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Distribution, abundance, reproduction and behaviour of Steller sea lions (*Eumetopias jubatus*) in Prince William Sound, Alaska

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Summary

This study is about the distribution, abundance, reproduction and behaviour of Steller sea lions (*Eumetopias jubatus*) on their rookery and haulout areas in Prince William Sound, Alaska in the period June–July 1988. Multiple counts during this period yielded varying numbers of animals present at the study sites. The behavioural data clearly show that in this geographical area, and in this period of the year, the haulout pattern of Steller sea lions is strongly influenced by the tide. This tidal-influenced haulout behaviour has so far not been taken into consideration in the timing of aerial surveys. In future aerial surveys of Steller sea lions this phenomenon should be taken into account, especially when counts from different years are compared in order to design a management strategy for this species.

Introduction

For more than a century there have been conflicts between the fisheries and Steller sea lions in many parts of the North Pacific (Kenyon, 1952; Calkins, 1985; Loughlin & Nelson, 1986; Hoover, 1988). Steller sea lions are known to feed on the fish caught on long lines, or in nets, and to sometimes damage the nets themselves. Some animals are killed accidently when caught in fishing nets and others are shot by fishermen. To evaluate the impact of Steller sea lions on fish stocks objectively, data on the dynamics of the fish populations have to be combined with the following data on the biology of Steller sea lions:

1) The prey species and the proportion in which they are taken by the Steller sea lions in different geographical areas and during different seasons.

2) The energy requirements of Steller sea lions of different ages, sex, reproductive stage and during the different seasons and,

3) The number of Steller sea lions that occur in different geographical areas, and the age structure of the populations.

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Data on the prey species and the proportion in which they are taken by Steller sea lions are available from samples of animals in the wild and from animals that were found dead at sea or on beaches (Evermann, 1921; Imler & Sarber, 1947; Wilke & Kenyon; 1952; Thorsteinson & Lensink, 1962; Mathisen *et al.* 1962; Fiscus & Baines, 1966; Pitcher, 1981; Lowry *et al.* 1982).

The early information on the energetics and nutritional requirements of Steller sea lions has been very incomplete (Fiscus & Baines, 1966; Keyes, 1968; Spalding, 1964a,b). However, basic information on energy requirements of Steller sea lions of different ages, sex, reproductive stage and during different seasons, has recently become available through a study on animals of this species in human care (Kastelein *et al.* 1990).

The number of animals in different regions in the North Pacific has been estimated for several years through aerial surveys (Kenyon & Rice, 1961; Mathisen & Lopp, 1963; Fiscus *et al.* 1981; Loughlin *et al.* 1984; Calkins, 1985; Merrick *et al.* 1987) and were recently summarized by Hoover (1988). The authors conclude a decline in the abundance of Steller sea lions in Alaska during the last 3 decades. Counts from some of these surveys may not be as valid as could be expected. The number of animals counted in such surveys may vary according to season, climatic conditions, time of day relative to the light cycle, and time of day relative to the tide cycle. Most of the authors paid attention to the season and the time of day, and Hoover (1988) recommends that future surveys should be conducted between 10.00 and 18.00 hrs. However, they did not consider the tide relevant to the numbers of animals recorded (Merrick *et al.* 1987). They based their negligence of the tide on studies which compared aerial surveys with ground observations, in which no correlation was found between Steller sea lion numbers hauled out on land and the tide (Withrow, 1982). This was confirmed by a study of Sullivan (1980) along Humboldt County, California. From anecdotal information and a study by Sandegren (1970), in which more animals were observed in the water at high tide, these conclusions

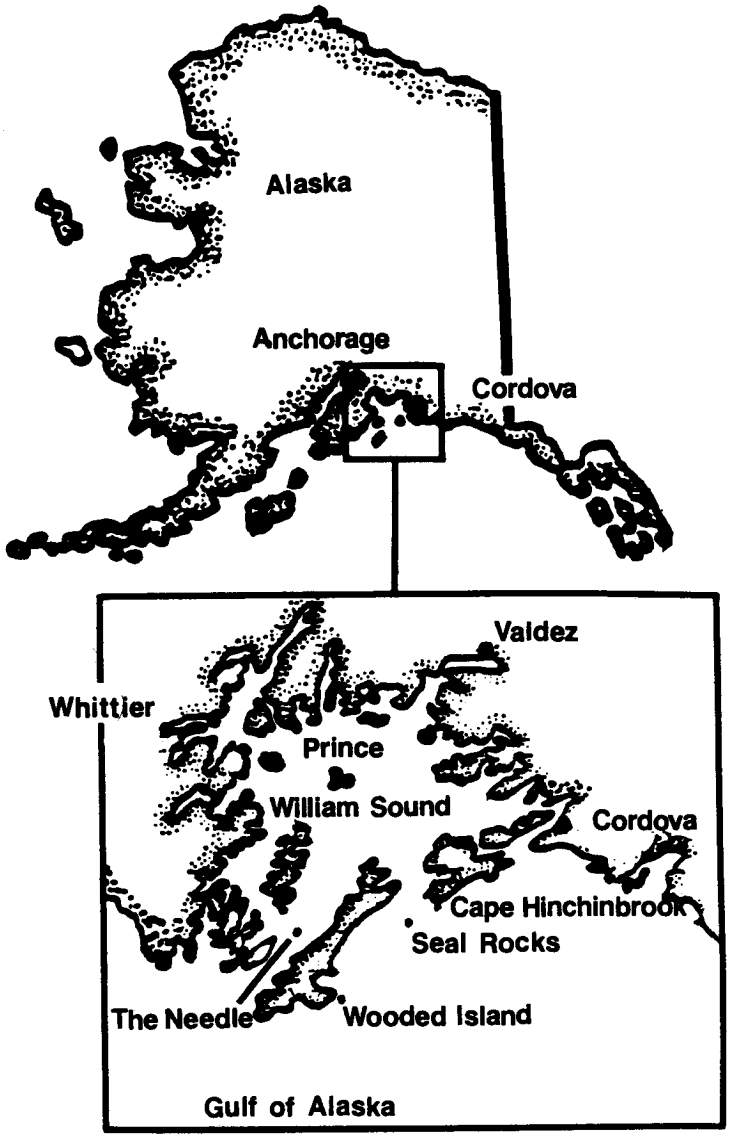

Figure 1. The study area: Prince William Sound, Alaska, with the studied rookery and haulout areas.

were questioned for a rookery and several haulout areas in Prince William Sound.

The purpose of this study was to investigate the influence of the tide on the behaviour (including the haulout pattern) of Steller sea lions in Prince William Sound and adjacent coastal waters. Also an estimate is given of the number of Steller sea lions present in part of this area (Cape Elrington and Cape St. Elias were not surveyed) during June and July 1988, the season in which reproductive bulls are territorial.

Materials and Methods

Study area

During a boat survey in June 1988, Steller sea lions (*Eumetopias jubatus*) were seen hauled out at 4 colonies in Prince William Sound, Alaska (Fig. 1). A description of the colonies follows:

1) Cape Hinchinbrook: a few small rocks on the open coast next to the entrance of Prince William Sound (Fig. 2).

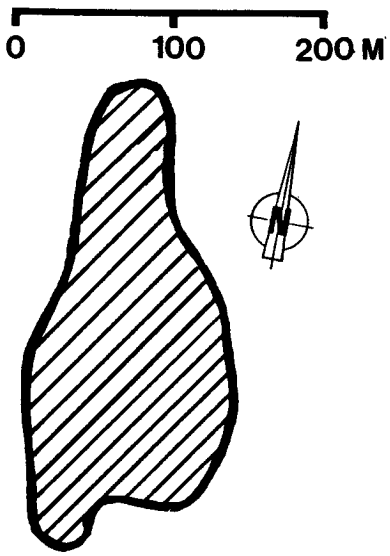

Figure 2. An island of Cape Hinchinbrook on which Steller sea lions were seen. The hatched area indicates the area occupied by Steller sea lions.

2) Seal Rocks: A series of small rocks around a large central island in the open ocean. No vegetation is present on the island, and a large part of the shore of the main island consists of boulders (Fig. 3).
3) Wooded Islands: A group of open coast islands, of which one large island is frequented by Steller sea lions. The island is partially covered with vegetation. Part of the coast of the island consists of a boulder beach which is not inhabited by sea lions (Fig. 4).
4) The Needle: A group of rocks in the middle of Prince William Sound without vegetation. The central high rock carries a large colony of Black-legged Kittiwakes, *Rissa tridactyla* (Fig. 5).

Behaviour

Behavioural observations were done at two different types of colonies; the Needle, a protected colony, and Seal Rocks, an unsheltered open ocean colony. The boat, which served as an observation platform, was anchored 50–100 m from the colonies. Because no females with conspicuous markings were present, well-identifiable territorial (mature) bulls were selected as study animals (Fig. 6). At each colony the behaviour of 7 territorial bulls was recorded each minute during 3 well-spaced 10 minute periods per hour. Each minute the behaviour was scored in one of the following categories: Resting (completely horizontal, eyes closed); Observant (no movement, eyes open, often in an upright position); Comfort (stretching, yawning, scratching); Locomotion without interaction with other members of the colony; Locomotion with interaction; Interaction without locomotion; Barking without locomotion; Fighting with other males; Chasing other males; In the water; Not visible. These categories were selected in such a way that they did not overlap. Because resting and observant behaviour are similar, the two categories are taken together and redefined as *rest*. Comfort and locomotion without interaction with other members of the colony were hardly ever recorded, and are taken together and redefined as *non-interactive behaviour*. Locomotion with interaction, interaction without locomotion, barking without locomotion, fighting with other males and chasing other males were also very little recorded and therefore taken as a group and redefined as *interactive (=social) behaviour*).

At the Needle it was possible to record for 18 hours on June 6 (06.00–24.00 hrs) and for 18.6 hrs on June 7 (05.20–24.00 hrs). At Seal Rocks the animals were observed for 9 hours on June 10 (14.00–23.00 hrs). Weather conditions were fairly equal during all observation days, there being no precipitation and an average temperature of around 14°C.

Photography

To record the size changes of the territories on the Needle due to the tides, photographs were taken of the territories of the studied bulls at high and low tide (Figs. 7 and 8).

Aerial photographic surveys were carried out twice over the 4 study sites. The first time on 12 June 1988 between 16.00 and 18.00 hrs (at half-tide). On that occasion, slides of the colonies were taken for the following purposes:
a) to draw maps of the study sites.
b) to make an accurate count of the number of animals at the colonies,
c) to determine a rough age composition and,
d) to determine the location of the pupping areas and the number of pups.

The second survey was done on 23 July, 1988 between 15.45 and 18.00 hrs (also at half-tide). This survey had the following objectives:
a) to determine the total number of animals in the colonies
b) to determine a rough age composition, and
c) to determine the number of pups still ashore.

Weather conditions were fairly equal during both survey days. There was no precipitation and moderate sunshine.

Afterwards, the slides from the surveys were projected on white sheets of paper, and individual animals were counted by marking them with pencil. This way a fairly accurate count could be made with a minimum of errors. Non-territorial bulls are defined as bulls with other bulls in their immediate surrounding and without a group of females around them.

Figure 3. Seal Rocks. The numbers indicate the surveyed bulls. The hatched areas indicate areas occupied by Steller sea lions. The dotted area indicates the boulder (= pupping) area.

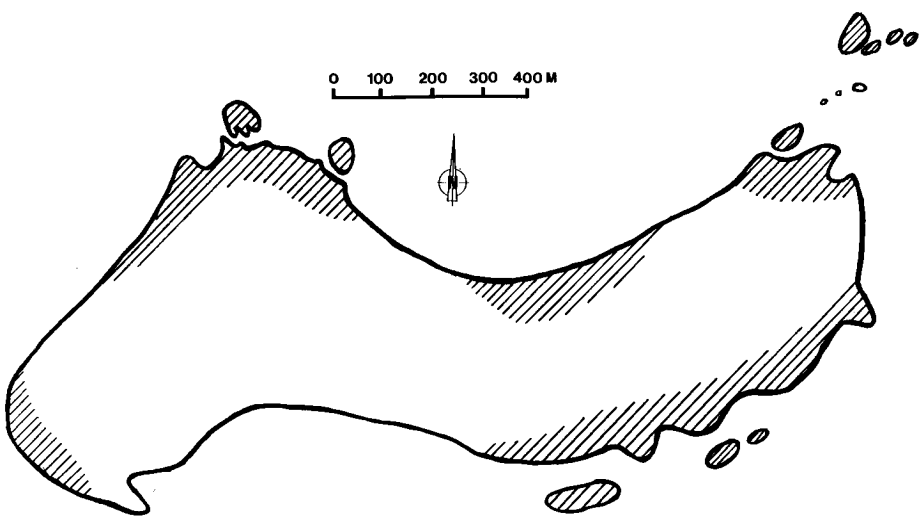

Figure 4. The Wooded Island on which Steller sea lions were seen. The hatched areas indicate areas occupied by Steller sea lions.

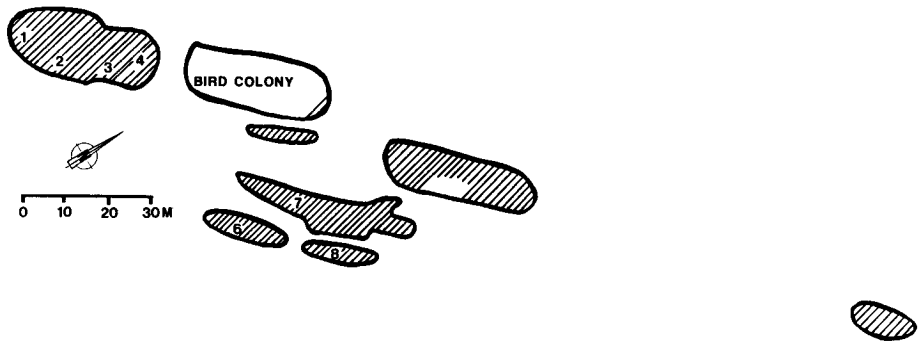

Figure 5. The Needle. The numbers indicate the surveyed bulls. The hatched areas indicate areas occupied by Steller sea lions.

Figure 6. Three territorial bulls and accompanying females on the western part of the Needle.

Results

Distribution and abundance

The results of the boat and aerial surveys are shown in Table 1. In some cases it was impossible to get detailed information, because of the state of the sea, the quality of the photographs, or due to problems in distinguishing territorial from non-territorial bulls. These cases are either indicated with dashes, or described in words.

Cape Hinchinbrook: The count from the boat survey and from the aerial survey the next day (both at half-tide) are quite similar. This match is in part due to the small size of the rocks, so that a boat survey may produce a reliable picture. The data from the second aerial survey indicate a strong increase in number of animals.

Seal Rocks: The count from the boat (at high tide) and the aerial count 2 days later (at half-tide) differ strongly. The two aerial surveys, which had a 6 week

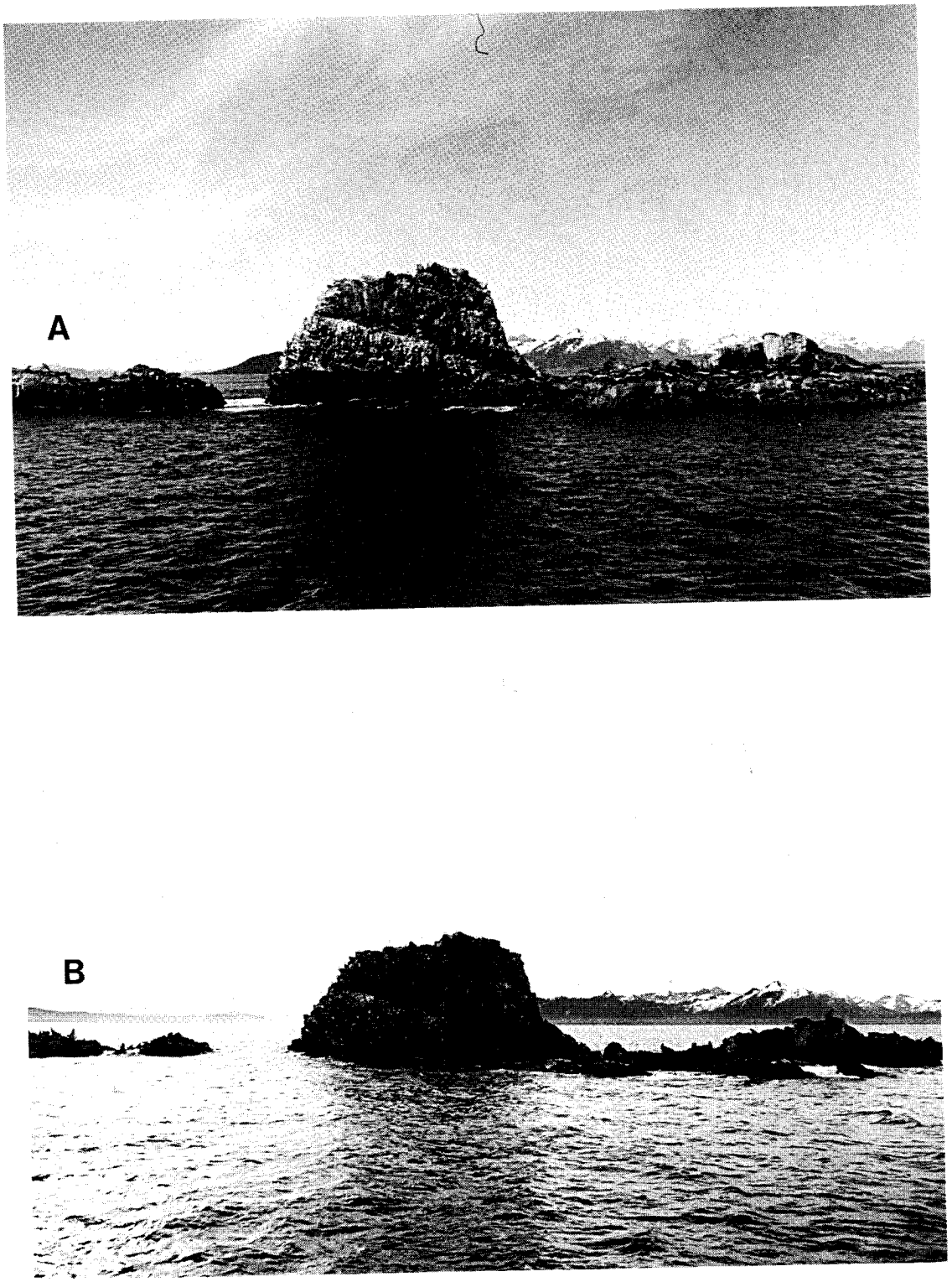

Figure 7. The Needle during low tide (A) and during high tide (B).

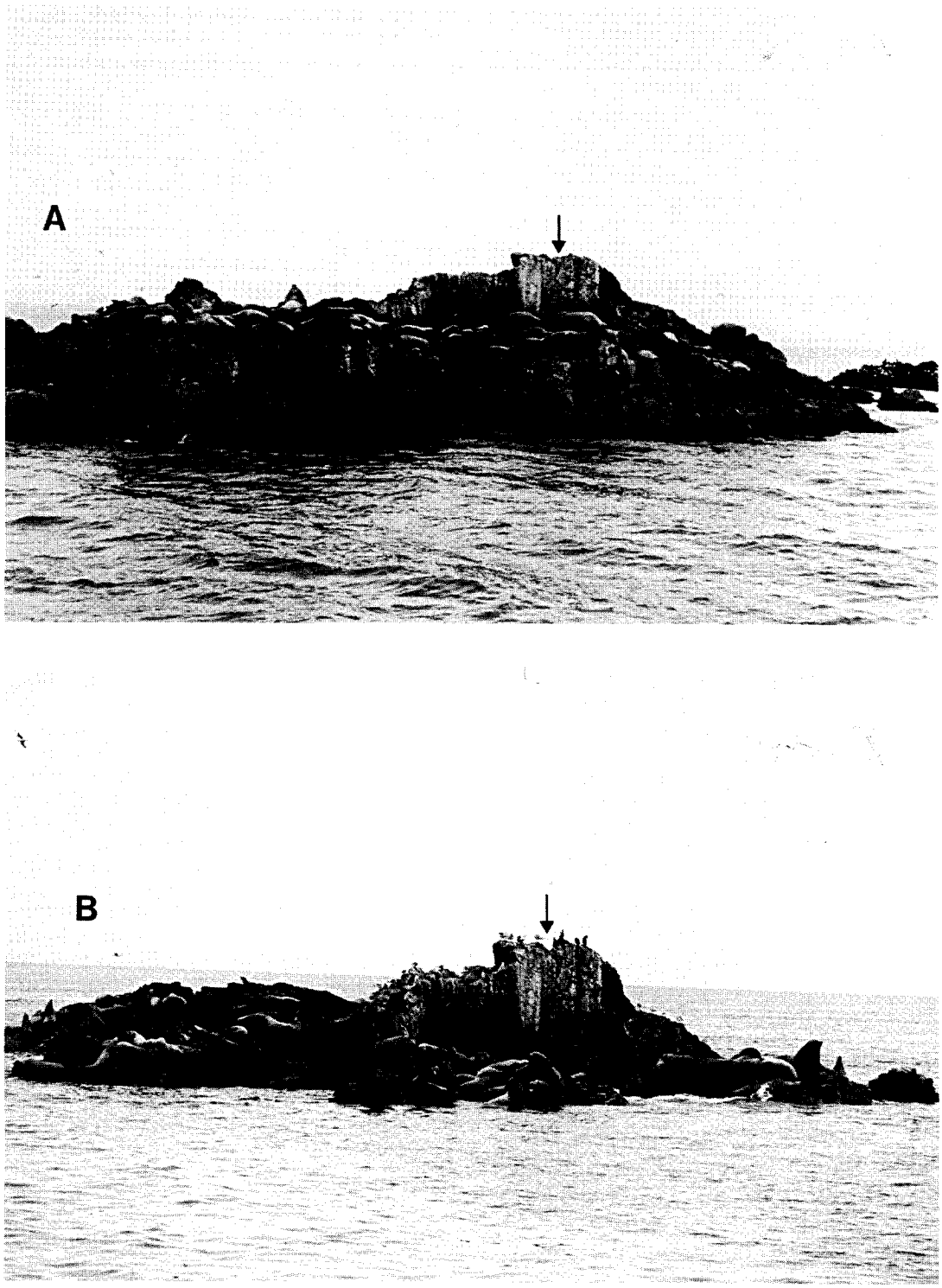

Figure 8. The eastern rock of the Needle at low tide (A) and at high tide (B). Note the reduction of the rock surface above the water (the left-hand rock is the territory of animal no. 8).

Table 1. The number of Steller sea lions on the 4 study locations recorded through boat surveys or by aerial surveys. Pups are not included in the total number of animals

(1) Place: Cape Hinchinbrook				
Date	11-06-88	12-06-88	23-07-88	
Time	10.00	16.15	16.15	
Tide	half	half	half	
Survey type	Boat	Aerial	Aerial	
Total no. of animals	60	70	110	
No. of territorial bulls	0	0	0	
No. of pups	0	0	0	
No. of non-territ. bulls	—	10	20	
(2) Place: Seal Rocks				
Date	10-06-88	12-06-88	23-07-88	
Time	13.00	16.30	16.30	
Tide	high	half	half	
Survey type	Boat	Aerial	Aerial	
Total no. of animals	1300	1839	1740	
No. of territorial bulls	—	—	Very few	
No. of pups	—	487	In tide pools	
No. of non-territ. bulls	—	—	Many	
(3) Place: Wooded Island				
Date	12-06-88	23-07-88		
Time	17.00	17.00		
Tide	half	half		
Survey type	Aerial	Aerial		
Total no. of animals	945	1221		
No. of territorial bulls	0	0		
No. of pups	0	0		
No. of non-territ. bulls	92	Many		
(4) Place: The Needle				
Date	05-06-88	08-06-88	12-06-88	23-07-88
Time	12.00	09.00	17.30	17.30
Tide	low	high	half	half
Survey type	Boat	Boat	Aerial	Aerial
Total no. of animals	466	615	421	950
No. of territorial bulls	15	15	15	15
No. of pups	0	0	0	0
No. of non-territ. bulls	3	1	5	65

interval, show a small decrease in number of animals hauled out. The aerial photographs of the boulder (=pupping) area had a very high quality, so pups could be counted well. Photographs of some of the other parts of this irregular colony had sometimes a poor quality so that only the number of animals could be counted, and no differentiation between sexes and territorial or non-territorial bulls could be made.

Wooded Island: More animals were seen on this island during the second aerial survey than during the first. The number of non-territorial bulls was (10% of the total population).

The Needle: The two counts from the boat show a large difference in number of animals hauled out. The first count was at low tide, and the second count at high tide. The number of territorial bulls remained constant (the animals seen in the surrounding of the colony were included in the counts). There were over twice as many animals present at the Needle during the second aerial survey than during the first survey.

Seal Island: No Steller sea lions were seen on this group of various sized islands and surrounding rocks in a protected area of Prince William Sound, although some animals were seen in the water around the Island during an aerial survey in mid July (the time of this survey is not available).

Behaviour at The Needle

The behaviour of 7 territorial males at the Needle is shown in Table 2. The males spent a large proportion of their time resting (average: 79% on June 6, and 73% on June 7) and most of the remaining time in the

Table 2. The proportions of the behaviours carried out by territorial bulls recorded on June 6 and June 7 at the Needle and on June 10 at Seal Rocks

	Rest (%)		In water (%)		Interactive behaviour (%)		Non-interactive behaviour (%)	
The Needle								
June	6	7	6	7	6	7	6	7
Animal no.								
1	75	81	13	8	11	10	2	1
2	90	75	5	17	3	5	2	3
3	89	87	4	3	4	8	3	2
4	73	82	21	12	4	5	2	1
6	68	44	26	52	5	3	1	1
7	83	73	8	19	8	7	1	1
8	76	72	13	8	8	18	3	2
Seal Rocks								
June	10		10		10		10	
Animal no.								
1	49		48		2		1	
2	73		25		1		1	
3	81		12		4		3	
4	72		15		11		2	
5	81		12		5		2	
6	59		30		8		3	
7	73		18		7		2	

water (average: 13% on June 6, and 17% on June 7). When territorial bulls go into the water they usually show one of two types of behaviour: either they float vertically in the water with their nose and eyes just above the water, or they float horizontally with one pectoral flipper sticking up out of the water. In both situations the animals watch their territory constantly, and rush towards it when an intruder approaches the area. One animal (no. 6 in Fig. 5) spent a relatively small proportion of his time resting, and a large proportion of time in the water. This was caused by the fact that his rock dissappeared completely at high tide and no other unoccupied areas were available. For most animals there were only minor differences in behaviour between the two observation days. Animal no. 6 spent less time resting on June 7 than on the previous day. This was partially due to the fact that the relatively high low tide on June 7 combined with increased ocean swell, made his rock accessible for only a short time. The territory of this animal can be considered of marginal quality. Animal no. 8 had a relatively high proportion of interactive behaviour on June 7. This was due to a copulation. During this study 4 copulations were observed at the Needle and Seal Rocks. They lasted 22, 14, 30 and 22 min., and all occurred in the tidal area to which the bulls had descended and where they were splashed by sprays of water.

None of the behaviours observed on land had a detectable daily cycle. However, the time of entering and leaving the water fluctuated in synchrony with the tide. When the tide was low the animals did not go into the water frequently. This cyclic bathing was very clear for all 7 animals on June 6 (Fig. 9A). The cycle was also apparent for 6 to the 7 animals the next day (Fig. 9B). Only animal no. 2 (Fig. 5) went into the water at low tide.

Behaviour at Seal Rocks

During the observation period on June 10 the studied territorial bulls at Seal Rocks spent on average 70% resting and 23% in the water (Table 2). These values deviate a little from the values recorded at the Needle. Some of the differences are probably due to the fact that the observations at the Needle were done during only a small part of the tidal cycle. Again, very little interactive and non-interactive behaviour was recorded. Most of the bulls at this colony also went into the water at half-tide (Fig. 10). Animals 1, 2, and 6 (Fig. 3) occupied territories that disappeared at high tide, and therefore spent a relatively long time in the water.

Discussion and Conclusions

Distribution and abundance

Seal Rocks: The mismatch between the count from the boat (at high tide) and the aerial count 2 days

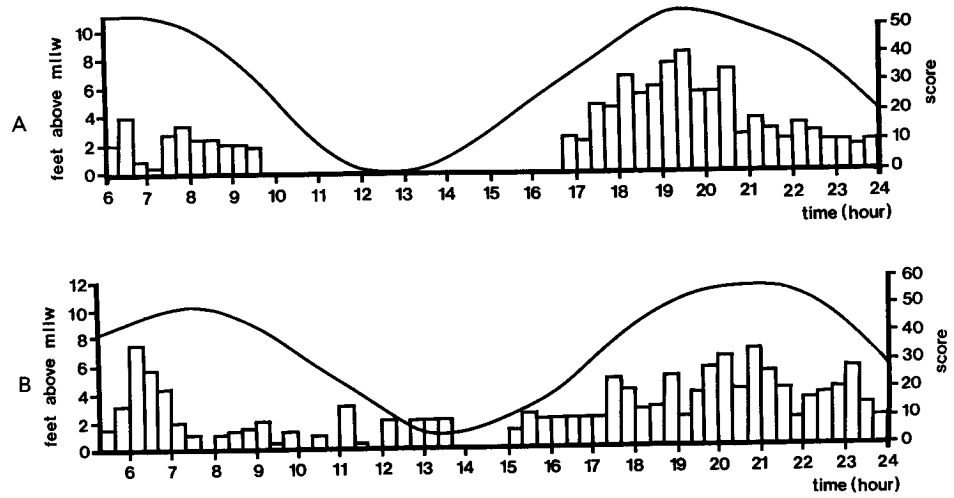

Figure 9. The tidal cycle (Marine Trade Publication, 1988) and total score of being in the water of the 7 studied bulls at the Needle on June 6 (A) and on June 7 (B). (maximum score per 10 minute interval: 10 (observations) × 7 (animals) = 70).

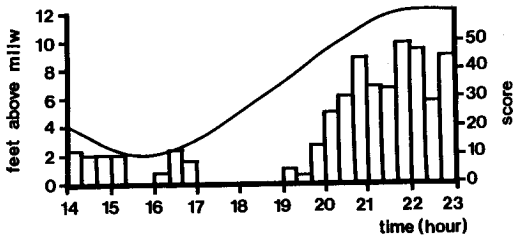

Figure 10. The tidal cycle (Marine Trade Publication, 1988) and total score of being in the water of the 7 studied bulls at Seal Rocks on June 10. (maximum score per 10 minute interval: 10 (observations) × 7 (animals) = 70).

later (also at half-tide) could be partially due to the inaccuracy of the boat count due to the ocean swell, and the rough surface of the rocks. When counting from a boat, some animals can be hidden in cracks, behind rocks, and/or behind each other. However, the main cause is probably the difference in numbers of animals present due to the tide.

The fact that many fresh placentas were visible amongst the pups on the first aerial survey (12 June 1988) indicates that possibly more pups were born later that month. Probably only few were born after the end of June, because no placentas were visible, and no pups were visible ashore, during the second aerial survey (23 July 1988). On this latter day most pups were seen in the tidal areas, which made an accurate count impossible. Most pups go into the water 2 weeks after birth (Gentry, 1970). Previous surveys recorded 545 (1978), 491 (1979) and 799 (1984) pups at Seal Rocks (Hoover, 1988). The number of pups seen in present study (487: when probably not all pups had been born) is within the range of these observations.

Wooded island: This colony is considered a haulout area because of the high percentage of non-territorial bulls and the lack of pups.

The Needle: In the two counts from the boat there was a large difference in number of animals hauled out. This difference is probably due to migration, or difference in numbers of animals out to sea feeding, since the same survey technique was used. On the second aerial survey more animals were seen than in the first aerial survey. Since this count was done during the same stage of the tide, this increase can only be explained by migration from other areas. The number of non-territorial bulls had increased greatly during the second aerial survey. All these newly arrived bulls were grouped together on the most easterly rock of the study site.

The total number of animals (including pups) hauled out on the studied areas in Prince William Sound during the first aerial survey, was 3762. The total number of animals during the second aerial survey was 4021. The difference between these counts can partially by explained by the fact that a number of animals are always in the water, so that these counts are underestimates for the total number of animals present in the survey area. Also there may be migration between the sites of the present study and sites on Cape Elrington (south-west entrance of Prince William Sound) and Cape St. Elias (on Kayak Island, 150 km south-east of Prince William Sound). Steller sea lions can migrate over long distances. On June 5, 1988 a branded female was seen at the Needle.

This animal was born and branded in 1987 at Kodiak Island, 350 km from the Needle (Wynne, 1988).

Reproduction

The data in Table 1 seem to indicate that, at least in 1988, 3 of the 4 study sites are haulout areas without births (The Needle, Cape Hinchinbrook and Wooded Island). Seal Rocks is the main rookery where pups are born. After the delivery of the pup, copulation occurs. All pups seen in the rookery were located on the boulder beaches of the central island (Fig. 3). Because the island is narrow at this area, it looks like one boulder area, but because few sea lions gather in a strip in the middle, the animals seem to consider this area as two separate beaches.

The Needle is considered a haulout area, because no pups were seen during the present study. However, copulations were seen at this colony. This suggests that the females may copulate at different colonies, but will deliver their calves only at specific rookeries. Maybe females have their first ovulation (and copulation) at such haulout areas.

Aerial survey technique

This study showed that it is very difficult to determine the age structure of a colony of Steller sea lions from aerial surveys. Better information on this aspect can be obtained from boat surveys. The number of animals present at a colony can best be derived from aerial photographical surveys. In order to gain the best information from an aerial photographic survey, the following guide-lines should be taken into consideration:

1) Weather conditions during the survey have to be good (i.e. no rain, otherwise the animals are difficult to distinguish from the rocks, and not too much sun, otherwise the animals create shadows in which pups cannot be seen).

2) One should fly around half-tide or at low tide in order to see a maximum number of animals hauled out.

3) First, a high altitude photograph of the entire colony should be taken at a perpendicular angle, showing the relative position of the surrounding rocky islands.

4) When taking photographs of parts of the island at low altitude for more details, the pictures should be taken in an orderly sequence (one should fly in one direction: clock wise or anti-clockwise) in order to be able to determine the location of the photographs on the colony.

5) The low altitude (detailed) photographs should be taken at a perpendicular angle so that all animals are visible, and no pups are hidden behind adult animals. This could also be accomplished by flying at a high altitude with a longer camera lens.

6) Colour slides are absolutely necessary in order to distinguish pups from rocks.

7) One should not fly too high, since the pups are difficult to distinguish from the surrounding rocks and boulders. On the other hand, the airplane should not fly too low (less than 165 metres), otherwise the animals will be disturbed and flee towards the water. We do not recommend 'spook' pup counts (where adults are driven from rookeries and the remaining pups are counted) as used in some previous surveys, because many pups are run over when adults flee towards the water (Hoover, 1988).

Behaviour at the Needle and at Seal Rocks

The period that the mature Steller sea lion bulls spend in the water is influenced by the tide, not only for those whose territories become flooded at high tide, but also for animals who occupy an area above the high tide line. When the territorial bulls go into the water they stay at the edge of their rock and do not go further out to feed. Also they do not swim much, but float as if they go into the water to cool down. Rand (1959) observed a similar behaviour in South African fur seal bulls (*Arctocephalus pusillus*). No attempt has been made in the present study to answer the question of why they enter the water mostly at high tide? One or more of the following aspects could be relevant:

a) they then have a relatively good view of their territory from the water,

b) if an intruder enters their territory, they can return faster than at low tide when the slippery aquatic vegetation is uncovered,

c) because it is more difficult to fight against an intruder from a low position than on an equal level,

d) because this behaviour developed during their youth. When they reach reproductive age, the males often occupy rocks at the perimeter of the favourable breeding grounds for several years. These rocks usually flood at high tide.

The portion of the rocks that is exposed decreased as the tide rose. This caused often crowding on the rocks and eventually some areas disappeared completely under water. At high tide, most of the studied territorial bulls were in the water next to their territories. Although not quantified, this pattern was also valid, to some degree, for the adult females and young animals. However, these animals did not stay around the colony. They probably went out feeding. The physical geography of a colony site may well also influence the degree to which animals exhibit the tidal-influenced haulout behaviour observed at the Needle and Seal Rocks. This tidal-influenced haulout behaviour may be only seasonal or regional, because Stack (1981) noticed no tidal height effect on the number of Steller sea lions hauled out at Klamath Cove, California between April and June.

The tidal influence on haulout behaviour has only been documented in few other pinnipeds: in Harbour seals (*Phoca vitulina concolor*) in Canada (Fisher,

1952; Venables & Venables, 1955; Bishop, 1967; Terhune & Almon, 1983 and Pauli & Terhune, 1987), and in Grey seals (*Halichoerus grypus*) by Cameron (1970).

Different counts during the present study yielded varying numbers of animals present at the study sites. The behavioural data show that in this geographical area, and at this time of year, the haulout pattern of Steller sea lions is strongly influenced by the tide. In future aerial surveys this phenomenon should be taken into consideration, especially when counts from aerial surveys from different years are compared and used for the design of a management plan for this species.

Acknowledgements

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