird was seen to make a series of short shallow dives in a straight line as the boat went by.

On 29 May, the first birds arrived at Green Island at 17:50 about 45 minutes after sunset. They were very active and noisy immediately after their arrival. Birds that were banded on previous trips were recaptured and examined closely for the development of the incubation patch. All birds examined on this date showed some thinning of the down over the incubation patch. Some had inflamed and swollen cloacas and at first I thought that this feature may be a way definitely to tell the female from the male as suggested by Serventy (1956: 213-214). However, I discovered that in individuals sitting side-by-side as pairs both birds may have inflamed and swollen cloacas. This led me to doubt the assumption that this was a good way to sex the bird at this stage of the breeding cycle. Perhaps the method may be more accurate later on during the egg-laying period.

By 20:00 hours the birds had mostly settled down and were sleeping. I watched one bird preen and scratch its head with its claws, as a cat or dog scratches. Only three or four possible attempts at copulation were observed above ground at this time. On two occasions I witnessed what looked like fights lasting for about 30 seconds. Both times the birds had mutual holds on the other's breast feathers so that they assumed a venter to venter posture as they tumbled over and over while flapping the wings. I thought that perhaps these may have been copulation attempts.

At 03:30 on 30 May the birds were all "meowing" but most of the noise was still in the burrows. A few pairs sat together above ground and slept with the bill tucked in the body coverts, a few were heard vocalizing from the air above. Fresh soil sprayed from the entrance of burrows and this together with the fact that a large number of individuals were seen with soil caked to their bills indicated that active digging was still going on below the ground. A few birds were seen with all their feathers literally caked with mud. In order to discover what engagements were taking place underground, burrows were opened at the rear and blocked during the day with rocks. Every time I observed these nests I witnessed no more than a pair of birds sleeping.

On 9 June I arrived on The Brothers in Cook Strait for two weeks' observation at this more southerly colony. Here I found several artificial nesting boxes placed among the rocks by some former investigator. Two of the boxes were occupied by Diving Petrel pairs. Observations made on 13 nights indicated that the birds entered the nests, billed and vocalized for a few minutes, then went to sleep side-by-side. Early in the mornings they would stir, "Meow" to each other for about a half-hour or more, then leave for the day at sea.

I soon noticed that on The Brothers, the Diving Petrels are in direct competition with the Fairy Prions *(Pachyptila turtur)* which outnumber the divers about four to one. Apparently they have similar feeding habits (one prion regurgitated euphausid-like shrimp, when captured), nest in the same niche at the same time, and often are seen fighting together at night. The Prion usually wins over the smaller Diving Petrel. I caught and examined one Diving Petrel after witnessing a fight in the light of my headlamp and found it to be bleeding slightly around the base of the bill. Divers may be able to enter a slightly smaller burrow entrance than Prions but I doubt this to be a factor in preserving their coexistence since the Prions can easily enlarge the cavity.

Once a pair of Prions was found imprisoned in a rock wall. Apparently the rocks had shifted slightly, making the entrance too small to squeeze through. One of the pair was already dead, the other was severely injured by its attempts to escape. I released the live bird.

Immediately north of The Brothers rip tides constantly churned up food material for sea birds. I spent hours during the day observing the motions of hundreds of Diving Petrels feeding in the rips. They kept up a constant cycle all day long. By dropping into the west end of the rips and disappearing for 15 - 20 seconds for each dive. they would drift with the current eastward and then coming to the end of the food source, they would fly west again to begin the interrupted submarine journey over again. During the brief pause on the surface at the end of each dive, the wings were held partly open apparently in preparation for the next dive. In watching them I could detect little difference in the habit of flight from the Cassin Auklets. They seem to fly exactly like an auklet, tilting from side to side and sometimes gliding briefly before splashing into the water. They usually dive immediately. Occasionally, one would hesitate on the surface to rotate a few times or make several short shallow dips before diving.

They also dip their bills in the water while floating as do the Alcids. I have seen this habit also in the Flesh-footed Shearwaters in which the habit is definitely a peering underwater for prey. Flesh-footed Shearwaters often follow down fisherman's line bait and I have seen them at close view locate the bait by peering underwater for it, then diving to retrieve it off the hook.

The wind was blowing at 55 - 60 knots over The Brothers on the evening of 21 June and only a few birds visited their burrows. It was difficult to understand how even the few that came were able to fly in such a high wind.

Back on Green Island, Mercury Group, on 26 June, I found most burrows complete with fresh leaves and twigs in the nesting chamber. Nocturnal activity of the birds had not changed except that they were less often making calls while on the wing. One pair taken for anatomical study on 27 June indicated the testes enlarged to 27 mm. in length in the male and the ovary well developed in the female. There were no eggs in the oviduct, but the incubation patch was markedly supplied with blood vessels and the down that covered it showed definite thinning.

There was little change in the activity on my last visit on 17 July and the density of down over the incubation patch of twenty birds examined was about one-half the thickness that it was one month earlier. Many were active billing and several pairs were seen to attempt copulation near their burrow entrance.

On The Brothers two of the lighthouse keepers, John Dunn and Trevor Porter, continued an active interest in my study. Trevor Porter kindly kept daily records of the activity of one pair which were using an observation nesting box. He recorded that fresh nesting material, leaves and twigs were placed in the nest on 19 August and that the activity of the birds on 24 August was outstanding. His notes say, "Birds are sitting in sheltered places all over the island. I have never seen so many. The noise is terrific."

He noticed that the bird in the box had its feathers fluffed up on the nights of 29 and 30 August. On 31 August the bird stayed all day and laid her egg between 15:00 and 20:00 hours. John Dunn observed that this egg hatched between 24:00 hours on 23 October and 07:00 hours on 24 October, making a total of 53 days plus 8 to 16 hours. I believe that this is the first time that anyone has observed the incubation time so closely. Richdale (1945: 43) calculated the time as about 8 weeks during his study.

According to my calculations the first eggs hatched on Green Island about 1 October 1966 and the last two eggs in 50 study nests hatched on 28 October, 1966. This suggests that the egg-laying period on Green Island was from about 7 August to 4 September.

THE EGG STAGE

The behaviour of the birds during egg laying and early incubation period was largely missed in this study but some data on a few late hatching eggs in October, 1966, on Green Island are worth reporting. The measurements and weights of eggs from the Mercury Island average slightly larger than those from Whero reported by Richdale (1945: 44). See Table 1.

TABLE 1

Measurements and weights of Diving Petrel eggs from Green Island compared with Richdale's (1945: 44) figures from Whero in parentheses.

Feature	Number	Average	Range	Condition
Weight in grams	14	16.61	14.50 - 20.00	At various stages of incubation
	(27)	(14.90)	(11.00 - 18.25)	(addled or deserted)
Length in mm.	15	37.86	35.90 - 41.80	
	(39)	(37.68)	(34.50 - 42.00)	
Width in mm.	15	30.56	28.00 - 30.70	
	(39)	(29.42)	(27.25 - 31.50)	

It quickly became obvious when observing nests of banded birds that both birds incubate and that the change-over periods are usually on alternate days but often the egg is left unincubated during the day. Bartle (1968: 83) has observed similar vacations in Pycroft's Petrel *(Pterodroma pycrofti)* and Matthews (1954) has noted the same phenomenon in the Manx Shearwater *(Puffinus puffinus)*. It may well be that most species of petrels exhibit these long inattentive periods thus contributing to the relatively long incubation period known for petrels.

One deserted egg was found to be pipping. By holding it in the warmth of my hand close to my ear I could hear pecking sounds and peeps from within. The egg was checked twice a day and also during the evening hours to note its progress. I found no evidence that the parent birds ever visited the burrow at night. On the morning of the tenth day (22 October, 1966) after discovering it, the chick hatched at a burrow air temperature of 16.6°C and a humidity of 56%. I warmed the chick for the rest of the day in my shirt pocket and returned it to the burrow in the evening hoping that perhaps the parent birds may return, but the chick was dead the next morning. This seems to indicate that temperature tolerance may be more critical after hatching than before and that the egg has a remarkable tolerance to long exposure to average burrow temperatures.

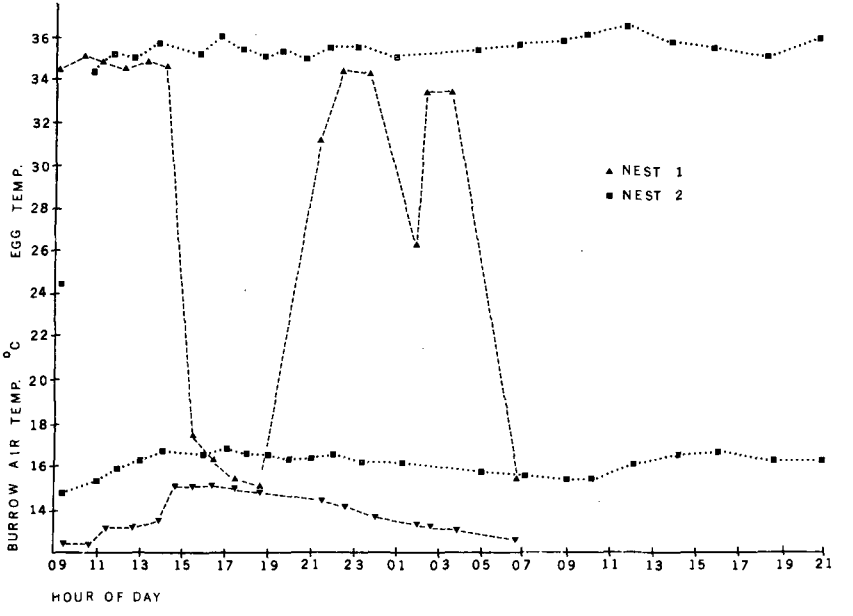


FIGURE 2 — Fluctuations in egg temperatures during late incubation in two eggs. Temperatures were recorded with the thermistor probe inserted into the air space of the egg.

Figure 2 indicates the incubation temperature fluctuations during attentive periods in two well incubated eggs recorded with the probe inserted into the air space to avoid the thermal gradient differences between the upper and lower surfaces of the egg when the egg is rolled. Egg number 1 was recorded on 15 and 16 October and egg 2 on 17 and 18 October, 1966.

No definite correlation was noted between air temperatures and incubation. The sudden drop in the temperature of egg number 1 may have been caused by my presence being detected near the burrow. Incubation resumed later in the evening but the nest was left unattended the next morning. Burrow 2 was also unattended the day following the recordings.

DEVELOPMENT OF THE CHICK

Growth of Diving Petrel chicks on the Mercury Islands closely paralleled the descriptions given by Richdale (1945: 46-51) although his earlier data (1943) is difficult to follow due to miscalculation of the ages of his chicks. Data on the growth and temperature regulation in developing chicks is presented here in Figures 3, 4 and 5. Parent birds guarded the chick by day until they were 10 - 15 days old at which time they had attained the minimum adult body temperature. Upon the day of hatching 9 chicks weighed an average of 12.1 grams with a range of 11.1 - 13.9. The average body temperature of 3 first day chicks was 35.1°C. The chicks have their eyes closed for about the first 12 hours and then only casually open them until 3 days old. When dry the primary down is about 1 cm. long, and is white-tipped giving the chick an all white appearance except for a wedge of gray tapering to a point on the belly from the cloaca. By the 10th day the white tips of the down has almost rubbed off but it sometimes persists in the ventral side for several more days. The chick is now light gray in colour, weighs 34.6 grams (average of 14 with a range of 23.5 grams - 44.5) and has an average body temperature of 36.0°C (average of 10 records). Table 2 presents the average daily measurements of Diving Petrel chicks.

At 22 - 26 days of age the chicks have reached the average at rest body temperature of the adult. Adult active body temperatures averaged 2° higher than at rest temperature.

The average age of 16 individuals when they finally left the nest was 50.5 days with a range from 45 to 56 days. Richdale (1945: 51) gives the average of 58 chicks on Whero Island at 54.26 days with range from 47 to 59 days. In my study area the first juvenile left on 22 November. They left at any time during the dark hours and from this date onward many were seen clambering between the boulders toward the sea. Once in the water they "flew" well underwater and were presumably able to catch their own food.

Handling of the birds resulted in the raising of body temperatures, but the elevation varied considerably with the individual. For example, in one bird a temperature of 38.3°C rose after 5 minutes to 38.6°C and in the second one it rose from 38.2°C to 39.5°C after 3 minutes and to 40.1°C after 5 minutes. For this reason temperatures were recorded during the first 60 seconds of capture. Temperatures recorded at rest mean that the bird was sleeping with head tucked in the lateral coverts when captured.

TABLE 2

Average measurements in millimeters of developing Diving Petrel Chicks

Age in Days	No. of Specimens	Body Length	Closed Wing	Tarsus	Midtoe	Culmen	Tail
0	8	69.6	15.4	11.4	13.3	8.3	--
1	6	72.5	16.5	11.8	13.2	8.6	--
2	6	74.5	18.0	12.4	13.3	8.7	--
3	5	75.0	18.2	13.3	13.9	8.8	--
4	10	79.6	18.7	13.5	14.3	8.9	--
5	10	84.6	19.6	13.9	14.8	9.0	--
6	10	86.5	21.2	14.9	15.9	9.3	--
7	13	86.5	21.7	15.3	16.8	9.6	--
8	9	88.0	22.7	15.7	17.0	9.6	--
9	12	91.3	24.0	16.3	17.8	9.9	--
10	14	96.1	23.5	16.4	18.4	10.2	--
11	10	97.3	26.8	17.3	18.9	10.3	--
12	10	101.3	27.3	17.6	19.0	10.3	--
13	10	112.1	29.3	18.5	20.6	10.6	--
14	10	112.9	29.7	18.8	21.5	10.6	--
15	7	118.6	32.0	19.5	22.2	10.7	--
16	11	124.0	33.1	20.2	22.4	11.0	--
17	6	128.0	36.0	20.8	23.2	11.4	--
18	7	134.3	37.7	21.2	23.5	11.5	--
19	12	137.6	39.9	22.3	24.8	12.0	--
20	8	139.9	43.0	22.5	25.6	12.0	--
21	11	146.4	46.0	23.1	26.0	12.4	--
22	2	146.0	45.0	23.2	27.0	12.3	--
23	9	145.0	45.2	24.1	27.6	12.6	2.0
24	6	157.5	53.8	25.1	29.2	13.0	3.0
25	5	156.0	61.0	25.3	29.6	13.4	3.5
26	7	160.0	64.0	25.7	30.2	13.6	4.7
27	6	165.0	68.0	26.9	32.5	14.1	4.9
28	5	167.0	69.0	27.3	32.7	14.5	7.3
29	4	171.2	69.8	27.6	32.8	14.5	9.0

TABLE 2 (Continued)

Average measurements in millimeters of developing Diving Petrel Chicks

Age in Days	No. of Specimens	Body Length	Closed Wing	Tarsus	Midtoe	Culmen	Tail
30	--	--	--	--	--	--	--
31	5	175.0	77.0	28.2	24.2	15.1	16.0
32	2	180.0	82.2	28.0	34.2	15.8	17.0
33	1	180.0	83.0	27.7	33.7	15.3	14.0
34	--	--	--	--	--	--	--
35	2	182.0	92.0	27.9	34.4	15.7	19.0
36	1	180.0	92.0	28.1	34.0	16.0	22.0
37	5	184.0	95.2	28.1	34.8	16.0	24.8
38	5	186.0	96.2	27.9	34.6	15.9	28.0
39	4	186.2	102.0	28.0	35.0	16.3	32.2
40	6	189.2	97.5	28.0	33.8	16.0	32.0
41	4	185.0	96.0	28.0	34.3	16.0	31.0
42	5	188.0	104.4	27.9	34.3	16.2	36.0
43	9	188.0	102.7	27.9	34.3	16.2	35.0
44	5	188.0	105.8	28.0	34.4	16.3	38.2
45	11	187.3	106.3	27.3	34.5	16.1	37.1
46	6	190.0	111.5	27.9	34.2	16.3	42.0
47	8	190.0	111.8	27.7	34.1	16.2	41.4
48	5	189.0	111.2	27.4	34.2	16.3	42.2
49	7	189.0	115.1	27.8	34.4	16.3	43.6
50	2	192.5	114.0	27.9	34.1	16.3	44.0
51	1	195.0	116.0	28.0	34.5	16.3	43.0
52	2	190.0	117.5	27.4	33.8	16.4	45.0
53	2	192.5	117.5	27.6	33.3	16.3	45.0
54	2	192.5	118.0	27.6	33.3	16.3	47.5
55	1	195.0	123.0	28.0	34.5	16.3	50.0

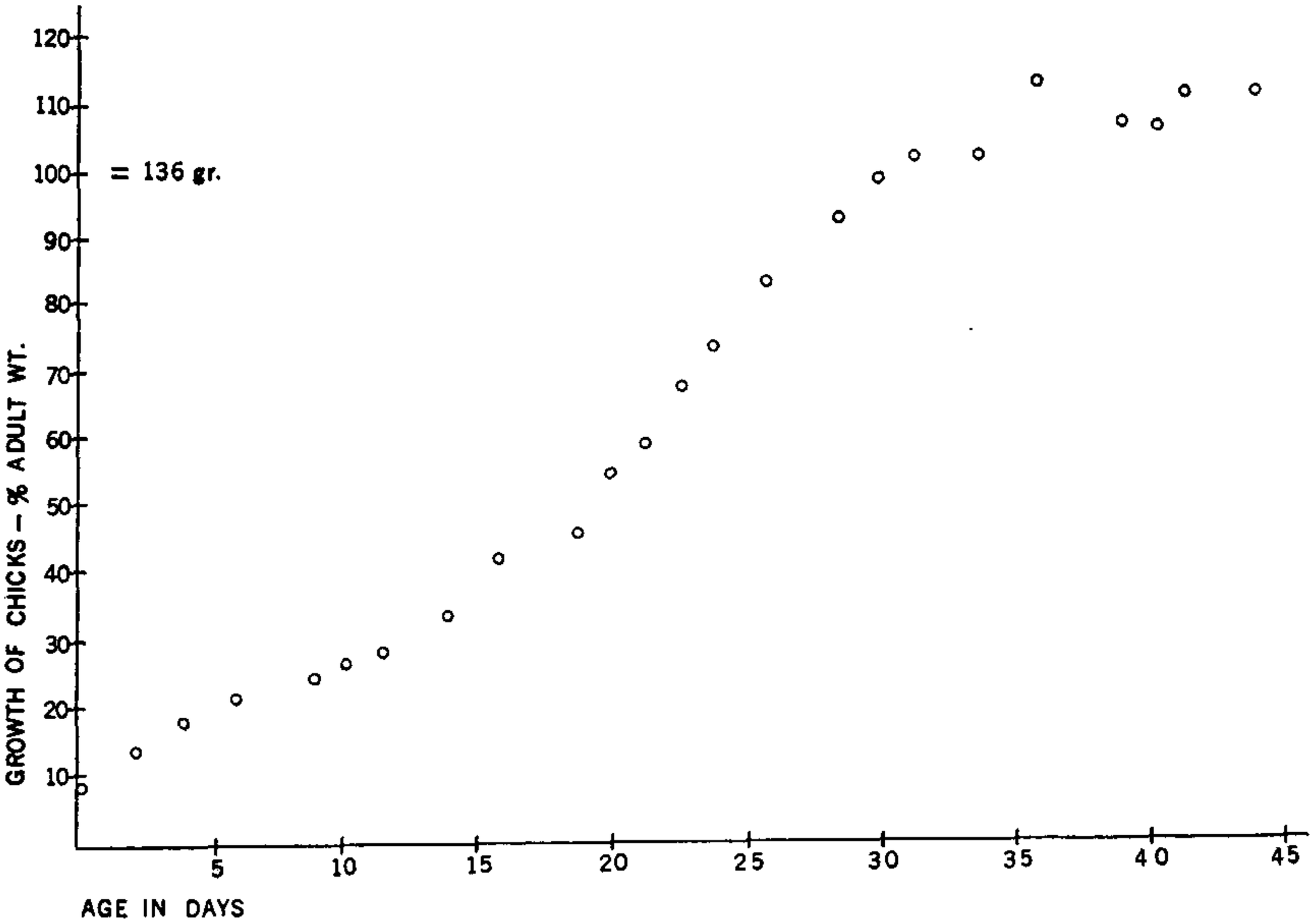


FIGURE 3 — GROWTH curve of Diving Petrel chicks expressed as percent of adult average weight. Adult weight is the average of 14 birds weighed in October.

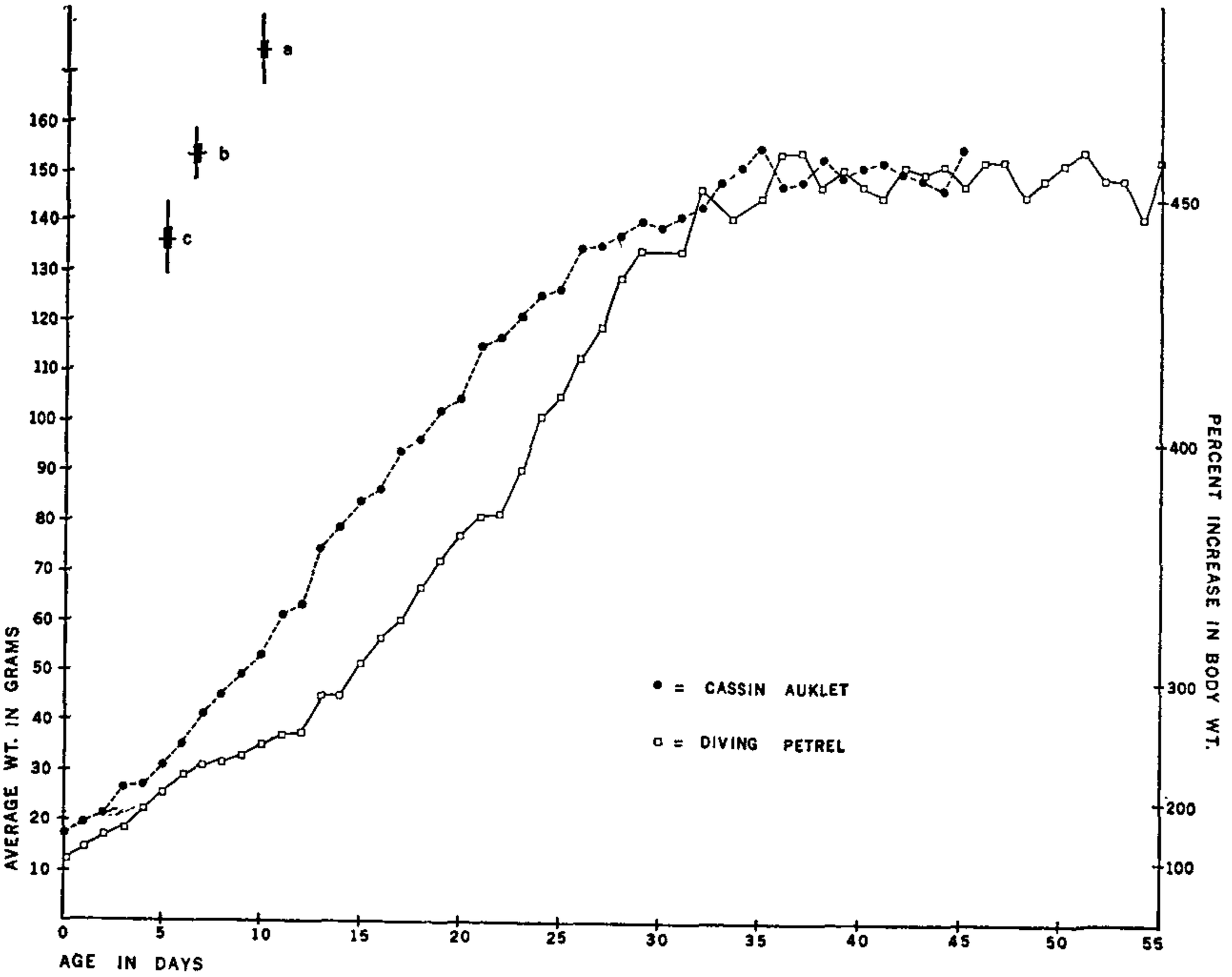


FIGURE 4 — Daily growth by weight comparing the Cassin Auklet with the Diving Petrel. a. represents the weight of 19 adult Cassin Auklets with standard error and deviations indicated. b. is the average weight of 20 adult Diving Petrels in April and c. is the average weight of 14 adult divers in October. Note that the Cassin Auklet chicks fall short of the adult weight at fledging time. The number of Diving Petrel chicks weighed corresponds to the figures given in Table 2 for each day of age.

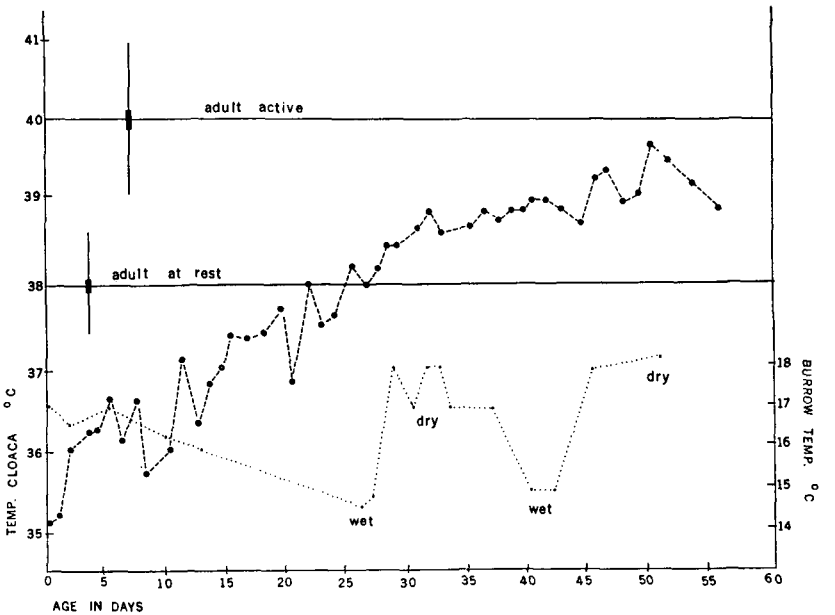


FIGURE 5 — Development of temperature regulation in 10 Diving Petrel chicks compared with 122 active adults and 60 adults at rest. The temperatures of the chicks were measured between 13:00 and 15:00 hours each day.

FEEDING OF THE YOUNG

Observations on the method of feeding the young were accomplished by digging out the rear of a burrow to expose the nest area and young. The excavation was kept covered with a flat rock during daylight hours and removed after dark. The incoming adult bird, unaware of the change, would enter the real entrance and proceed to feed the young. By shining my headlamp to one side I could view the activity without disturbing the bird and also focus to take flash pictures.

The chick frantically begged as soon as the adult entered the burrow. It set up a constant rasping " Squeer " and waggled its head up and down, back and forth and around the parent's bill until, with a satisfied peep, it ravenously sipped the slowly oozing mixture of pink " whale krill " (probably an Euphausid shrimp) which was regurgitated from the parent's bill.

I was never able to witness the adult rubbing the chick's head as described by Richdale (1943: 37). During my many hours of observation it was always the chick that made the motions contributing to the wearing of the down from the chick's head.

MORTALITY IN THE YOUNG

Young birds were frequently found dead outside of their burrows especially in areas where the Flesh-footed Shearwaters

(Puffinus carneipes) were active. In my study area seven Diving Petrel chicks met their fate in this manner. On another occasion I found two mortally injured chicks at the foot of a cliff from which they had fallen when their burrows slid away. Of the fifty nests under study two were deserted in the egg stage, two others failed to hatch, four chicks died before the age of 5 days, one was found dead in the burrow at 40 days of age for no apparent reason, and one juvenile died of a broken neck after crashing into a boulder on its way to the sea. It appears from these observations that the most critical period is the first few days after hatching.

Another critical period is when the juveniles vacate their burrows. At this time they do not fly well and actually often roll off the cliffs to clamber between the rocks to the water. It seems that they have the best chances of surviving if the tide is full when they make their excursion. I found many juveniles around the island that were injured or had met their death by falling. One had a leg missing and the left manus amputated. I placed it in deep sheltered water hoping it could survive in the sea, but it could only hopelessly propel itself in circles underwater. Others were seen floating dead in the sea. At this time of the year numbers were also found in the stomachs of snappers *(Pagrosomus asuratus)*, one of the local commercial fish. Southern Black-backed Gulls *(Larus dominicanus)* were seen to feed on dead juveniles and a Harrier *(Circus approximans)* was responsible for the death of at least 10 juveniles on the summit of Green Island early in December.

NEST SANITATION

The fecal material consists of a mass of whitish fluid containing chunks of red matter resmbling squashed raspberries. I noted that it is almost identical to that of the Cassin Auklet which has similar food types. However, in the auklet the feces is squirted toward the burrow entrance, whereas the Kuaka deposits its wastes in the back end of the burrow where it becomes an odorous mass of moisture filled with fly maggots. Accumulations of this material drive the chicks, as they get older, further forward in the burrow and after the age of forty days they actually do considerable digging of new side tunnels. I have found burrows completely remodelled after this time and have seen the juveniles actually digging and occupying the clean side passages.

OTHER ACTIVITIES OF THE ADULTS

Compared to the auklets the Diving Petrels are rather uninteresting birds. At least their displays and behaviour are simple in comparison. Both species dig their holes in much the same fashion, scattering soil for a couple of metres from the hole. But the activity is less ceremonious than in the auklets. Both species use old burrows if available and these are ready for occupation earlier than new holes.

Upon arrival in the evening the Diving Petrels drop through the tree canopy on to the ground with a thud. Often they would sit somewhat dazed or stunned for several minutes, otherwise they would dash off on tiptoes and wings flapping into their nearby burrows. Each night it was necessary to toss birds out of my tent and from the sagging plastic sheet that I used to catch rain water.

I returned after a rainy week-end to my camp to find two, one drowned the other very exhausted, birds floating in about 3 gallons of water collected in the plastic catchment. They were unable to climb the slippery plastic sheet or fly out of the pool.

Social activities such as circling, passing, wing-raising, bowing, head-waggles and bobbing demonstrated by auklets are not seen in these petrels, but billing and nebbing are common to both species.

Diving Petrels frequently sit with their wings dropping which gives them a rather ovate flat appearance from above. A few minor squabbles were seen in which the two birds engaged in brief forward-jabbing and bill-pulling sessions. Departure ceremonies involved only the " meow-chorus " previously described. Apart from these actions, the noisy two hours in the evening and the " meowing " early in the morning, the adult birds did little but sleep with the bill tucked under their coverts.

On one occasion I witnessed a brief encounter of a Kuaka with a Flesh-footed Shearwater, when the Kuaka accidentally dashed into the large bird and frightened it. On another night a Tuatara *(Sphenodon punctata)* ran into a sleeping petrel which awoke with such a fright that it leaped about a meter in the air then scuttled away up the hillside.

As soon as the eggs hatch the incubation patch begins filling in and in about 35 - 40 days the bare patch is completely covered with short dense down. By the end of November the adults show considerable wear on the feathers. The remiges and rectrices were all frayed at the tips; however, I detected no evidence that the moult had begun. Payne (1965: 221) reports that the wing moult in the Cassin Auklet begins while still raising young.

Apparently, the Divers' moult later while at sea. By the end of November, the number of adults coming in at night was diminishing and by 10 December very few were seen or heard. Watson (1968: 182-183) has recently indicated the synchronous moult of remiges and rectrices in the Diving Petrel.

EXTERNAL PARASITES

Ectoparasites were frequent on the Diving Petrel. These included fleas, lice, ticks and mites.

The fleas were identified as *Parapsyllus jacksoni,* and according to Dr. R. L. C. Pilgrim (personal communication), this is the first record of this species of flea on the Diving Petrel. Three different lice were found: *Pelmatocerandra setosa, Halipeurus* sp. (possibly *H. falsus pacificus*), and *Austromenopon elliotti,* one pair of which has been deposited in the British Museum of Natural History. The ticks were identified as *Ixodes auritulus zealandicus.* The mites are yet to be determined.

Ticks were often found attached to the flesh around the eye of the young birds in the burrow, but no effects upon the growth of the individuals was obvious. None was found on adult birds. The fleas seemed to prefer the belly down of both the chicks and the adults.

WEIGHT CHANGES IN THE ADULTS

A definite increase in body weight was noted to occur during the post-breeding period at sea. This excess weight was rapidly lost after the nocturnal visits to the breeding grounds began. By a month before egg laying the average body weight had declined to the October level when the adults were feeding young (Figure 6). The data indicate that the main loss of weight occurs before the eggs are laid. This may be due to the shortening of daily feeding periods after the nocturnal activity on land begins. However, it is not known positively that the birds feed at night while at sea. Baird (1965: 426) notes that Leach's Petrel is unlike other petrels in that it feeds at night. Richdale (1947) suggests that the weight may increase during the incubation period and then fall again when feeding the young. More data is needed during the incubation period and during the feeding period to fully understand the phenomenon.

Bartle (1968: 85) noted unusual weight losses in breeding Pycroft's Petrels even when food was apparently plentiful. These losses corresponded to the weight losses in birds that were incubating and thus not feeding.

Since the Diving Petrel tends to change incubation roles on an alternate night basis, weight loss due to long periods without feeding would not be expected. It is apparent then, that the weight loss in the Diving Petrel is related to increased breeding activity and less time spent in feeding.

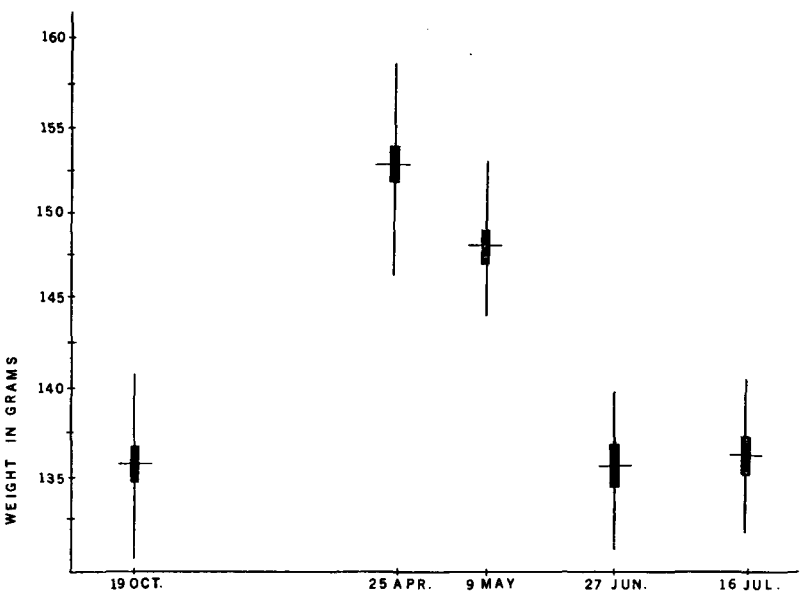
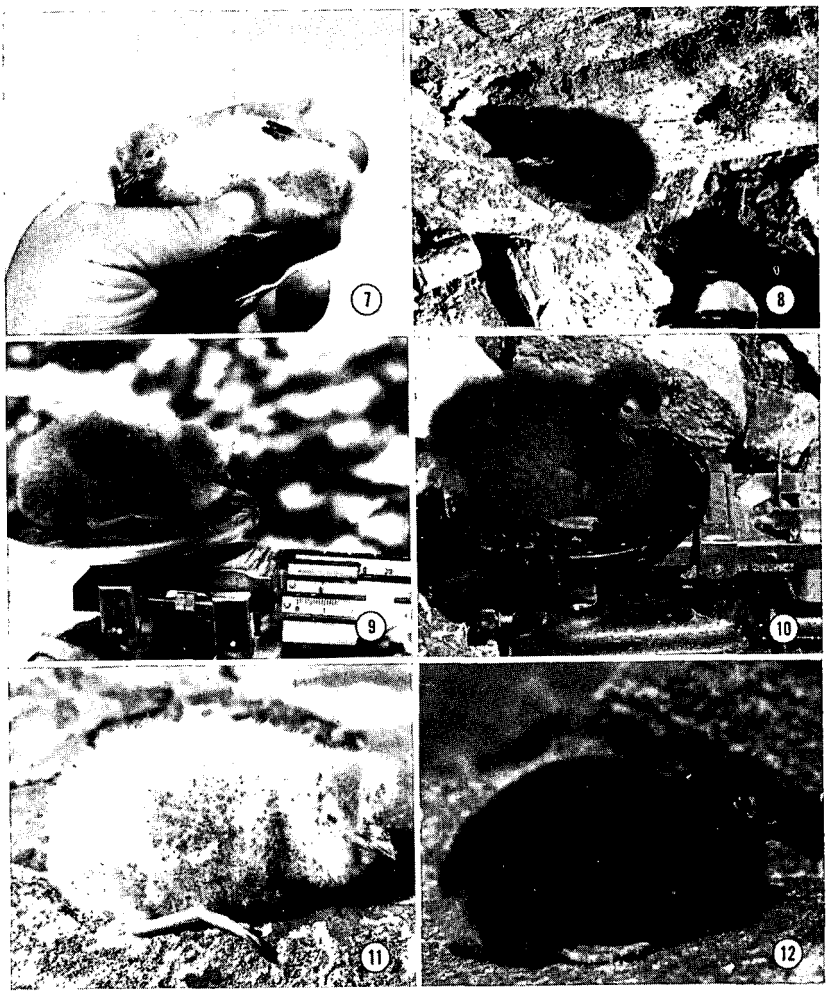


FIGURE 6 — Weight changes in adults recorded at difficult months of the year. For the October entry n = 14 and for April to July n = 20. Standard error and deviations are indicated.



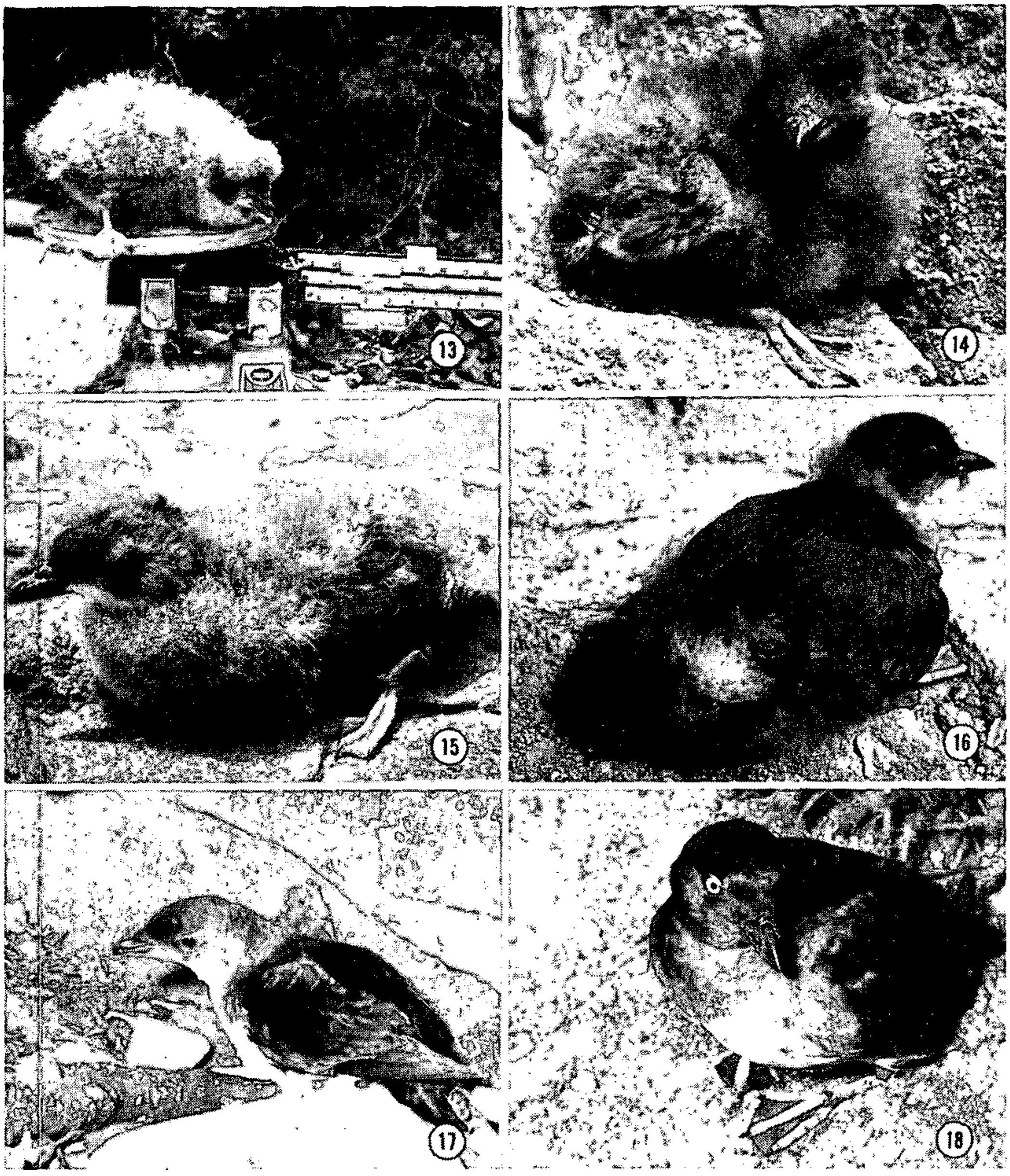
FIGURES 7 - 12 — Illustrations of Diving Petrel and Cassin Auklet chicks of comparable ages. Divers are shown on the left, auklets on the right.

7: A three or four-day-old diver chick showing the wedge of darker down on the venter.

8: A 24-hour-old Cassin Auklet chick.

9 and 10: Chicks 18 - 20 days old.

11 and 12: About 25 days old.



FIGURES 13 - 18 — Continuation of growth in divers (left) and auklets (right).

13 and 14: Chicks 28 - 30 days of age.
15 and 16: About 35 days.
17 and 18: Adult birds.

Falla (1934: 246) suggests that during courtship, adults probably refrain from eating, for he found nothing in the stomachs of those he examined. Harris (1966: 22) noted that adult Manx Shearwaters during incubation lost an average of 10 gm. a day but that the average weights throughout different stages are reasonably constant. However, he did not record weights of birds during the time of initial return from inter-breeding time at sea.

TABLE 3

Summarizing Comparative Habits of the Cassin Auklet and Diving Petrel

CASSIN AUKLET (**Ptychoramphus aleutica**)	DIVING PETREL (**Pelecanoides urinatrix**)
Nests	
Burrows in soft soil in open areas. Often no nest material used, but occasionally a few leaves or blades of grass are used. Fecal wastes deposited toward burrow entrance.	Burrows similar to auklets in soft soil under tree cover or in the open. Leaves often used as nesting material. Fecal material deposited in rear of burrow.
Incubation	
Continuous, male and female alternates, no incubation patch present in adults. At least 37 days duration. Temperature tolerance unknown. Fresh eggs may be found through several months of the year.	Egg sometimes left to cool, male and female alternates. Have well developed single incubation patch. Approximately 53 days duration. Demonstrate remarkable tolerance to lowered temperatures. Fresh eggs limited to 3 or 4 week period.
Pipping	
2 - 3 days.	Same.
Fledgling Period	
Adults stay with young only 3 - 4 days. 41 - 50 days spent in nest. Do not fly well when they enter water. Juveniles reach lower limits of adult weight before fledging.	Adults stay with young 10 - 15 days. 48 - 56 days spent in nest. Do not fly well when they enter water. Juveniles reach upper limit of adult weight before fledging.
Moult	
Adults moult while feeding young. Primaries are moulted a few at a time (Payne, 1965: 225). *Previously this has been considered a* petrel-like trait.	No evidence of moult while feeding young. The moult takes place at sea after breeding *is completed. According to Murphy and* Harper (1921: 509), this is an auklet-like trait.
Behaviour of Adults	
Arrival at night similar in both species. *Flight and swimming similar.* Food habits similar.	Similar. *Similar.* Similar.
Social Activities	
Digging of burrows ceremonial in auklet. Exhibits billing and nebbing. Sleep posture—bill tucked in lateral coverts. Circling, passing, weed plucking. Jabbing. Face-to-face combat with feet used. Wing-raising. Head-waggles, *head-bobbing and bowing.* Departure ceremony includes display.	Less ceremonial but otherwise similar. Similar. Similar. Not seen in divers. Similar in divers. Engage in bill pulling but not with feet. Not seen in divers which rather tend to drop their wings. *Not observed in divers.* Confined to "Meow" chorus with no apparent display.
Calls and Communication	
At least 10 variations: " Krick-i-er," " Kut-reeah," " Kut-reeah." Location and begging calls of young a constant " Squeer."	At least 9 variations: " Kuaka," " Kuaka-did-a-did," " Meow." Similar to auklet.
Feeding Young	
Adult assumes hunched posture and regurgitates. Young beg by sound.	Adult sits flat, regurgitates. Young beg by sound and head waggles.

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