Cohnstaedt

HAUL-OUT AREA USEAGE BY HARBOR SEALS (*PHOCA VITULINA*) AT THE NORTH COVE OF CAPE ARAGO, OREGON

by

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A THESIS

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Approved: Janet Hodder
Dr. Janet Hodder

Harbor seals were observed on 70 occasions from 7 April to 10 August, 2001, at the North Cove, Cape Arago, Oregon, to determine if the harbor seals used different haul-out zones within the haul-out area during different life history stages. This study identified sex and age as the most important factors influencing the selection of haul-out zones. A haul-out pattern was observed on days when both low tides occurred during daylight hours: the number of animals hauled-out during a morning low tide was fewer than those during the afternoon low tide regardless of weather conditions.

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I wish to thank Professor Janet Hodder for all her guidance and patience as I learned the process. I really would never have been able to finish this thesis or learned so much about the process without her efforts. I would also like to thank Professor Alan Shanks for his time and help with my presentations. Professor Bishop who always helped me through all the problems I encountered during my four years at the Honors College. Further thanks must go to all the people at OIMB for their help, Doctor Pete Zani for his help with my statistics and my wonderful roommates who dealt with me through this process.

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Introduction

The greatest difficulty encountered when studying most marine mammals is our inability to observe them in their natural habitat. Pinnipedia (seals and sea lions), however, spend as much time out of the water as they do in it which provides us with an opportunity for observation. The harbor seal, *Phoca vitulina richardsi* (Gray 1864), spends on average 44% of its time out of the water (Sullivan 1979) making it easily observable for long periods.

Harbor seals are common marine mammals with an estimated eastern Pacific population of 200,000 (Seaworld 1999). Harbor seals are found in temperate and sub-arctic waters of the Northern Hemisphere from Alaska to Baja, California (Reeves et al. 1992). Approximately 10,000 harbor seals live in the coastal waters of Oregon (Brown 1997). They feed close to shore (Iverson et al. 1997) and are found along coastlines and estuaries in rarely disturbed areas near regions of high fish abundance.

The majority of the harbor seals feed during the evening and haul-out during the day (Boulva and McLaren 1979; Thompson et. al. 1989). A seal is considered hauled-out if it leaves the water and lies on a solid substrate. Seals haul-out because of reproductive and survival needs such as skin cell maintenance[1], thermoregulation and predator avoidance.

Harbor seals have a seasonal reproductive behavior, causing seal haul-out numbers to fluctuate (Graybill 1981; Wilson 1993). On the Oregon coast, *P. vitulina* give birth in late April and the pups nurse for about four weeks before they are weaned in June. Seals replace their fur or molt in early August (Fisher 1952), and copulate in

[1] Seals are unable to regenerate skin cells in their flippers if the water temperature is less than 17° C (Feltz and Fey 1966). The seals must haul-out for routine cell maintenance.

Life History Stage affected	Factors	Specifics
Pup	Survival	Mother is the food source
Juvenile and Adult	Survival	Food availability (Bartholomew 1970)
		Predator avoidance (Terhune 1985, Dasilva and Terhune 1988)
	Reproductive	Pupping
		Nursing
		Copulation
		Mate selection (Renouf and Larson 1986)
All ages	Body maintenance	Molting (Johnson and Johnson 1979)
		Skin cell maintenance (Feltz and Fay 1966)
		Thermoregulation
		Energy conservation (Schneider et al. 1980)
	Environmental	Tide height
		Storms
		Temperature (Krieber and Barrette 1984, Watts 1992)
		Time of day (Clambokidis et al. 1979)
		Wave action (Cite or erase)
	Disturbance	Humans (Brown 1981)

Table 1. Factors and disturbances that affect harbor seal haul-out.

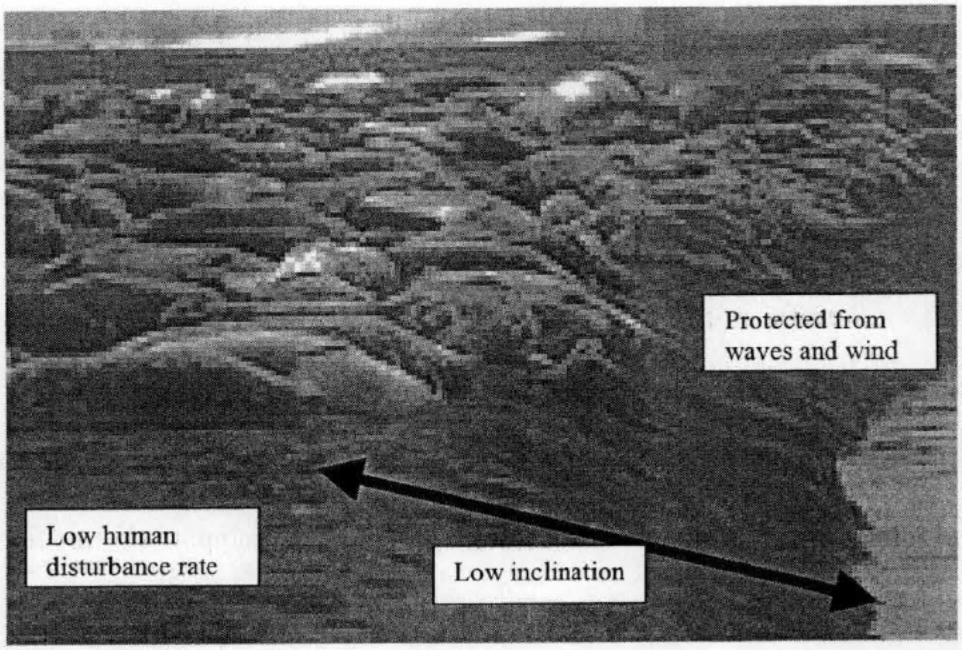


Figure 1. Seal haul-out considerations

September or October (Scheffer and Slipp 1944; Fisher 1952). The implantation of the fertilized egg is delayed for two months (King 1991) so the seals are born during the spring when food abundance and weather conditions are more favorable. During each of the life history stages (pupping, nursing, weaning, molting, and mating), the seal's biotic and abiotic needs change causing the seals to change the amount of time spent being in the water (swimming or feeding) and out of the water (hauled-out).

Two reasons harbor seals haul-out during the non-reproductive portion of their life cycle are personal upkeep like skin cell maintenance (Feltz and Fay 1966) and molting (Johnson and Johnson 1979). Haul-out time is further regulated by environmental pressures such as thermoregulation, energy conservation (Schneider et al. 1980), food availability (Bartholomew 1970), and predator avoidance (Terhune 1985; Dasilva and Terhune 1988). Table 1 contains a complete list of factors affecting haul-out. Reproductive behavior also contributes to the fluctuating haul-out numbers. Male seals perform underwater acoustic displays to attract a mate (Renouf and Lawson 1986) which limits their time on land. Pupping and nursing increases the amount of time females haul-out.

Several other factors affect the number of seals hauled-out in an area. They include environmental factors like tide height, storms, temperature, and time of day (Stewart 1984). Human disturbance is another common factor that negatively affects haul-out numbers (Brown 1981). Seal haul-outs are generally found in areas sheltered from weather and human disturbance (Fig 1).

Harbor seals haul-out on a variety of substrates including sand and mud bars, intertidal rocks and reefs, ice, beaches and manmade floats. The haul-out must have a low incline and easy access to open water because on land harbor seals move by dorsal ventral undulation, limiting their mobility. The availability of haul-outs is negatively affected by tide height, which limits the potential amount of haul-out substrate in coastal regions of high variation between tides. The greatest number of seals haul-out during low tide (Everitt and Braham 1980; Schneider and Payne 1983) and in the mid-afternoon (Stewart 1984).

Harbor seals exhibit high haul-out site fidelity (Thompson et al. 1989; Yochem et al. 1987; Allen 1988), but within a haul-out site they partition the habitat at certain times of the year based on a number of factors. Male groups and mother-pup groups separate within a haul-out area (Knudtson 1975; Slater and Markowitz 1983). Haul-out area partitions and site fidelity can be altered by human activity (Pauli and Terhune 1987) and continual disturbance can cause abandonment of a haul-out site (Allen 1991).

Past year-round population abundance surveys conducted at Cape Arago observed seasonal fluctuations in seal haul-out numbers. (Graybill 1981; Wilson 1993). In these studies the fluctuations were attributed to fish abundance and not seal migrations because harbor seals, as a group, are considered non-migratory animals (Scheffer and Slipp 1944; Paulbitski and Maguire 1972; Rosenthal 1968; Wilson 1993). Seals are assumed to haul-out more frequently when an increase in fish reduces their foraging time (Graybill 1981).

If seals are partitioning their haul-out area to create male groups and nurseries, it is probable that the seals will change their haul-out patterns within the area according to life history stage and possibly to compensate for the changing seasonal conditions. Brown and Mate (1982) found that "harbor seal [movements] were seemingly related to the use of a particular area specifically preferred by harbor seals for feeding, for birth and care of young, or for both." If seal haul out numbers are fluctuating then is seal usage in certain areas fluctuating as well? This finding would imply that seals use different areas more than others at different times. The goals of this study were to 1) look for differential seasonal haul-out usage by seals at North Cove, Cape Arago, Oregon, and 2) look at the effects of life history stages, weather and tides on haul-out usage.

Materials and Methods

The study was conducted at the harbor seal haul-out at North Cove, Cape Arago (43° 18' N, 124° 24' W), on the southern Oregon coast, USA. This haul-out is the largest harbor seal haul-out area in Oregon and is designated as part of the Oregon Islands National Wildlife Refuge (Wilson 1993). The beach at the North Cove is closed to the public annually from 1 April to 30 June reducing the amount of human impact at the site.

During mean low tide, the North Cove of Cape Arago has approximately one square kilometer of potential haul-out area consisting of several wind exposed and protected rocky shelves, depending on the weather. The zones within the haul-out area (Figure 2) were defined by previous studies and by personal observation. Each zone has similar haul-out substrates, tidal elevation and proximity to the open ocean. The substrate consists of sand and cobble beaches on Shell Island (A), rock bench on Simpson's reef (B), rocky boulders on Volcano Island (C), and two large stretches of intertidal rock (D & E).

Between 7 April and 10 August, 2000, I made 70 counts of the number of harbor seals hauled-out at North Cove. I divided this time into three different periods representing events in the life history of the harbor seals: pre-pupping before 24 April, pupping between 24 April and 19 May, and post-pupping after 19 May, the peak of pupping. These periods were ascertained from past studies conducted at the Cape (Table 2), personal observation at the study site and by looking at the data I collected (Figure 3). I defined the time period from the start of the study until the first pup was born as pre-pupping. The pupping stage was defined as the time from the first pup until the number of animals and pups peaked, at which time the post-pupping period started.

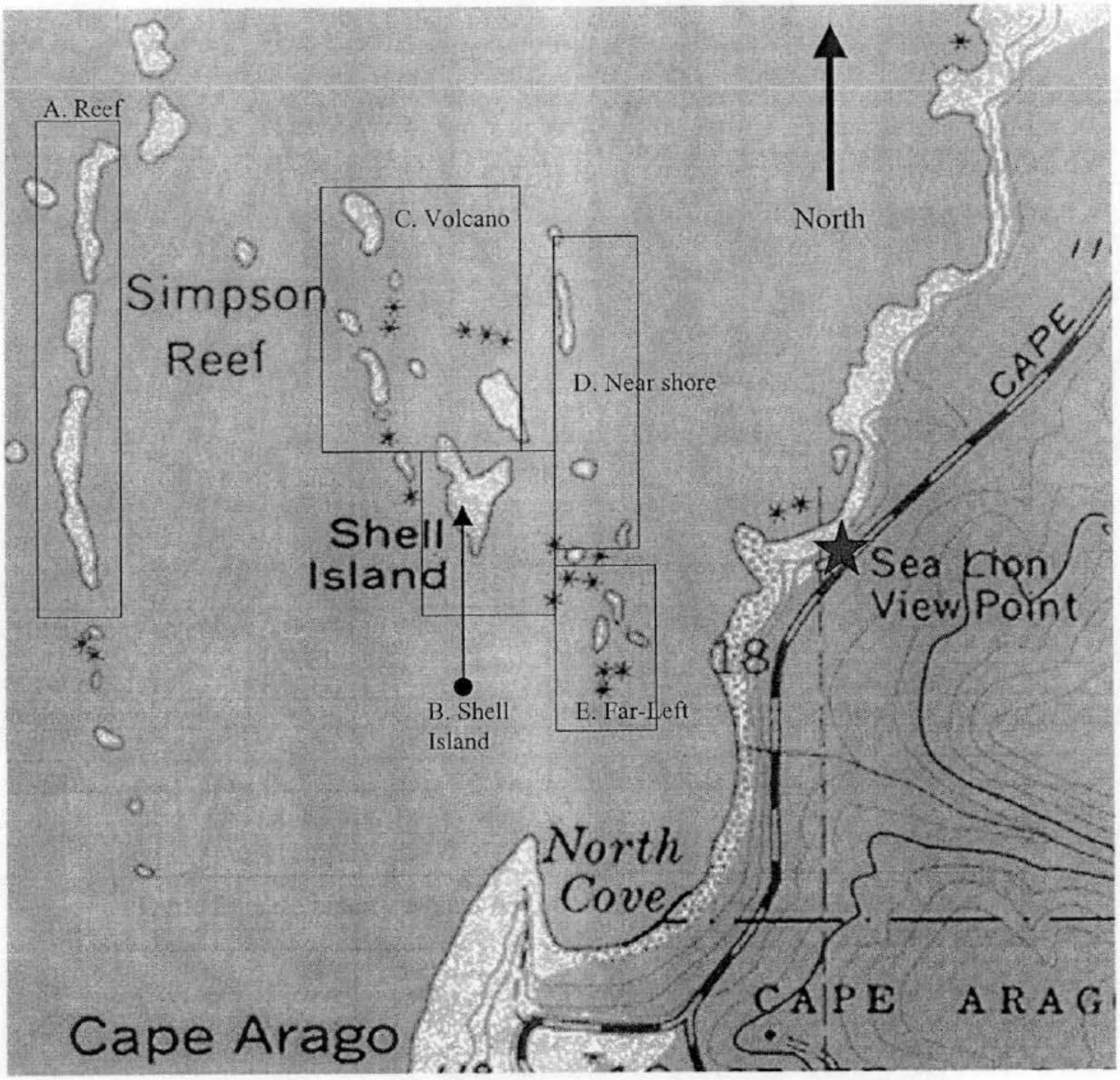
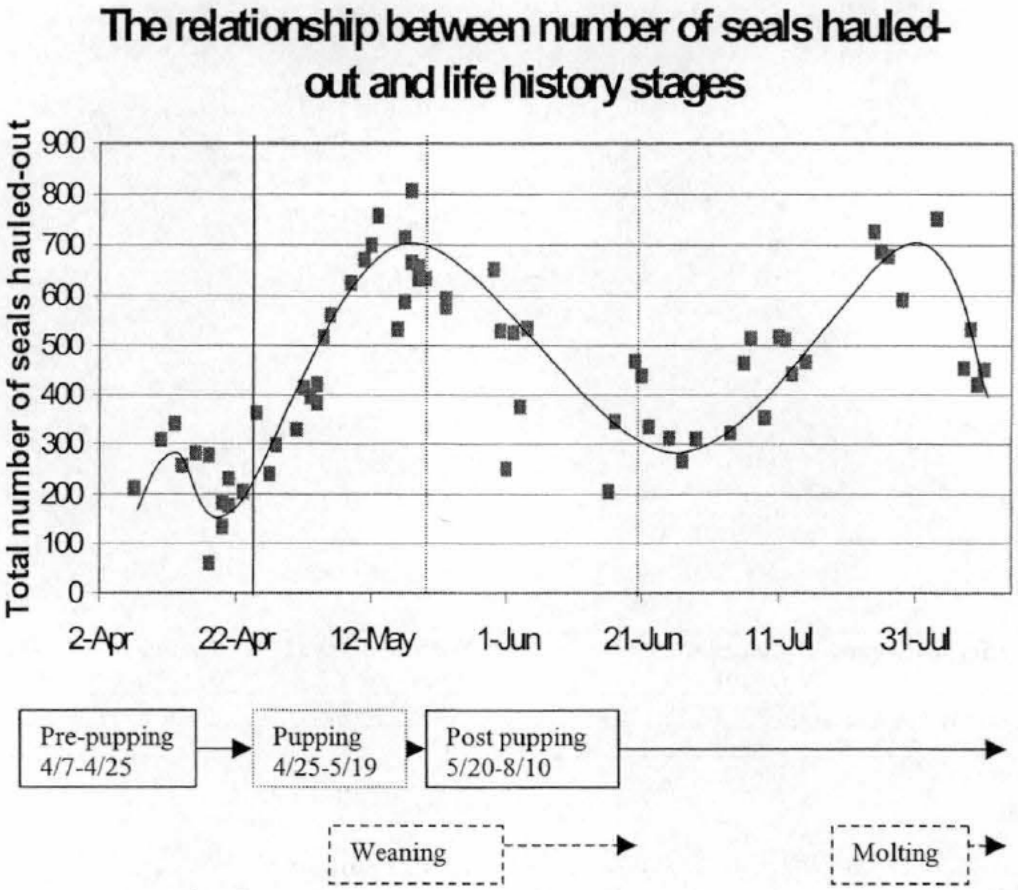


Figure 2. The zone divisions (A-E) in the North Cove of Cape Arago haul-out area.

Life history event	Cohnstaedt survey (2000)	Wilson survey (1992-1993)	Graybill survey (1981)
Start of pupping	April 25	April 15 and 12	Late April
Peak number of pups	May 19	May 27	May 17
Peak number of seals	July 25	July 14	July
Mating	N/A	September 3	September

Table 2. Life history events recorded for harbor seals at Cape Arago.



60-342 adults mean=227+/- 42 0 pups mean=0	137-645 adults mean=428+/-57 4-163 pups mean=86+/-18	154-622 adults mean=396+/-38 31-132 pups mean=81+/-11

Figure 4. The data points represent the actual counts and the best-fit line represents the seasonal fluctuations in seal numbers for each life history stage. The solid vertical lines indicate observable events and vertical dotted lines indicate estimated events.

Previous studies have shown that the maximum number of seals are hauled out at low tides (Everitt and Brahm 1980; Schneider and Payne 1983). For this reason, when weather conditions permitted, I counted the number of pups and adults within an hour of low tide. Since the daily low tides occurred at different times and heights the variations in tide height and time of day were incorporated into the haul-out totals. The counts were conducted only on days and at times when sufficient light was available to distinguish individual seals and their sizes to ensure that all hauled-out animals were counted. I considered a seal hauled-out if a part of its body was out of the water lying on a substrate.

To determine if there were differences between the number of seals hauled-out during the morning low tides and the number hauled-out during the afternoon low tides I counted both tides on nine days during the survey. Not every day allowed for two counts per day because two low tides during daylight hours on the same day happens rarely because of the 12 hour and 25 minute tide cycle. Other factors that limited twice daily counts were fog or sun glare, particularly during July and August.

Counts were made with a Nikkon variable zoom spotting scope (x15-x45) from approximately 25 meters above sea level at a lookout maintained by the State Parks service. I scanned with the spotting scope from left to right and counted the number of seals and pups with separate hand counters. The small sexual dimorphism in size between males (1.4-1.9 m in length and 140 kg in weight) and females (1.2-1.7 m. and 80 kg in weight) (Reeves et al. 1992) did not allow me to distinguish sexes. I could not tell if male groups existed. But female groups consisting of mother and pup pairs were distinguished. A pup was considered anything less than half the size of an adult.

The height of the low tide was obtained from tide charts. Caro3, a weather station approximately 1.6 km from the cove run by the National Data Buoy Center (NDBC), allowed for accurate measurements of air temperature and wind speed and direction. The wind and wave directions changed over the course of the study creating different windward and leeward sides of the zone depending on the weather during each observation.

Four marine mammals haul-out at Cape Arago: harbor seals (*Phoca vitulina*), California sea lions (*Zalophus californianus*), Northern or Stellar sea lions (*Eumetopias jubatus*) and Northern elephant seals (*Mirounga angustirostris*). Though the animals have been known to haul-out together, the larger pinnipeds likely out-compete the harbor seals for haul-out places, creating interspecific competition (Sullivan 1980) within zones. Of these animals only the harbor seals are present in consistent numbers throughout the year. The number of other pinnipeds fluctuates throughout the year at Cape Arago with the greatest number of animals occurring during the late summer due to the presence of migrating California sea lions. To get a rough idea of possible interspecific competition during pupping I estimated the number of sea lions hauled-out.

I used analysis of variance (ANOVA) to analyze the data and compare the haul-out zone usage during the three periods (pre-pupping, pupping and post-pupping). To look for haul-out patterns related to environmental conditions, I compared the percentage of seals on the windward and waveward sides compared to those on the lee side of the haul-out area. Chi-squared tests were conducted to determine if a diurnal haul-out imbalance was present during the double low tide counts made on the same day.

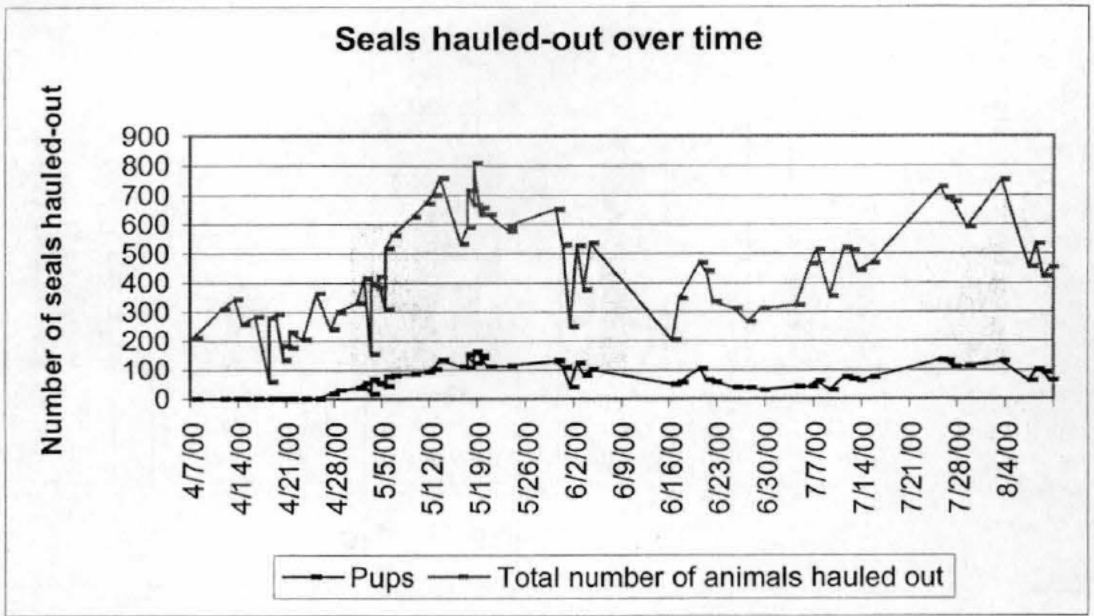


Figure 4. The daily number of adults and pups hauled-out during the five-month observation period.

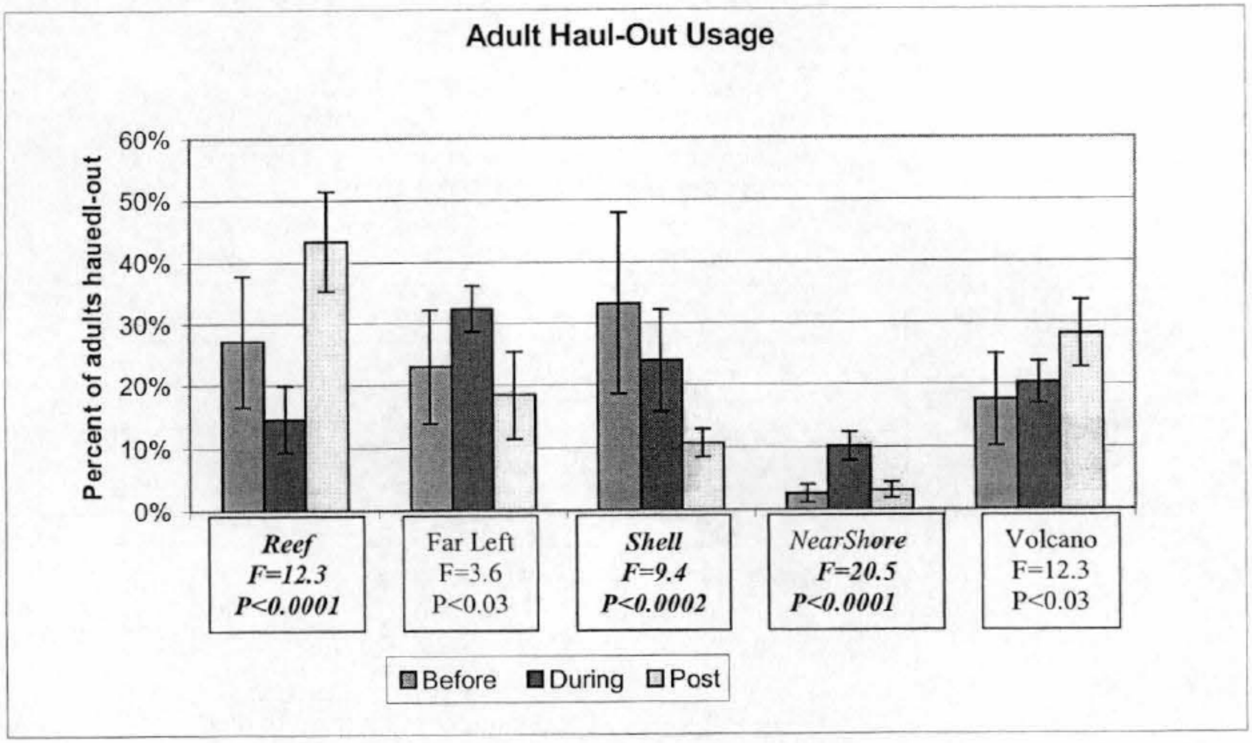


Figure 5. The mean percent of seals +/- two standard errors hauled-out during each life history stage for each zone. The ***italicized*** lettered zones had significant usage changes. The F-value and P-value for ANOVA are under each zone name.

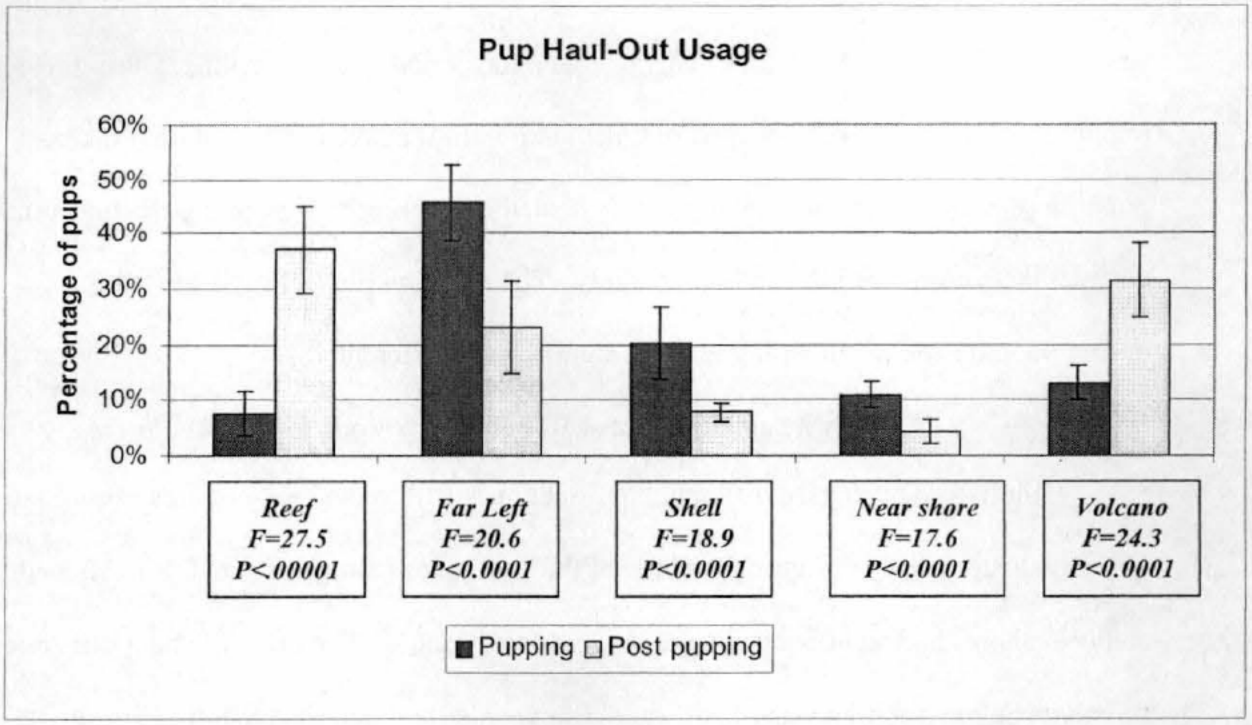


Figure 6. The mean number of pups +/- two standard errors during each life history stage for each zone. The ***italicized*** zones had significant usage changes. The F-value and P-value for ANOVA are under each zone name.

Results

Fluctuations in seal haul-out numbers

From 7 April to 10 August the number of seals at the Cape Arago haul-out area fluctuated daily (Figure 3). The daily haul-out pattern numbers can be correlated to the life history stages during these periods (Figure 4). Low seal haul-out numbers before the first pup was born (25 April 2000) characterized the period of pre-pupping. During pupping the number of seals hauled-out increased until it peaked, which started the post-pupping season. The mean number of seals hauled-out during post-pupping fluctuated in a wave-like pattern until the end of my study. The mean number of seals hauled-out during pupping and postpupping was not significantly different.

Mean number of seals between periods

Adults and pups used different haul-out zones within the haul-out area during the three life history stages (Figure 5). Three of the five zones (Simpson's reef, Shell Island, and near shore) had significant change in zone use by adults. The principle haul-out zone for adults before pupping was Shell Island, Simpson's Reef and the far-left. During pupping adult seals reduced their use of these two zones and hauled-out in higher numbers in the far-left and shore zones, although usage of the far-left zone, there was no statistical difference between life history stages due to the high variance during each stage. After pupping, adult seals significantly reduced their use of the Shore and Shell Island zones and increased their use of the Reef and the Volcano zones.

All five zones showed significant changes in pup haul-out use (Figure 6). During pupping, the pups used the far-left zone suggesting that this is an important area for the females to give birth. After pupping the percentage of pups using the far-left, Shell Island anf the shore zone decreased and the number of pups in the reef and volcano increased.

Twice daily harbor seal counts

Despite lower tides in the morning and similar environmental conditions harbor seals haul-out more often during mid-afternoon low tides than early morning low tides of the same day ($X^2 = 4014$, d.f.= 8, P<.0001) (Table 3). The contrast between the morning low tide counts compared to the number of seals hauled-out during the afternoon low tides on the same day indicates that the seals at Cape Arago may follow what the literature describes as a diurnal haul-out pattern. The precipitation, weather, wave direction, and air temperature during these counts were not significantly different. Furthermore, I observed no disturbances that disrupted the seals during either of the twice-daily low tide counts.

Wind/Wave influence on haul-out pattern

Wind and wave patterns had little effect on the seal haul-out behavior. The wind direction changed during the survey but the percentage of animals on the windward side (52%) was not different than those on the leeward side (49%) of the haul-out area. Likewise the pups followed the same non-significant pattern of 57% hauled-out on the windward side and 44% of the pups on the down wind side. The effect of waves on haul-out behavior was similar; despite changes in wave direction the percentage of seals hauled-out on the wave swept side of the haul-out area (51%) was not significantly different than those using the sheltered side of the haul-out area (48%). Similarly the percentage of pups hauled-out on the waveward side of the haul-out (58%) was not significantly different from those out of the breaking water (44%). The changing wind and wave direction did not cause the seals to change their zone usage.

	Number of seals hauled-out at low tides	
Date	Morning 6:49-9:09	Afternoon 17:38-20:03
4-18	60	278
4-20	134	182
4-28	176	230
5-3	154	396
5-4	383	421
5-5	308	517
5-18	588	715
5-19	666	808
5-23	633	657

Factors that remained constant

Tide height was higher in afternoon
Weather and precipitation were similar
Air temps were within 4 degrees but all below 13.9
Wave directions were same
No disturbances disrupted the seals.

Table 3. Comparison of morning and afternoon haul-out counts when two low tides occurred during daylight on the same day (X^2=4014, d.f.=8, P> 0.0001).

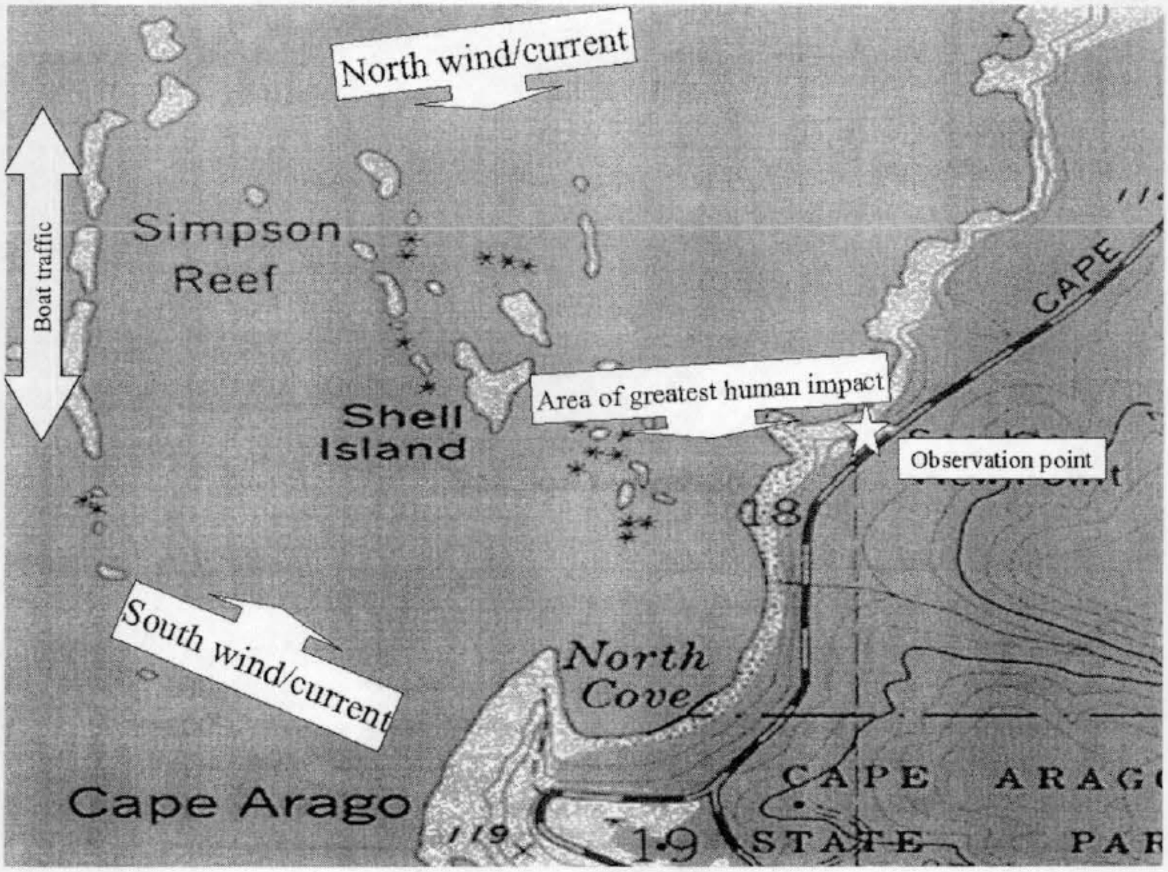


Figure 7. The Cape Arago haul-out with the areas of disturbance, observation point, and wind and wave directions.

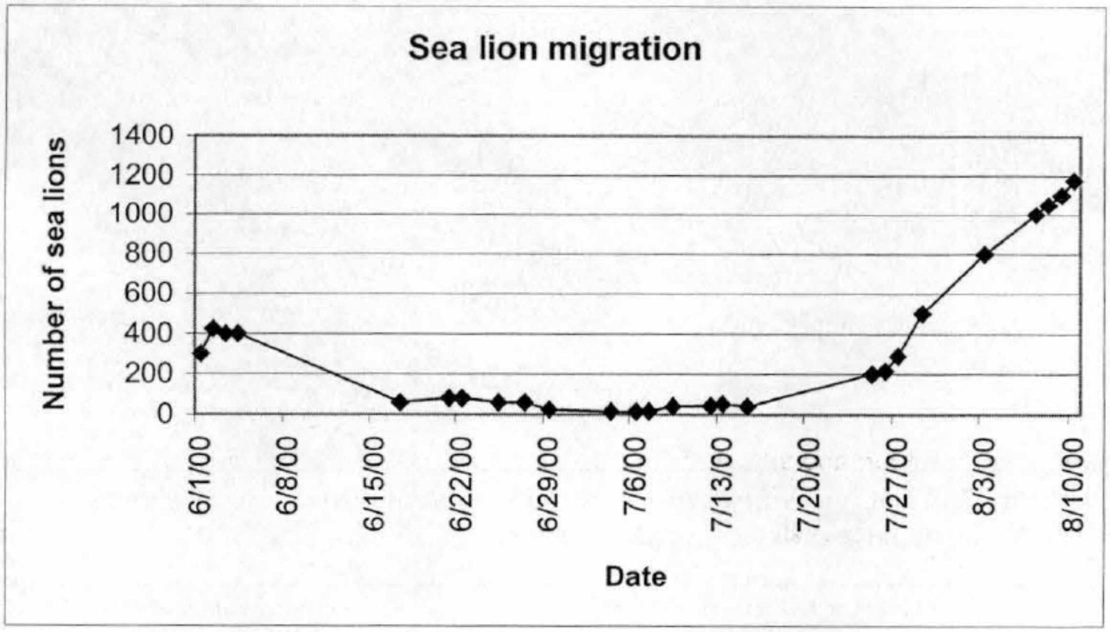


Figure 8. A combined estimate of the number of California and Stellar sea lions hauled-out at Cape Arago from 1 June to 10 August, 2000.

Disturbances

The principle disturbances affecting the number of seals hauled-out were people walking on the beach (four events), surfers on the north side of Shell Island (two events), and fishermen near the reef and the islands (four events) (Figure 7). The presence of people on the beach increased scanning behavior[2] but the seals did not abandon their haul-outs in the four events I witnessed. When surfers were present animals did not haul-out near them and the animals abandoned the near shore haul-outs if the surfers were between the seals and the open ocean. The fishermen behind Simpson's reef did not seem to affect the seals. When boats would stray within the reef the sea lions would start barking and the seals would increase their scanning behavior but few would leave the haul-outs.

Presence of other Pinnipeds

The number of sea lions, which could cause interspecific competition, fluctuated during my study from approximately 10 animals to 1200 animals (Figure 8). The number of sea lions was estimated during this survey and the observed seasonal numbers were consistent with those described by Mate (1973) and Graybill (1981). Sea lions were absent between 17 June and 15 July (Figure 8). When the sea lions were present they used the reef, Shell Island, the far-left and volcano zones and I routinely found sea lions and seals hauled-out in close proximity within these zones. I saw seals move out of the way of sea lions but I never observed a sea lion to walk on a seal, rather I observed a sea lion walk around a harbor seal pup. Additionally, I never saw a sea lion move for a harbor seal.

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[2] Scanning behavior is when a seal raises its head and looks around for predators. Scanning increases when the seals feel threatened.

Discussion

The changing haul-out zone usage by harbor seals at the North Cove of Cape Arago appears to be associated with pupping. The partitioning of the haul-out into sex- and age-specific groups seems to be the principle cause for haul-out variation. Social interactions such as predator detection, interspecific competition, and environmental factors like tide height, time of day, air temperature, and wind and wave direction did not influence the zone usage. It is unclear if human disturbances are important in influencing haul-out zone usage.

Partitioning of haul-out

Harbor seals have been observed to partition the haul-out areas into male dominated areas, nursery areas consisting of mothers and their pups (Slater and Markowitz 1983; Knudtson 1977) and after weaning, juvenile areas. The observed changes in zone usage by both adults and pups is important to note because though the pups are essentially inseparable from their mothers while they are nursing, after they are weaned the independent pups do not use the same zones as the other adults. The mothers and pups would be the animals most likely to change zones during my survey.

Mother-pup groups or nursery areas were concentrated mainly in the far-left and near shore zones. The mother-pup pairs remained at the periphery of the haul-outs until weaning the pups, after which the mothers returned to the main body of seals on the reef or volcano haul-out. This pattern is consistent with Newby's (1973) observations. The haul-out zones used for pupping were in shallow areas, sheltered from waves, and easy to access at varying tide levels. This is consistent to studies by Newby (1973) and Sullivan (1980). It would seem these nursery areas are sheltered areas (Davis and Renouf 1987;

personal observation 2000) that protect the pups from environmental conditions that may hinder them from initially getting onto the rocks. In one extreme example, Renouf and James (1975) found that pregnant females on Sable Island, Nova Scotia traveled 1 km over land to birth in an inland lake, presumably to provide a calmer environment for pupping. More commonly, Sullivan (1979) found that pups had less success getting on rocks than adults and subadults, and Venables and Venables (1954) determined that newborn pups have very little power in their hindquarters; they cannot wriggle up a slope and are easily washed back by a wave. The nursery area consisted of many low inclined rocks, which provided the pups with easily accessible haul-outs.

The areas of greatest pup concentration, the far left and near shore, were most sheltered from wind- and wave-driven currents and were free of human disturbances when the beach was closed. These shallow rocky intertidal areas fit the characteristics described in other surveys as ideal nurseries for pups. Therefore it is most probable that the seals used this area during pupping and later moved out of the area when the pups no longer needed the protection. The mothers returning to the main group of seals after pupping most likely caused the observed haul-out zone change in the post-pupping period. Furthermore, after being weaned the pup's zone usage changed during the post-pupping period as they moved to a zone out of the nursery.

Predator detection

Similar to flocking birds, seals aggregate possibly to increase predator detection (Krieber and Barrette 1984). By aggregating the individual seals spend less time scanning but benefit from the scanning of the other seals in the group. In this way the individual can spend more time resting and caring for its pup. The individual seals have shorter scans and more time between scans if they are in a group of ten or more seals (Terhune 1985). Though the seals don't coordinate the scanning they are aware of the other seals and will desert the haul-out if disturbed (personal observation 2000; Sullivan 1979). The Cape Arago seals are probably weakly aggregating. Since seals can evaluate a haul-out without leaving the water (Terhune and Brilliant 1996) they may preferentially chose haul-outs where other seals are already present causing clustering. On the other hand, since individual seals were always found in each zone, it is unlikely that they will haul-out only in close proximity to one another.

Haul-out competition

The number of seals at a haul-out can potentially limit the amount of available haul-out area for other seals and in this way create potential haul-out competition. The limiting resource in the haul-out zone is substrate-ocean interface and though seal aggression does not increase with group size (Krieber and Barette 1984), the seals avoid crowding and touching each other when aggregated (Terhune and Brilliant 1996). Since they will not touch each other the seals possibly limit the haul-out numbers by preventing other seals from hauling-out if all the ocean-rock interface is being used.

Harbor seals are considered non-migratory animals with a high haul-out fidelity (Divinyi 1971), therefore haul-out competition should remain constant. Local movements between haul-out areas, however, are common indicating the seals can move away from areas if conditions change. For example, eight of 35 tagged seals moved 24-194 km away from the tagging area, with an average movement rate of 27 km/day

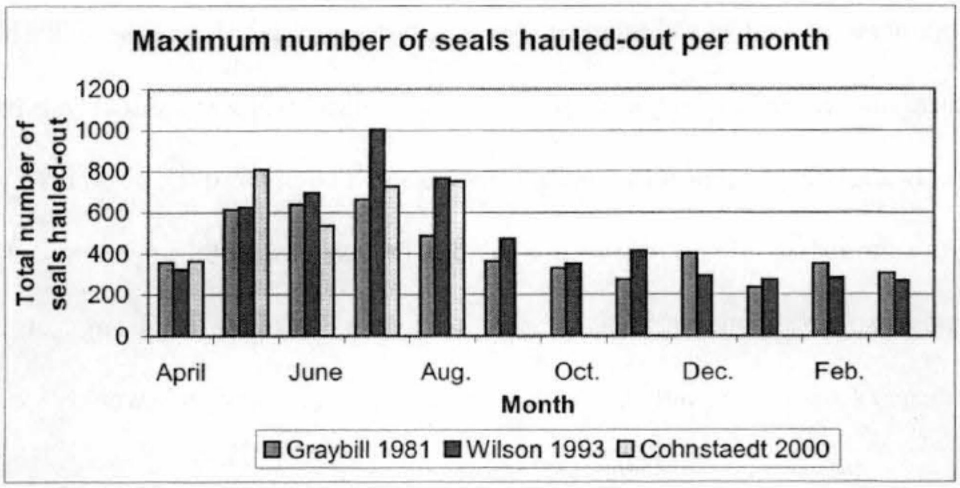

Figure 9. A comparison of my maximum counts each month with Graybill (1981) and Wilson (1993).

(Pritcher and McAllister 1981). Wilson (1993) and Brown and Mate (1982) found during radio-tracking surveys of Oregon harbor seals that individual seals will move distances of 25-40 km to change haul-out sites. Graybill (1981) and Wilson (1993) attributed changes in haul-out number and high haul-out numbers to the seals spending less time at sea foraging when fish migration makes food more abundant. The seals at Cape Arago follow a seasonally fluctuating haul-out pattern described in the literature and in previous surveys conducted at the Cape (Figure 9); the haul-out competition may therefore be greater during the life history stages of pupping and molting when more seals are present at the cape. But the large haul-out zones at Cape Arago also prevent the seals from crowding or running out of haul-out area. Seals use the same zone during a particular life history stage despite the number of seals hauled-out each day in that zone suggesting that if the number of seals hauled-out does influence zone use it is only very weakly.

Interspecific competition

Competition for haul-out space by California and Stellar sea lions can affect haul-out zone usage. Sullivan (1979) found both species of sea lions to be behaviorally dominant to harbor seals. The larger sea lions displace the smaller seals out of zones and when sea lions abandon the zone the seals return (Sullivan 1980). This relationship between pinnipeds probably did not happen at Cape Arago because my survey occurred at a time when few sea lions were present.

Tides and time of day

Low tides are negatively correlated to the number of seals hauled-out at Cape Arago (Graybill 1981). Time of day also affects the number of seals hauled-out;

however, the survey was conducted at low tides which occurred at varying times throughout the life history stages. Seals did not change the pattern of zone usage with changing tide height or time of day, despite the influence these two factors have on the number of seals hauled-out in each zone. Haul-out zone usage did change with life history stage and not according to daily changes.

<u>Factors that may have influenced zone usage</u>

1.. Temperature

Air and water temperatures (Watts 1991; Grellier, et al. 1996) influence haul-out numbers since seals must haul-out if the water is too cold and must reenter the water if the air temperature is too warm. Seals cannot sweat and have a thick blubber layer; heat loss occurs only from their flippers. On land, the basal metabolic rate is sufficient to heat the seals which means if the insolation (the sunlight converted to heat on the surface of an object) is higher than the seal's body temperature (i.e. the seals are getting heated by the sunlight) they cannot stay out of the water or they will overheat (Watts 1991). The average air temperature during my survey was 11.8° C. On the other hand, harbor seals cannot metabolize their skin cells if the water temperature is below 17° C (Feltz and Fay 1966) and the average ocean surface temperature near Cape Arago was 13° C (National Data Buoy Center 1991-1993). The air and water temperatures would make hauling-out calorically and energetically favorable for Oregon harbor seals (Graybill 1981). Since the air temperature was not much cooler than the water surface temperature, seal haul-out may not be regulated or only weakly regulated by thermal constraints off the Oregon coast.

2. Wind direction

Seals seem to prefer areas out of the wind (personal observation 2000) and will haul-out away from it (Pauli and Terhune 1987), which could increase zone usage on the windward side of the haul-out area. Though wind direction changed during the survey, it did not change the seal's zone usage at Cape Arago. However, I did not inspect the micro-habitat of each haul-out zone to determine if the seals were out of the wind despite being on the windward side of the haul-out area.

3. Wave direction

Rough water negatively affects seal haul-out numbers as the seals will haul-out away from surface spray and breaking waves (Sullivan 1980; Pauli and Terhune 1987; Schneider and Payne 1983) or the haul-out may not be available due to the wave action. During my survey, the Cape Arago seals did not seem to haul-out away from the waves and white caps. The effect of the breaking waves and currents on haul-out behavior may have been reduced because of a submerged reef that creates a buffer protecting the far-left haul-out zone from waves. Likewise, the haul-outs on Volcano Island were protected from northern waves and along-shore currents. Since both sides of the haul-out area were partially protected from waves and ocean currents the seals were probably not changing sides of the haul-out area to move away from the incoming wind generated waves. The changes in zone usage would therefore not be attributed to wave direction.

4. Disturbances

Human disturbances may cause the zone usage variation, but there were not sufficient events to demonstrate an influence because the amount and types of human impact varied between zones within the haul-out area. Fishing boats and surfers found occasionally near the reef, Volcano Island, and near shore zones did not disrupt the seals. On the other hand the beachcombers in the near and far-left zones did cause the seals to increase their scanning behavior and could have been a disturbance. Since seals are more alert in areas of disturbance (Terhune 1985) and when disturbed (Terhune and Brillant 1996) the seals could avoid the beach and near zones when the beach was open to the public. The beach area at the North Cove of Cape Arago is closed April through July, reducing the amount of human impact in the areas that were used most by seals during this time period. The usage in the shore area fell when the beach was open to the public and when the pups were weaned. Human disturbance along the shore, prior to April and after July, may have caused the seals to avoid the near shore haul-outs when they were no longer needed by the newborn pups. It must also be stated that the seals still used the areas and the human disturbances did not cause complete and permanent abandonment, which is normal in routinely disturbed areas (Brown 1981). Human disturbance at North Cove Cape Arago was essentially non-existent except in the far-left and near shore zones. In these two zones the impact on the animals was probably minimal.

Daily haul-out pattern

Stewart (1984) and Watts (1996) found that seals hauled-out more frequently during mid-afternoon. The Cape Arago seals seemed to follow this pattern. The literature cites many environmental factors that can affect haul-out numbers such as the ocean currents, air temperature, cloud cover, precipitation, wave action, wind direction and velocity. None of these factors were found to be significantly different between the morning and the afternoon counts and therefore cannot explain the differences in counts separated by less than 12 hours and 50 minutes. Thermoregulation (Watts 1991), the nocturnal peak in prey availability (Watts 1993), the cost of commute[3], and predator avoidance (Watts 1993) are factors that may influence the daily haul-out pattern I observed.

The haul-out time during my counts could have been limited by air temperature according to Watts (1992), who found that seals can potentially overheat if the environment is warmer than the seal's core temperature. The Oregon Coast weather is very mild and would only place moderate thermal constraints on the seals. Additionally, more seals were hauled-out in the mid-afternoon or the warmest part of the day than in the morning, contrary to the idea of the seals hauling-out to thermoregulate.

The nocturnal peak in prey availability may cause seals to feed at night when midwater fish rise to the surface to feed. By studying seal scats during a harbor seal dietary study, Graybill (1981) found that 52% of the fish eaten were bottom dwellers and 47% were midwater types. The seals seem to have no "preference between mid-water species over bottom dwelling fish" (Graybill 1981) and are opportunistic feeders, eating any fish they encounter rather than specializing on particular fish. Scats in the Graybill study were collected in the Coos Bay estuary, but it was not known where the seals fed. The fish species encountered have also been documented along the coastal areas (Richardson and Pearcy 1976). Seals may have a greater likelihood of finding food during the evening hours because they can hunt by feeling vibrations in the water with their whiskers. Newby (1973) found three blind mothers with healthy pups, indicating that seals can forage both visually and with their whiskers. Haaker et al. (1984) also

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[3] The cost of commute is the amount of energy the seal spends moving from the haul-out to the feeding area relative to just staying at sea.

found seals feeding at night by silhouetting the fish against the surface or seeing the fish in the presence of the diver's lights. When the lights were off the seals used their whiskers.

The feeding area of the seals at Cape Arago is not known if the cost of commuting is greater than remaining in the water. Staghorn sculpin (*Leptocottus armatus*), English sole (*Parophrys vetulus*), Shiner surf perch (*Cymatogaster aggregata*) and Pacific herring (*Clupea harengus*) comprise 58% of the fish consumed by harbor seals in the local area (Graybill 1981). All of these fish are found in the coastal waters so it is safe to assume the seals are staying near the coastline when foraging and not traveling into the open ocean to feed; therefore, seals may not be expending much energy traveling from their haul-outs to feeding areas.

Predator avoidance is a stronger factor in some areas like British Columbia, where Watts (unpublished) estimates that a seal has a 50-80% chance of being eaten by a killer whale before it is five years old. This could cause seals to avoid the water during the daylight hours to avoid visual predation. Killer whale pods and great white sharks were seen off the coast during my study period but their effects cannot be quantified in this study.

The observed daily haul-out variation I observed corresponds to the literature and is probably a consequence of the nocturnal peak in prey availability and the low cost of commute between the haul-out and the feeding areas. It is important to establish this diurnal haul-out pattern and to take it into account when studying seal populations. Counting seals during non-peak haul-outs will lead to inaccurate population numbers.

Conclusions

Harbor seals at Cape Arago use different haul-out zones during pupping and nursing. This change in zone usage is probably due to the seals creating nursery zones during the pupping season. Environmental factors could not explain zone changes, which occurred during life history stage transitions and not daily like the weather or tides. Seasonal changes such as pinniped haul-out numbers and human disturbance did not impact the seal's haul-out choices or cause the seals to change zones. The seasonally fluctuating seal numbers may have increased the haul-out competition while the seal's spatial needs remained constant; therefore, it may weakly influence the amount of area the seals can haul-out in within a zone.

On the days when two low tides occur, the Cape Arago seals seem to follow a pattern of low seal counts in the morning and higher ones in the afternoon despite similar environmental conditions. This pattern is most likely caused by the seal's ability to forage efficiently at low light levels combined with a low cost of commute. Both patterns of zone usage and the daily haul-out pattern are important to establish for harbor seal animal behavior studies, when creating land use plans near seal haul-outs and complying with the Marine Mammals protection act.

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