Moult and changes in body shape and pelage in known-age male New Zealand sea lions (Phocarctos hookeri)

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Abstract   We observed a small population of male New Zealand sea lions (*Phocarctos hookeri*) in 7 consecutive years at Otago, New Zealand, a region north of the main breeding population. Changes in pelage, body shape, and body length, with growth of tagged, known-age males were used to define age class categories: "juvenile" (1–3 years), "subadult" (4–5 years) and "adult" (6 years and older). Accurate assessments of age are important to determine immigration rates of cohorts into a small population. We used photographic identification to recognise individuals so that the progression of moult could be determined. Individuals 2+ years old underwent a complete annual moult over a period of c. 2 months between December and June. Juveniles moulted earlier than subadults and adults. However, 1-year-old males underwent only a partial annual moult. Knowledge of the timing of moult is important for the deployment of remote sensing devices glued to the pelage, because moult will result in the loss of attached equipment.

INTRODUCTION

New Zealand sea lions (*Phocarctos hookeri* (Gray)), also known as Hooker's sea lions, have a restricted breeding distribution, with 95% of pups born at Auckland Islands (Gales & Fletcher 1999). A few pups have recently been born on the New Zealand mainland at Stewart Island and Otago, South Island (Childerhouse & Gales 1998). The total population was estimated at c. 13 600 in the 1995/96 breeding season (Gales & Fletcher 1999). They were widespread around the New Zealand mainland before their extirpation following human colonisation (Childerhouse & Gales 1998), and past breeding on the mainland has been verified from sub-fossil records of pup remains (Worthy 1994; Gill 1998). Small numbers of males have spread north and have become resident along the south-east coast of the South Island, New Zealand (Hawke 1986, 1993; Beentjes 1989). Here they are readily accessible for monitoring throughout the year, and individuals are identifiable by a combination of diagnostic features (McConkey 1999).

New Zealand sea lions are polygynous and show strong sexual dimorphism in size and pelage. Males may reach 3.25 m standard length (SL), much larger than females which reach up to 1.89 m (Cawthorn et al. 1985; Crawley 1990). Females are pale throughout life and lack a mane. Young males resemble females, but they darken with age to blackish brown, and develop a mane of coarse hair over the chest, neck, and shoulders (Marlow 1975; Hawke 1986; Crawley 1990). This study was conducted on a small population of New Zealand sea lions at Otago, consisting almost exclusively of males. For this reason we have not presented data for females.

Classification of individual males into age classes has been inconsistent and confusing. Marlow (1975) presented five age categories based on colour, size, and shape: two "juvenile", one "subadult" and two "adult" categories. He concluded that breeding males were >6 years old. Hawke (1986) and Beentjes (1989) each used three categories based on length measurements, but allocated different terms. Hawke (1986) used "small" (<2 m), "medium" (2–2.3 m), and "large" (>2.3 m), but Beentjes (1989) used "immature" (4 years), "sexually mature" (5–7 years) and "sexually and socially mature" (8 years), calculating ages from length measurements.

The primary objective of the New Zealand sea lion population management plan is to encourage emigration away from the Auckland Islands and the establishment of new breeding sites by increasing the size of the population at Auckland Islands (Maunder et al. 2000). The ability to accurately age individuals from physical characteristics is important for establishing the rate of emigration by different cohorts when other methods of ageing are not available. This may in turn help to define factors affecting emigration away from the Auckland Islands.

Moult, a process through which all mammals appear to continually or periodically replace their pelt hairs (Ling 1970), can affect the appearance of age-related pelage changes such as colour and mane development. Seals undergo moult following the breeding season (Ling 1970). Patterns of moult differ between species in progression (systematic or diffuse) and direction (Ling 1970). In many species the timing of moult varies with age, and young animals usually moult first (Rand 1956; Thompson & Rothery 1987; Riedman 1990; Le Boeuf & Laws 1994). Descriptions of moult in New Zealand sea lions have been limited to anecdotal comments (Marlow 1975).

The practical importance of documenting the timing and progress of moult is highlighted by the recent widespread use of electronic tags and recording devices to document seal movements, physiology and diving behaviour; e.g., Gales & Mattlin (1997) for New Zealand sea lions. These devices are glued to the pelage and are shed with the hair during moult unless they are removed earlier. Knowledge of the season of moult in different age classes would help to maximise information available from electronic tags by minimising their loss.

METHODS

Ninety-five percent of pups are born at Auckland Islands (50°S, 166°E; Gales & Fletcher 1999), between early December and early January (Marlow 1975), with mean pupping date 17–20 December (Cawthorn et al. 1985; Crawley 1990). For convenience, we designated a birth date of 1 January, so that an individual sea lion belonged to a single year class throughout the calendar year. Marking pups with plastic tags in the trailing edge of fore flippers began at Auckland Islands in 1980 (Gales 1995). Throughout our study, we encountered known-age animals that had been tagged as pups at Auckland Islands. From these individuals we deduced features characteristic for each year class of males and used these to assess ages of untagged animals.

Our surveys covered all regularly frequented haul-out sites of sea lions at Otago Peninsula (45°50′S, 170°40′E) and South Otago (46°30′S, 169°40′E), South Island, New Zealand (mapped in Beentjes 1989 and Hawke 1993). All sites at Otago Peninsula were visited at least monthly between June 1991 and April 1998. More frequent observations were made June 1991–May 1992 (fortnightly), June–December 1994 (fortnightly), January–December 1995 (weekly). Sites at South Otago were visited at least 3–6 times annually between September 1991 and April 1998. More frequent visits were made in January–June 1995 (fortnightly), and July 1995–April 1997 (bimonthly).

We found that New Zealand sea lions ashore were usually passive and tolerant of our approach to within 1 m. Individuals were recognised by tags, or by photographic identification (Lalas & McConkey 1994; McConkey 1999). We measured SL (to nearest 0.1 m) of prone and passive individuals with a tape measure. Valid measures were difficult to obtain for two reasons. First, we had difficulty in judging whether animals were fully prone, and therefore suitable for measurement. Second, animals rarely remained motionless for long enough to be measured. For animals measured more than once, only the first record each year was included in analysis. Animals dark in colour or with a mane were considered obviously male. Pale animals that lacked any sign of a mane were sexed only after observation of their genitalia. Data on body shape were limited to descriptions of subjective criteria from direct observation or photographs.

We recorded descriptions of pelage and moult for each individual seen from June 1994 to September

Fig. 1 Comparison of head shape between 1-year-old and adult male New Zealand sea lions at Otago (white, 1-year-old; black, adult), drawn from photographs.
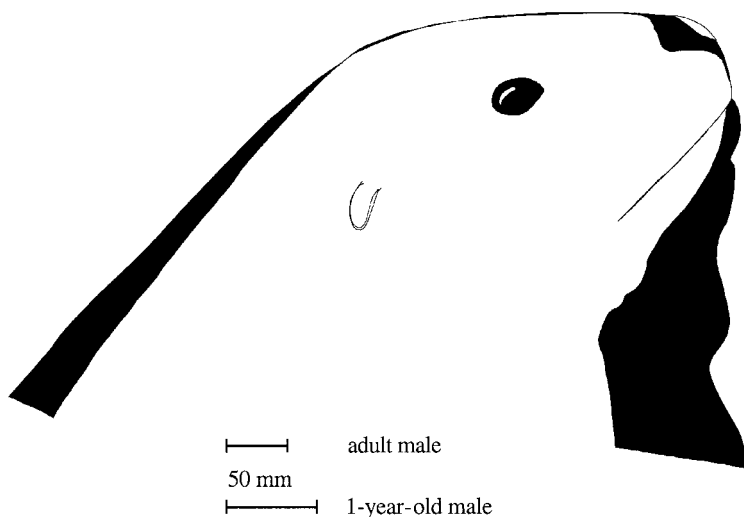

50 mm ⊢———⊣ adult male

⊢————⊣ 1-year-old male

Table 1 Annual numbers of known-age (tagged as pups) male New Zealand sea lions seen at Otago, 1991–97.

Year class	Number of individuals seen in calendar year							Age totals
	1991	1992	1993	1994	1995	1996	1997	
1				2				2
2			1	1	4			6
3				1	2	4		7
4	1				2	3	4	10
5	1	1				3	3	8
6		1	1				2	4
7			2	1				3
8				2	1			3
9					1	1		2
10						1	1	2
11							1	1
Annual totals	2	2	4	7	10	12	11	48

1995. Observations in later years were limited to noting inconsistencies with the previously recorded patterns. The hair of all individuals changed colour in the 1–2 months preceding the start of moult. All hair turned ginger with the exception of the mane, which in animals older than 5 years turned pale yellow. As the moult progressed, the old ginger or yellow hair was shed as the new hair grew. Our documentation of the progression of moult was simplified by observing the distribution of ginger or yellow hairs. We defined duration of the moult as the period of hair loss. Dates for the onset and for the completion of moult were estimated by interpolation from consecutive sightings that straddled the start and the end of moult, respectively. For animals with no sightings near the start or end of moult, the state of hair loss was compared with other individuals and the same rate of hair loss was assumed. This may have had the effect of artificially producing similar results for duration of moult, but should have had little effect on estimates of the timing of moult. Only animals seen in moult at least twice were included in results.

RESULTS

Tagged animals

Fifteen of the 76 males we encountered at Otago had been tagged as pups at Auckland Islands. Sightings of these animals combined to produce 48 annual records of known-age animals (Table 1). This assemblage included two individuals that we encountered throughout the study. One was 4 years old in 1991 and 10 years old in 1997, and the other 5 years old in 1991 and 11 years old in 1997. The latter lost his flipper tag in 1993 but remained recognisable through photographic identification. Both were still present in 2000.

Table 2 Standard lengths (SL) for male New Zealand sea lions measured at Otago, 1995–97. This total of 42 measures was taken from a minimum of 25 animals; for animals measured more than once, only the first record each year was entered. (SD, standard deviation; CV, coefficient of variation.)

Year class	Number measured	Range SL (m)	Average SL (m)	SD	CV (%)
1	5	1.2–1.5	1.4	0.11	8
2	6	1.3–1.7	1.5	0.16	11
3	6	1.6–1.9	1.8	0.15	8
4	3	1.7–1.9	1.8	0.12	7
5	2	2.0–2.2	2.1	0.14	7
6	20	1.8–2.5	2.2	0.17	8

Body shape

Perceptible changes in body shape began as males turned 2 years old, when the testes descended into the scrotum. An expansion of the nares, an increase in bulk of the forequarters (neck, chest, and shoulders), and development of the mane first became apparent in 4-year-olds (Fig. 1). The gradual transition to adult body shape and pelage appeared to be completed during the 7th year. Any changes in the extent or length of the mane occurred only during the annual moult. Pelage colour, expansion of the nares, and extent of the mane were similar for all individuals aged 6 years and older. Animals at least 6 years old when first identified could not be accurately separated into single year classes.

We measured mane hair from two dead males at least 7 years old as 4–5 cm long, compared with 2–3 cm for other body hair. We noticed, but did not quantify, individual differences in seasonal and annual fluctuations in bulk of the forequarters, and in length of mane hair. Two of the males at least 7 years old we encountered had white hairs in their manes. We did not establish an age for onset of this feature. However, neither of the two oldest known-age males, 13 and 14 years old in 2000, had white hairs in their manes.

Body length

We were cautious in our interpretation of our data for body length because our sample sizes were small and showed a broad range within each age class (Table 2). Consequently, we did not generate a growth curve. Our largest recorded measure of body length (2.7 m) was not included in the analysis as it may represent the second measurement of an individual adult male within the same year.

Growth in body length appeared to cease after c. 6 years (Table 2). This conclusion was supported by the consistency in five SL measures of the second-oldest known-age male at Otago, presented here in chronological order: 7 years old (1994) = 2.3 m, 8 years old (1995) = 2.4, 2.3, and 2.4 m, and 13 years old (2000) = 2.3 m.

Pelage colour

Any age-related changes in colour of the pelage developed during the annual moult. Outside the moult, 1-year-olds were pale brown dorsally and cream ventrally. Two-year-olds remained cream ventrally but dorsally they either remained pale brown or changed to a pale grey. Three-year-olds were dark grey above while the ventral surface remained cream or turned pale brown. Four-year-olds and 5-year-olds were dark blackish brown dorsally and along the ventral midline, but most retained paler flanks. Males older than 5 years were blackish brown all over. These results represent general trends, though individual variation means they cannot be taken as definitive.

Annual moult

Moult began on the face bordering the nares, eyes, and ears (Fig. 2). This was followed in order by the hair on the flippers, the ventral midline, the mane, around any prominent body scars, the forequarters, the dorsal midline, and finally by the sides of the body. Flippers were the first zones to complete the moult. The head was next, usually finishing with the crown. In individuals 2–4 years old the sides of the body were the last to complete the moult, whereas in animals at least 5 years old the mane was the last to moult.

In contrast to older males, 1-year-olds did not undergo a complete annual moult. The extent of this moult varied between individuals (Fig. 2). All moulted the pelage of the head, flippers, and forequarters, but in half (8 of 16) the moulted zone extended posteriorly along the dorsal midline.

We documented the duration and timing of moult for 37 males in 1995 (Fig. 3 and 4). The duration of moult averaged 57 days across the total sample and did not exhibit any consistent age-related differences. Statistical investigation of any age differences in the date of the start of moult were frustrated by low sample sizes for sea lions aged 2 years ($n = 1$) and 3 years ($n = 2$). Combining the results for these two age classes facilitated analyses and seemed reasonable biologically, as these age classes do not go through significant biological

Fig. 2 Dorsal view of the progression of moult for New Zealand sea lions at Otago. The delineated zones moult in numerical order 1–5. In 1-year-old males, zone 4 sometimes moults and zone 5 never moults.
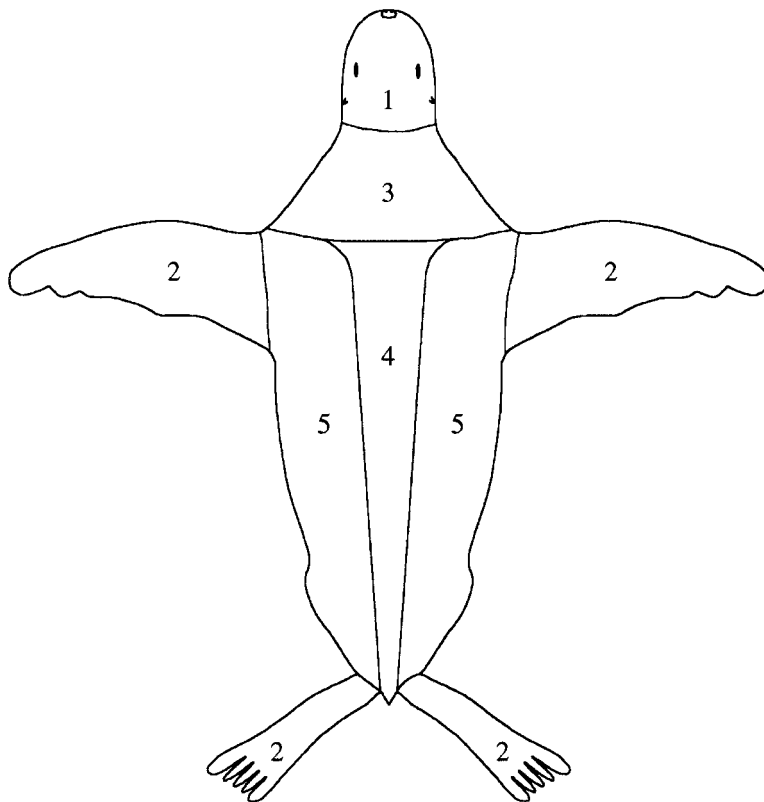
Table 3 Timing of start of moult by age for male New Zealand sea lions at Otago in 1995. (Day, Julian day; SD, standard deviation.)

Year class	Number monitored	Mean date for start of moult		
		Date	Day	SD
1	8	9 Mar	68	2.5
2 + 3	3	16 Jan	16	16.3
4	5	27 Feb	58	12.8
5	4	13 Mar	72	5.3
6	17	12 Mar	71	5.2

changes such as weaning or puberty which could have affected results (Table 3). The mean date for the start of moult was significantly different among age classes (1-way ANOVA, $P < 0.0001$). The 2–3 year age class started moult significantly earlier than all others, and timing of the start of moult of 4-year-olds was significantly different from all others.

Three sea lions seen in moult in 1995 did not fit the expected pattern of moult (Table 4). These animals, one 2-year-old and two 4-year-olds, were in moult when seen for the first time (24 April, 22 June, and 11 July, respectively). The 2-year-old ended moult on c. 30 May, 103 days after the end of moult by the other male in his year class. The corresponding dates for the two 4-year-olds were c. 21 July and c. 23 July, respectively 97 and 99 days after the mean end of moult by others in their year class.

Table 4 Number of identified individual male New Zealand sea lions seen during the moult at Otago in 1995.

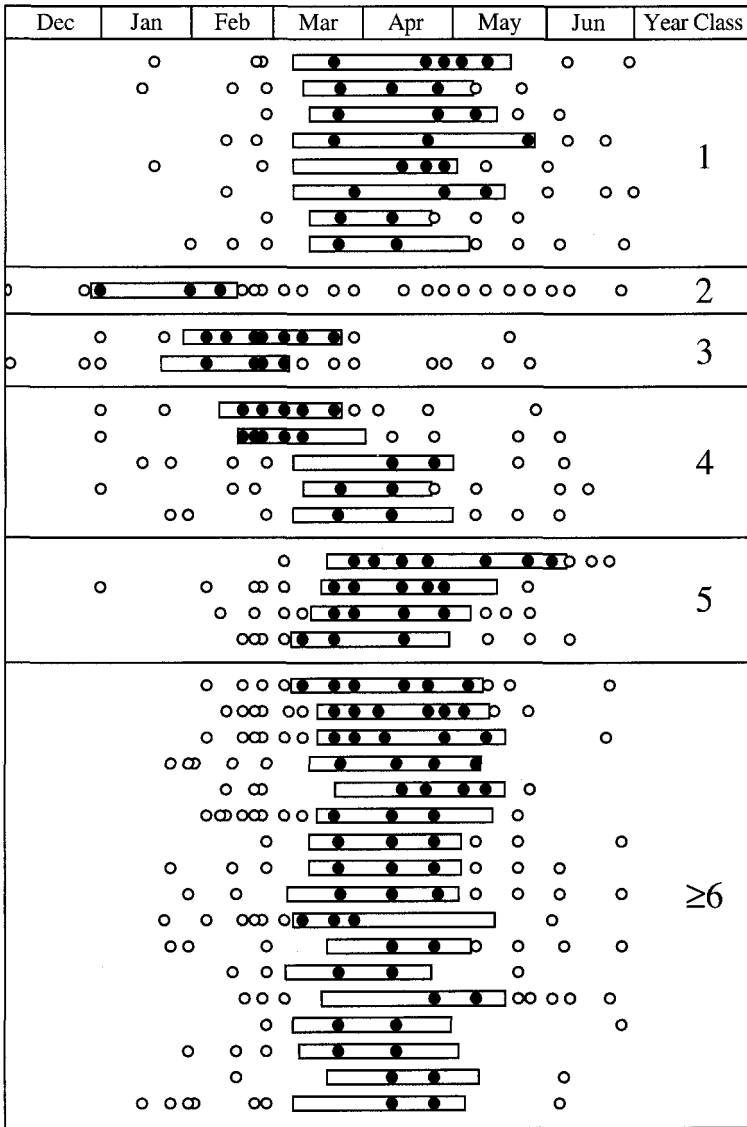| Year class	Total	Used to determine timing of moult (Fig. 3)	Fitting the moult pattern	
1	16	8	16	(100%)
2	5	1	4	(80%)
3	3	2	3	(100%)
4	10	5	8	(80%)
5	4	4	4	(100%)
6	23	17	23	(100%)
Total	61	37	58	(95%)

Fig. 3 Timing of moult for 37 New Zealand sea lions at Otago (open circles, sighting of animal not in moult; closed circles, sighting of animal in moult; box, estimated duration of moult).
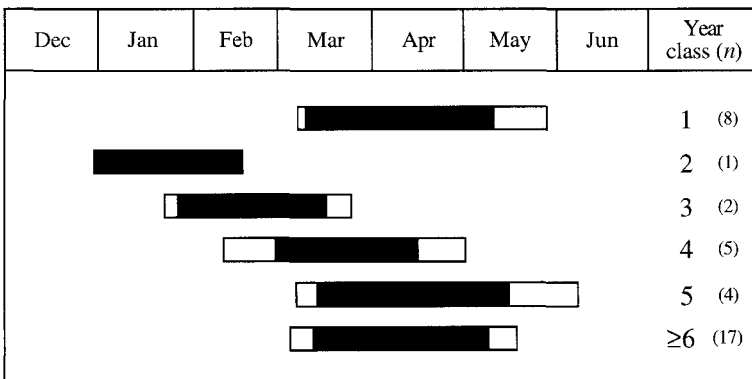

Fig. 4 Age differences in timing of moult for New Zealand sea lions at Otago (black, average duration for individuals; white, range for age class).

DISCUSSION

Male New Zealand sea lions at Otago reached maturity in body shape and pelage when 6 years old. More precisely, they reached maturity at the end of the moult mid way through their 7th year, and would be 7 years old at the next breeding season. A minimum age of maturity at 7 years old for male New Zealand sea lions is consistent with the >6 years of age for harem bulls, given by Marlow (1975), and the 8 years to become sexually and socially mature, from Beentjes (1989). Growth in length also probably ceased during the 7th year, but more data are required for a definitive conclusion on this. Our longest measure from a minimum of 15 males 6+ years old was 2.7 m SL, less than 85% of the maximum 3.25 m reported for the species in Cawthorn et al. (1985) and Crawley (1990). Some males sighted regularly at Otago have also been seen as territorial or peripheral males at breeding colonies at Auckland Islands (Wilkinson pers. comm.). Therefore, it seems unlikely that the animals found at Otago are significantly smaller in size than those in the rest of the population. Dickie (1999) recorded a maximum of 1.95 m SL for males aged up to 12 years old, from a sample of 13 males caught in the Auckland Islands squid fishery. It is possible that this 3.25 m measure was not SL or is unrepresentative for the species. Average length increased with age of sea lions up to 5–6 years old. It is possible that growth continues after this age and our method of measurement was not precise enough to detect these changes. However, inter-annual overlaps in ranges of lengths were too great to use length alone as a reliable indicator of age.

Our descriptions of six year classes of male New Zealand sea lions bore a strong resemblance to the five age groups described by Marlow (1975). We conclude that individual male New Zealand sea lions can be allocated reliably into one of three age categories, based on a combination of body length, body shape, and pelage: juvenile (1–3 years old), subadult (4–5 years old), and adult (6+ years old), as follows.

(1) Juveniles are easily distinguished from older males by the absence of a mane. In common with Marlow (1975), but in contrast with Hawke (1986), we could not reliably distinguish between females and juvenile males less than 2 years old without inspecting their ventral midline for presence or absence of a penile opening. Testes descend as young males turn 2 years old and so 1-year-olds can be distinguished from older juveniles if they allow a close rear inspection.

(2) Subadults show the onset of adult features: dark pelage, a mane, an increase in bulk of the forequarters, and expansion of the nares.

(3) Adults are wholly dark and are distinguished from younger animals by the lack of paler pelage on the ventral surface, the presence of a well-developed mane and bulky forequarters. We recorded white hairs scattered through the manes of two adults, but not from either of the oldest known-age males at 13 and 14 years old. Perhaps white hairs appear only in older animals. If quantified in the future, this feature might be used to designate an age category of "old males".

The combination of the recognition of individuals and the gingering of the hair shortly before it is shed allowed us to follow the progression of moult of individual sea lions. Male New Zealand sea lions exhibited a systematic progression of moult, starting on the face and then followed chronologically by the flippers, the ventral midline, the mane, the forequarters, the dorsal midline, and finally the sides of the body. Though the mane started to moult early it was often the last area to complete the moult. The presence of prominent body scars was often correlated with an earlier moult of the surrounding hairs than would normally be expected for that area. The only other detailed study of the moult pattern for an otariid seal found a similar anterior to posterior progression in South African fur seals (*Arctocephalus pusillus*), though the dorsal surface moulted prior to the ventral surface (Rand 1956). This systematic progression of moult contrasted with northern fur seals (*Callorhinus ursinus*) and New Zealand fur seals (*Arctocephalus forsteri*), other otariid seals that both exhibit diffuse progressions of moult (Scheffer & Johnson 1963; Ling 1970).

Timing of moult in the animals we observed differed according to the age of the individual. Only one 2-year-old was observed: it was the first to moult starting in late December, and finished by mid February. Older year classes moulted successively later until individuals 5 years and older started moulting in early March and finished by early June. Younger animals moult first in South African fur seals (Rand 1956) and in many phocid seals (Ling & Bryden 1981; Thompson & Rothery 1987; Riedman 1990).

Three New Zealand sea lions did not fit the pattern of timing of moult observed in other individuals of their year class. As these three sea lions had not been seen before, they were assumed to be recent arrivals in the region. Late moult has been attributed to malnutrition (Ling 1970), or to lowered skin temperatures (Ashwell-Erickson et al. 1986; Boily 1995).

The extent and timing of the annual moult by 1 year old New Zealand male sea lions did not fit the pattern of older males. They underwent only a partial, rather than complete, annual moult. Timing of the moult was later than that of older juveniles and was similar to adults. Rand (1956) found that yearling South African fur seals also moulted later than older juveniles and at a similar time to adults, but he did not mention a partial moult.

Knowledge of the season of moult will reduce the potential loss of electronic devices which are glued to the pelage. We conclude that these electronic devices should not be attached to male New Zealand sea lions at Otago from January–June each year, depending on the age of the animal. We consider our results to be accurate for Otago but they may not be definitive for the species. They should, however, be cautiously taken as indicative of New Zealand sea lions at other locations until data shows otherwise.

The aim of current conservation management of New Zealand sea lions is to increase the size of the population at Auckland Islands to encourage emigration and the establishment of new breeding sites elsewhere (Maunder et al. 2000). Young males typically form the vanguard of a spread in distribution by polygynous mammals (Greenwood 1980). Our study has established reliable designations of age for young males. This will facilitate accurate assessments of emigration rates of cohorts, born at Auckland Islands, to Otago and to other peripheral locations in the distribution of the species.

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