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Temporal and spatial variability of harbor seal diet in the San Juan Island archipelago

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Abstract

Harbor seals are the most abundant resident pinniped species in the San Juan Islands of Washington. They forage high on the food chain, are a relatively long-lived species, and have been used as sentinels of marine ecosystem health. Harbor seals are primarily piscivorous and consume seasonally and locally abundant prey, which allows us to investigate changes in their prey base, both on a temporal and spatial basis by examining diet. We use percent frequency of occurrence of prey species in fecal samples (scats) collected from rocky island and reef haul outs in the San Juan Islands to describe diet seasonally and regionally in 2006-2007 and to examine changes in diet between 2005-06 and 2006-07.

Harbor seals fed mainly on Pacific herring (occurring in 57% of samples), adult salmonids (19%), and Walleye pollock (15%). Diet differed among seasons with Pacific herring and Northern anchovy important during spring, adult salmonids and Pacific herring important during summer/fall and Pacific herring, walleye pollock, shiner perch, rockfish species, and sculpins important during winter. Mean number of different prey species differed among seasons with winter diet the most diverse (2.79 prey species) and summer/fall and spring slightly less diverse with (2.20 and 1.98 prey species respectively). In general, species composition in harbor seal diet was similar to fish abundance based on bottom trawl data and the timing and abundance of salmon return through the San Juan Islands. Pacific herring was the most important prey species for both study periods. In 2006-07, gadid species, adult salmon, Pacific sand lance, Northern anchovy, spiny dogfish and flatfish species decreased in occurrence and shiner perch, rockfish species, plainfin midshipman and eelpout species increased in occurrence. We also collected Steller sea lions scats and found dogfish and skate occurred most frequently in the diet. Our results suggest that harbor seal diet provides a good indicator of fish availability and consequently, ecosystem health and can be used to detect localized changes in prey availability.

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Introduction

The collapse of fisheries throughout the Pacific Northwest has fueled the need to move away from a single-species management approach and beyond conventional methods of marine coastal management (Bargmann 1998). Increases in pinniped populations have coincided with dramatic decreases in many marine and anadromous fish populations (WDF et al. 1993, Bargmann 1998, Jeffries et al. 2003). Fish species such as Pacific herring and Pacific sand lance form the base of the San Juan Island marine food web, supporting higher trophic fish, seabirds, and marine mammals (Calambokidis et al.1978, Calambokidis et al.1989, Olesiuk et al. 1990, Suryan and Harvey 1998, Lance and Thompson 2005, Lance and Jeffries 2006). The role of seal and sea lion predation in structuring marine ecosystems and affecting recovery of depressed fish stocks is a critical management issue (NMFS 1997) and has not been addressed in the San Juan Island ecosystem.

The harbor seal is the most abundant resident pinniped species in the inland waters of Washington and is the most common pinniped in the San Juan Island archipelago. They use over 150 intertidal haulout locations that are distributed throughout the San Juan Islands and number nearly 4,000 animals (Jeffries et al. 2003). There are an additional 1,000 animals in the adjacent Gulf Islands in British Columbia to the west and 2,000 animals in the Eastern bays (Samish, Skatgit, Padilla and Bellingham Bays) to the east (Jeffries et al. 2003). Harbor seals in the San Juan Islands, Hood Canal and Strait of Georgia forage within approximately 10 kilometers of a haulout site with most individuals foraging in the same specific area and returning to the same haul out site (Suryan and Harvey 1998, Olesiuk 1999, WDFW unpub. data). Because harbor seals forage in close proximity to haulout sites and eat locally abundant fish species, research on their diet can be used to examine temporal and spatial variability in their prey base, how the prey base varies over time and space, and their role in shaping the complex marine food web.

Diet data collected in the San Juan Islands in 2005-2006 indicate harbor seals fed mainly on Pacific herring (occurring in 57% of samples), adult salmonids (31%), Gadid species (24%), Pacific sand lance (20%) and Northern anchovy (19%; Lance and Jeffries 2006). North Puget Sound Pacific herring two-year stock profiles indicate that three stocks are depressed (Interior San Juan Islands, Fidalgo Bay, Semiahmoo Bay), two stocks are critical (Cherry Point, Northwest San Juan Island) and only one is considered moderately healthy (Samish/Portage Bay) based on 25 year spawning biomass estimates (Stick 2005). The Georgia Basin Pacific hake stock at one time comprised the largest fishery in central Puget Sound, but spawning biomass has declined 85% over the past 15 years and the fishery is now closed (Gustafson et al. 2000). Central Puget Sound Pacific hake are candidates for listing by Washington State (Brown and Gaydos, 2005). Populations of Pacific cod in North Puget Sound are “depressed” with South and Central Puget Sound populations of this fish listed as candidates species for listing by Washington State (Brown and Gaydos, 2005). Simultaneously, pinniped populations have increased seven to ten-fold in Washington with passage of the Marine Mammal Protection Act in 1972 (Jeffries et al. 2003). Harbor seals are unquestionably affected by the dramatic shifts that have occurred in their prey base. Understanding the importance of these prey species in the diet of harbor seals is needed to help develop ecosystem-based recovery and management strategies for Puget Sound and Strait of Georgia.

Marine Protected Areas have been considered as a tool to improve ecosystem health by providing fish refuge and restoring depleted fish stocks and may be valuable in enhancing fisheries, however; the effects of Marine Protected Areas on marine predators and how predators respond to the increased fish density in Marine Protected Areas have received little critical evaluation. In the San Juan Islands, a number of Marine Protected Areas were designated, at least in part, to preserve habitat for rockfish (13 species are listed by WDFW as candidates for increased protection), lingcod and other bottomfish species. The importance of rockfish species, lingcod and other bottomfish in the diet of harbor seals in other areas along the west coast varies by location and habitat type. For example, frequency of occurrence of rockfish in scats collected from haulout sites located at the entrance to the Rogue River in southern Oregon, ranged from 10–39 percent of the diet in late summer and fall 1997-1999, and lingcod was less than 2 percent (Riemer et al. 1999). During the same time period in Alsea Bay in northern Oregon, rockfish species were less important in the diet of harbor seals and ranged from 4-7 percent and lingcod was less than 1 percent (Riemer et al. 1999). In the San Juan Islands in 2005-2006, rockfish and hexagrammid (lingcod and greenling) remains were found in only 2.3 and 1.0 percent of samples collected, respectively. Currently, lingcod populations are in above average condition in north Puget Sound due to changes in fishing regulations, but rockfish populations in many or all areas of Puget Sound including the San Juan Islands are in critical condition (Puget Sound Update 2007). We suggest a small amount of localized predation could have a considerable effect on these fish species that spend the majority of their life in very small areas ("home ranges") on rocky reefs, and are among the slowest growing and longest-lived marine fishes on earth (Love et al. 2002).

The effectiveness of Marine Protected Areas in providing areas protected from human harvest for fish to grow and become reproductively mature has been evaluated with studies showing that rockfish and lingcod increase in abundance and size with protection from harvest even in small areas such as the Edmonds Underwater Park (Palsson and Pacunski 1995, Palsson 1998, W. Palsson, WDFW, pers. comm.). Although these zones are intended to primarily increase bottom fish recovery, the recommendation of no take of all fauna would likely result in an increase in fish abundance, species diversity and size. If this occurs, we would expect this change in prey abundance to influence harbor seal foraging ecology by preferentially feeding in these areas and in turn be reflected in their diet. Understanding the role of predators (e.g. harbor seals) in Marine Protected Areas designed to recover fish stocks is an important component when evaluating their 'success'.

Harbor seals are known to consume a wide range of prey sizes including adult salmonids returning to rivers to spawn, out-migrating salmon smolts and small schooling forage fishes (Calambokidis et al.1978, Calambokidis et al.1989, Olesiuk et al. 1990, Riemer et al. 1999, London et al. 2001, Browne et al. 2002, Orr et al. 2004, Lance and Jeffries 2006). Seasonal abundance of prey species undoubtedly plays a key role in the foraging ecology and diet of harbor seals. Determining harbor seal diet in the San Juan Islands, both spatially and temporally, has important implications for fisheries biologists in understanding whether harbor seal populations are consuming young of the year fishes that would be recruited into the population (e.g. Pacific herring), or larger fish with greater reproductive output (e.g. adult rockfish) and consequently have significant population effects on the prey base. Harbor seal diet comparisons are also useful in addressing the question of multispecies and community effects outside of Marine Protected Area boundaries by examining changes in fish size and composition over time.

In this study, we built upon the diet data collected in 2005-2006, which allowed us to investigate changes in predator prey relationships between years, seasons and regions within the San Juan Island archipelago. We obtained a large sample size of scats from a broad geographic area and used these to examine all prey species in harbor seal diet. Our study assumes that harbor seal diet composition reflects the composition and abundance of local prey items. We believe this assumption is reasonable because, harbor seals eat what is seasonally and locally abundant (Olesiuk et al. 1990, London et al. 2001, Browne et al. 2002, Orr et al. 2004, Lance and Jeffries 2006), harbor seals use haul out sites within 10 km of foraging areas and return to those haul out sites at regular intervals and deposit scat (Suryan and Harvey 1998, Olesiuk 1999, WDFW unpub. data) and hard parts (bones, otoliths, squid beaks) found in scats are representative of species being consumed by seals (Harvey 1989, Cottrell et al.1996, Bowen 2000, Orr and Harvey 2001)

Methods

Sample collection. Fecal samples (scats) were collected seasonally over three "collection windows": 1 March-30 April ('spring'), 1 August–30 September ('summer/fall') and 1 December–30 January ('winter'). Scats were collected on rocky haulout locations during daytime low tide windows from six regions in the San Juan Islands designated as: 'South Strait of Georgia', 'North Rosario Strait', 'Eastern Bays', 'South Rosario Strait', 'South San Juan Channel', and 'North San Juan Channel' (Figs. 1-3). Two to three collection trips were made each season and 100 scats was the target sample size for each region (Trites and Joy 2005). Effort was adjusted to allow for meaningful statistical analyses. Steller sea lion scats were collected opportunistically during winter and spring when this species is present in the area and were analyzed separately. Haulout locations on rocks or islands with important seabird colonies precluded collections during critical seabird nesting and breeding periods at some sites from 15 April – 31 August. Samples were collected in either plastic 'Whirlpak' bags or in fine mesh paint strainer bags and frozen until processing.

Sample processing. Samples were cleaned using a washing machine (Orr et al. 2003) or using nest sieves if samples contained rocks that would damage prey remains in the washing machine (Lance et al. 2001). Prey were identified to the lowest possible taxon using a dissecting microscope, reference fish bone collections from Washington and Oregon, and published bone, otolith and cephalopod beak keys (Kashiwada et al. 1979, Morrow 1979, Wolff 1982, Clarke 1986, Cannon 1987, Harvey et al. 2000, Lance et al. 2001). Identification of rockfish using bones is strait-forward, however identification to species is not possible because the types of bones that are recovered from pinniped scats (e.g. radials) do not differ significantly among rockfish species. Rockfish otoliths are identifiable in some cases based on level of erosion and species, but are typically reported to family as Sebastes spp. (S. Crockford, Pacific Identifications Inc. and S. Riemer, ODFW, pers. comm.). When condition allowed, otoliths were identified and aged by interpreting growth patterns using methods consistent with aging marine fish by Washington Department of Fish and Wildlife Marine Fish Aging Unit. Data were entered into an Access database.

Data analyses. Diet data are presented as percent frequency of occurrence for each season. To account for differences in samples sizes among seasons, we present an unweighted average that was calculated by taking the mean percent frequency of occurrence of the three seasons for each species. Samples did not contain bones identified to both the species level (e.g. walleye pollock) and family level (gadid species) unless they were different size (age) classes (e.g. large walleye pollock bones and otoliths and few small gadid species bones). Seasonal comparisons were possible in only two geographic regions due to limited sample sizes. We report diet diversity (average number of prey species per sample) and compare prey composition in the diet to regional fish composition data based on bottom trawls (Palsson et al. 2003) and salmon run timing data collected by Washington Department of Fish and Wildlife, Puget Sound Salmon Management.

Results

Diet composition. During three collection periods ('spring', 'summer/fall' and 'winter'), a total of 398 scats were collected from 17 sites distributed throughout the San Juan Islands (Figs. 1-3, Appendix 1). Data analyses were based on 98.5% of harbor seal scats (392 of 398 collected) that contained identifiable prey. Marine and anadromous fishes were found in all samples analyzed and cephalopods occurred in 11% of samples. Diet included 32 species from 20 different families. Individual samples typically contained one to three (mean = 2.23) different prey species, but occasionally contained as many as nine.

Overall, harbor seals fed primarily on Pacific herring (57% occurrence), adult salmonid species (19%), and walleye pollock (15%) in the San Juan Islands (Table 1). Other important species that occurred in greater than five percent of samples were, in decreasing order of importance, rockfish species (12%), threespine stickleback (12%), cephalopods (octopus and squids) (11%), shiner perch (11%), Pacific sand lance (10%), gadid species (9%), clupeid species (9%), Northern anchovy (8%), skate species (6%), sculpin species (6%), and eelpout species (5%) (Table 1). Scientific fish names are given in Table 1.

Season and Region. Mean number of different prey species differed among seasons. Winter diet was most diverse and samples contained a mean of 2.79 different prey species. Mean number of different prey species in samples collected during spring and summer/fall were 1.98 and 2.20, respectively.

Clupeid species, primarily Pacific herring, were important prey for San Juan Islands harbor seals year round, but primarily during spring (91%) and winter (71%). The "clupeid species" category could include any species of clupeid including Pacific herring, American shad, and Pacific sardine, but which cannot be assigned to species because the bones recovered are not species specific (e.g. vertebrae). Overall, 57% of samples contained Pacific herring (Table 1).

Adult salmonid species were the dominant prey species during the summer/fall collection period. The "salmonid species" category may include any species of salmonid, hatchery or wild, that might be in the San Juan Islands during the study period, but which cannot be assigned to species because the bones recovered are not species specific (e.g. gill rakers). Of the 140 samples that contained adult salmonid remains, 24 otoliths were identifiable to species (Table 1). Otoliths from adult salmon species included chum (13 otoliths), sockeye (7 otoliths), coho (2 otoliths), pink (1 otolith), and chinook (1 otolith). Juvenile salmon were found in 33 samples and otoliths from juvenile salmon species included chinook (8 otoliths), coho (1 otolith) and sockeye (1 otolith).

Gadid species were important prey species in the San Juan Islands primarily during winter. The "gadid species" category could include those species of gadid found in the San Juan Islands including walleye pollock, Pacific tomcod, Pacific hake and Pacific cod, but which cannot be assigned to species because bones recovered were not species specific. Walleye pollock was the most important of the gadid species present in their diet and occurred in 21% and 16% of harbor seal samples collected during winter and summer/fall and was also present in samples collected during the spring collection period (Table 1).

Seasonal changes in diet composition in the San Juan Islands are shown in Figure 4. Clupeids (Pacific herring, American shad and clupeid species), Gadids (gadid species, walleye pollock, Pacific hake, and Pacific tomcod), and Northern anchovy were the three most important prey species in seal diet during spring (Table 1, Fig. 4). Clupeids (specifically Pacific herring) remained important during summer/fall and winter, but returning adult salmonid species were also important prey species in summer/fall diet. Diet became more varied during the winter, with clupeids still dominant (71% of samples collected), but gadids (specifically walleye pollock), sculpins, shiner perch, rockfish and cephalopods (squid and octopus) were found in greater than 15% of samples collected (Table 1, Fig. 4).

Seasonal differences in diet is well illustrated by comparing samples collected within the Eastern Bays and South San Juan Channel regions. Eliza and Vendovi are the two rocky islands in the Eastern Bays region and are located east of Rosario Strait (Figs. 1-2). Over 60% of samples collected during winter and spring contained clupeid species (specifically Pacific herring). Clupeids remained important during summer/fall, but adult salmon and eelpout species increased in occurrence (Table 2). Both gadids and shiner perch were in 48% of samples collected during winter and occurred less frequently during spring and summer/fall. Rockfish occurred primarily in summer/fall diet. South San Juan Channel region is composed of Goose Island and Whale Rock (Figs. 1, 3). Clupeids (specifically Pacific herring) were found in 100% of samples collected during both spring and winter and only 33% during summer/fall, whereas adult salmonids composed 67% of the diet during summer/fall (Table 3). All gadids (primarily walleye pollock) were primarily important during winter and Northern anchovy occurred primarily in spring diet. Pacific sand lance was important year round in the diet composing 16-22%. Similar analyses in other regions were not possible because of insufficient sample sizes during winter and spring.

Weather and low numbers of harbor seals hauled out made sample collection at some haulouts challenging during winter and spring (Appendix 1). In general, poor weather and only moderately low daytime low tides precluded additional collection trips during these seasons resulting in low sample sizes. In addition, we regularly found large numbers of harbor seals at a number of haulout sites during winter and spring collection trips, however; very few scat samples were found during this period of time at these sites (Appendix 1).

Rockfish, lingcod and other bottom fish. Overall, rockfish remains were found in 38 samples (12%, Table 1). Rockfish otoliths were found in seven samples. Species identification was not possible for any of the otoliths recovered due to erosion. Samples contained juvenile (age 0-2) subadult (age 2-4) and adult (age 6+) remains and were found during all seasons and in all regions (Table 4). Relative age (subadult and adult) was based on bone and otolith size and supported by those samples containing otoliths where age was determined. Hexagrammid species (greenling and lingcod) remains were found in only one scat sample (0.14%). This sample was collected during summer/fall from Peapod Rocks located in north Rosario Strait (Table 4).

Interannual comparison. Overall, the mean number of different prey species in a sample in 2005-2006 (1.95) was slightly lower than it was in 2006-2007 (mean = 2.23). Diet was more diverse during spring and summer/fall in 2006-2007, however winter diet diversity was lower in 2006-2007 (mean = 2.79) than in 2005-2006 (mean = 3.59).

The overall weighted average of prey species in harbor seal diet remained constant for Pacific herring and dropped slightly for both adult salmon and all gadids between 2005-2006 and 2006-2007 (Table 5). Pacific sand lance, Northern anchovy and spiny dogfish decreased in occurrence by greater than 10% between years. Rockfish species increased in occurrence by nearly 10%. Shiner perch, cephalopod species (squid and octopus), plainfin midshipman and eelpout species increased in occurrence by 3-7%. Sculpins, skate species and snailfish species remained relatively stable between years.

Steller sea lion diet. A total of 12 scats were collected from two sites (Bird and Whale rocks) in the San Juan Islands (Figs. 1-3) during winter and spring. All samples contained identifiable prey. Diet included nine fish species from nine different families and cephalopods. Dogfish and skate were the two most predominate species found in the diet (Table 6).

Discussion

Diet composition.

Harbor seals fed predominantly on Pacific herring, adult salmonids, and walleye pollock in the San Juan Islands during spring and summer/fall 2006, and winter 2007. These results are similar to data collected in the San Juan Islands in 2005-2006 and other studies conducted in close proximity to the San Juan Islands and elsewhere that show that harbor seals feed primarily on adult salmonids when they are abundant, as well as small schooling fish and gadid species (Calambokidis et al. 1989, Olesiuk et al. 1990, London et al. 2001, Lance and Jeffries 2006).

Season and Region.

In general, diet composition data collected during this study indicates that harbor seals forage opportunistically on prey that is locally abundant throughout the region, but that varies seasonally. Walleye pollock, spotted ratfish, Pacific tomcod, english sole, Southern rock sole and dover sole were the six most frequently observed species in bottom trawls conducted by Washington Department of Fish and Wildlife in the San Juan Islands during May and June of 2001 (Palsson et al. 2003). While gadids (specifically walleye pollock) were found in harbor seal diet during all seasons and in a high percentage of samples collected in the winter, spotted ratfish did not appear in the diet. We speculate harbor seals do not consume this abundant species because they have a serrate, venomous dorsal spine (Hart 1973). English sole and Pleuronectid species occurred in harbor seal diet, but in low frequencies compared to overall availability based on bottom trawl data (Palsson et al. 2003). Bottom trawls are best designed for flatfish and benthic oriented gadids and do not generally sample schooling forage fishes. Key prey species found in harbor seal diet in this study are primarily pelagic. This suggests harbor seals are feeding mainly in the water column rather than on the bottom and likely explains differences observed between trawl and diet data. Time-depth recorder data from harbor seals foraging in the Strait of Georgia indicates they spend the majority of their time feeding in the water column (P. Olesiuk, DFO-Canada, pers. comm.).

Current population status and trends for juvenile and adult forage fish species in the San Juan Islands and throughout Puget Sound are not well known. Washington Department of Fish and Wildlife and others have conducted extensive surveys to map and protect spawning habitat for Pacific herring, Pacific sand lance and surf smelt. The Cherry Point Pacific herring stock that was once the largest in the state with an average run size of over 6,000 tons is now considered "depressed" with a two year stock status of "critical", and is a proposed candidate for listing by Washington State (Bargmann 1998, Brown and Gaydos, 2005, Stick et al. 2005). Only one North Puget Sound Pacific herring stock is considered moderately healthy (Samish/Portage Bay) based on 25 year spawning biomass estimates (Stick 2005). Pacific sand lance occurred in approximately 10% of samples collected and is receiving more attention recently for its importance to alcids (S. Pearson, WDFW, pers. comm.). Systematic spawning surveys for Pacific sand lance and surf smelt were conducted in the late 1980s and early 1990s by Washington Department of Fish and Wildlife with approximately 200 survey stations (D. Penttila, WDFW, pers. comm.) and more recently (2001-2004) by Friends of the San Juans, in concert with the San Juan County Marine Resources Committee, with the support of a number of funding entities with approximately 2000 survey stations (Moulton 2000). Northern anchovy was eaten almost exclusively during spring by harbor seals and primarily in South San Juan Channel. There have been no detailed spawning surveys for Northern anchovy in the San Juan Islands by Washington Department of Fish and Wildlife or others, however eggs were detected during plankton sampling throughout the rest of Puget Sound basin during summer 2006, including Whatcom and Skagit Counties (D. Penttila, WDFW, pers. comm.). Other apex marine predators feed on Pacific herring and Pacific sand lance in the San Juan Islands. They are the two most important prey species for thousands of Common murres (*Uria aalge*) and Rhinoceros auklets (*Cerorhinca monocerata*) in late summer and fall in the San Juan Islands (Lance and Thompson 2005) and were the two most important prey species delivered to Rhinoceros auklet chicks on Protection and Smith Islands located just south of the San Juan Islands in the late 1970s and early 1980s (Wilson and Manuwal 1985) and during the 2006 and 2007 breeding seasons on Protection Island (S. Pearson, WDFW, pers. comm.)

The peak of adult salmon in harbor seal diet during summer/fall coincides with high concentrations of returning adult salmon in waters around the San Juan Islands. In August-September 2005, pink salmon were the most numerous species in the San Juan Island area and harbor seals ate more pink salmon than other salmon species (Lance and Jeffries 2006). In August-September 2006, Puget Sound fall chum salmon numbers were up significantly in 2006 and sockeye salmon were the predominant adult salmon species with approximately 13 million late-run sockeye salmon were estimated to have passed through inland waters of Washington and British Columbia while returning to the Fraser River with 30-40% of those returning through the Strait of Juan de Fuca and San Juan Islands (K. Adicks, WDFW, pers. comm.). Harbor seals ate all species of salmon found in the San Juan Islands during this time period, with chum and sockeye occurring most frequently in the diet. In 2006, pink salmon were essentially absent, coho salmon return numbers were down significantly from 2005 throughout Puget Sound and southern British Columbia, and chinook salmon were more available based on by-catch in sockeye salmon fisheries, present during this study (K. Adicks, WDFW, pers. comm.).

Pink salmon return to their natal streams during only odd years (e.g. 2005). The overall weighted average of all salmonids remained constant. We may not have observed a difference in adult salmon in the diet because pink salmon were replaced in 2006 by other abundant salmon species such as chum or sockeye salmon. Sockeye salmon are only slightly larger (5-6 pounds) than pink salmon (3-4 pounds). The overall weighted average of adult salmonid species (those species for which species could not be determined with an otolith) decreased only slightly between 2005 and 2006.

Studies of pinniped predation on salmonids elsewhere have shown harbor seals are generally a terminal predator on salmon, taking them in estuaries and river mouths (Riemer et al. 1999, London et al. 2001, Olesiuk et al. 1990, Orr et al. 2004). In this study, harbor seals are feeding on salmon in “open water” areas as they funnel through narrow passages in the San Juan Islands. In Johnstone Strait, which is another area where salmon funnel through, a high proportion of salmon was found in harbor seal diet (30% of diet in July and September) (Olesiuk et al. 1990). Interestingly, adult salmon moving through these areas in the San Juan Islands also attract killer whales (*Orcinus orca*).

Rockfish, lingcod and other bottom fish.

Rockfish were consumed in all six regions in the San Juan Islands and during all three seasons. The overall weighted average of rockfish in harbor seal diet was 12% and was highest in frequency of occurrence during the winter when harbor seal diet becomes more diverse. During the winter, other prey species such as adult salmon are less available and these data support the idea that this may be a period of time when rockfish, lingcod and other bottom fish would be more likely to be consumed. We were unable to determine species for any of the rockfish otoliths recovered, but did confirm that harbor seals are consuming “subadult” (age 2-4) and “adult” (age 6-8+) individuals. A very large rockfish otolith was recovered during spring from Goose Island. This otolith showed advanced acid deterioration and only 6 years were counted, but based on size it could have been between age 14-40 depending on the species (S. Rosenfield, WDFW, pers. comm.). With over 7,000 harbor seals in the San Juan Island archipelago and surrounding waters and rockfish populations not recovered from intense commercial and sport fisheries in the late 1970s and early 1980s, we suggest this small amount of predation may be important when harbor seal and rockfish populations are put into context.

Interannual comparison.

Pacific herring was the most important prey species for harbor seals during both sampling years and considerably higher than any other prey species in the diet. The most noticeable shifts between years were seen in Pacific sand lance, Northern anchovy and spiny dogfish, which all decreased in occurrence in 2006-2007. In 2006-2007, we observed overall higher diet diversity with rockfish higher in occurrence, as well as shiner perch, cephalopod species (squid and octopus), plainfin midshipman, and eelpout species. Forage fishes in general, and Pacific herring specifically, are critical components of the marine web and are an important indicator of the overall health of the marine environment (Stick 2005). We do not know availability of these species between years because their abundance is not monitored in the San Juan Islands.

Steller sea lion diet.
In the past five years, an increasing number of adult male Steller sea lions weighing in excess of 1,000 lbs have moved into the San Juan Islands during the late winter and early spring, hauling out on Whale and Bird Rocks and occasionally on Peapod Rocks. Typically, 2-6 individuals are on each rock, but 23 were recorded during February-April, 2005 (S. Jeffries, WDFW, unpubl. data). After their breeding season, Steller sea lions disperse widely moving to areas where prey species are locally and seasonally most abundant or accessible. A major wintering area of sea lions off southern Vancouver Island shifts in relation to changes in distribution of pre spawning Pacific herring (COSEWIC 2003). Preferred prey species appear to be small or medium-sized schooling fishes in British Columbia and on the Washington outer coast (COSEWIC 2003, M. Lance, WDFW, unpubl. data) and these data are consistent with the small sample collected during this study. We believe this large top-level predator with high energetic demands is an important component in the San Juan Island food web and we will continue to monitor abundance and diet to help understand trophic relationships needed for management.

Significance to SeaDoc Society

In the San Juan Islands, harbor seal populations have increased and multiple marine fish populations including, Pacific herring, several rockfish species and Pacific hake are in precipitous decline. We document the importance of Pacific herring and adult salmon as well as gadid species in the diet of harbor seals and important seasonal shifts in diet composition. Forage fish are important prey of other species of fish, seabirds and marine mammals in the San Juan Islands. Variation in distribution and abundance of forage fishes can have major impact on higher trophic levels, thus potentially exerting direct control on the trophic dynamics of entire ecosystems. Harbor seals are high trophic level predators known to consume a wide range of prey sizes, such as adult salmonids returning to rivers to spawn, large numbers of out-migrating salmon smolts and schooling forage fishes such as Pacific herring. We documented regional and seasonal abundance of these prey species in harbor seal diet, which we feel is important in understanding their role in these dynamic food webs and for recovery of multiple depressed fish stocks. We believe this information is critical to evaluating the ‘success” of Marine Protected Areas designed to recover fish stocks and to develop sound scientifically based resource management policies and practices for the San Juan Islands in the future. We are building upon this project and using these new diet data along with satellite and time depth recorder instrument data and to begin to address questions of multi-species and community effects by examining foraging ecology along with changes in prey composition and selection over time.

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Planned and accepted publications

Proposed title: Diet and trophic relations of harbor seals in the San Juan Islands, Washington, 2005-2007.

This manuscript will include data from our 2005-2006 and 2006-2007 SeaDoc grants. We anticipate submitting for review during winter/spring 2008.

Figure 1. Map of the San Juan Islands showing sample collection locations

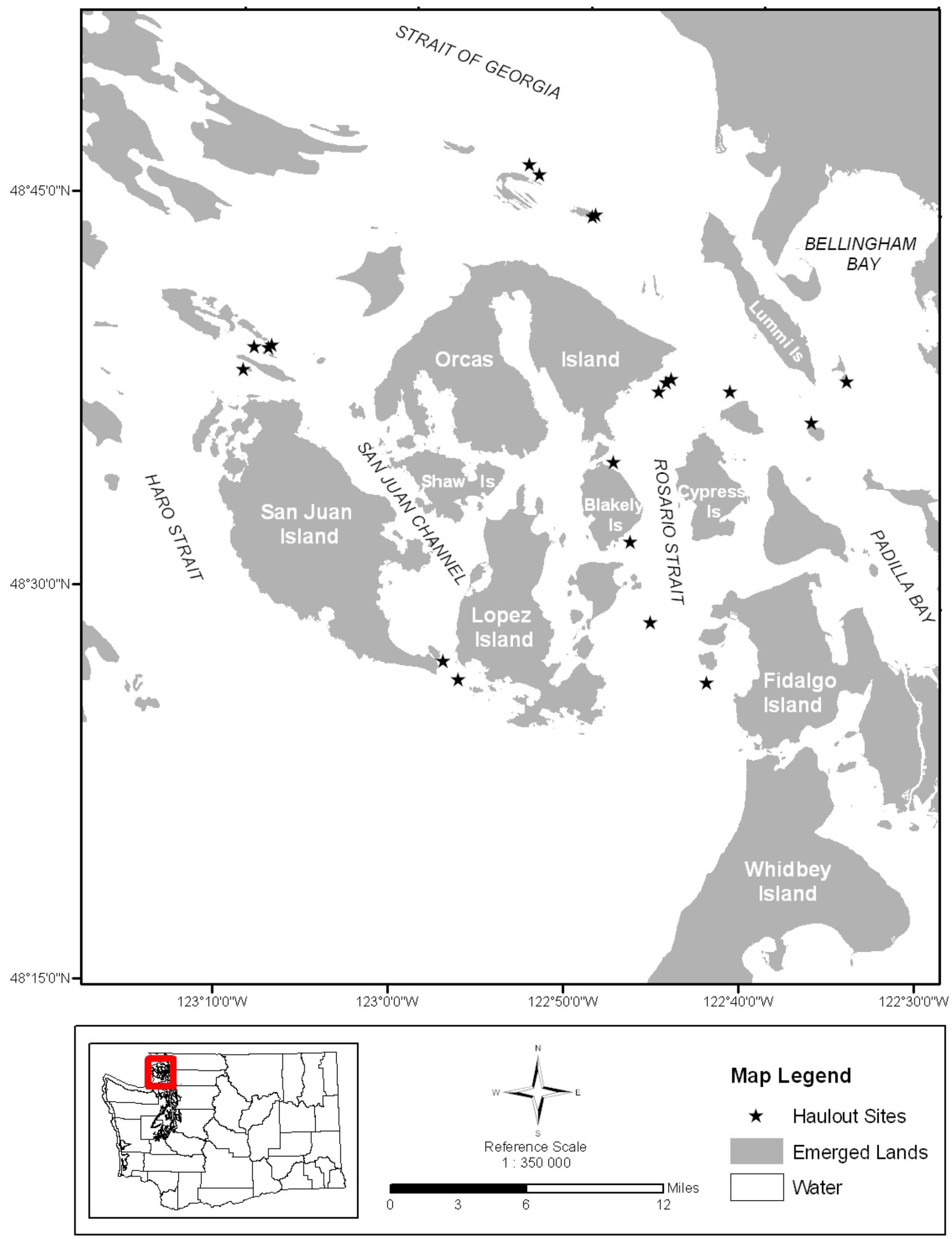


Figure 2. Map of the eastern portion of the San Juan Islands with names of reefs and islands where samples were collected

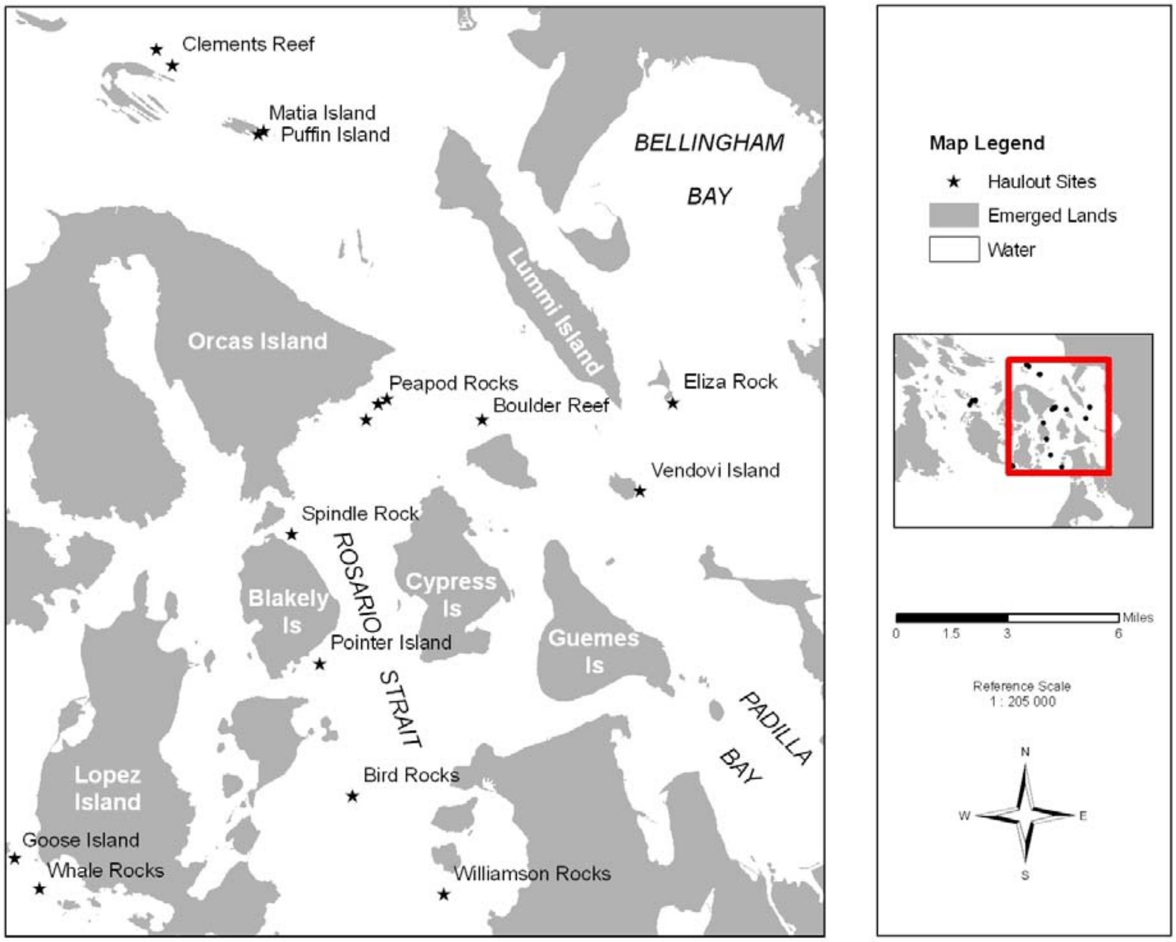


Figure 3. Map of the western portion of the San Juan Islands with names of reefs and islands where samples were collected

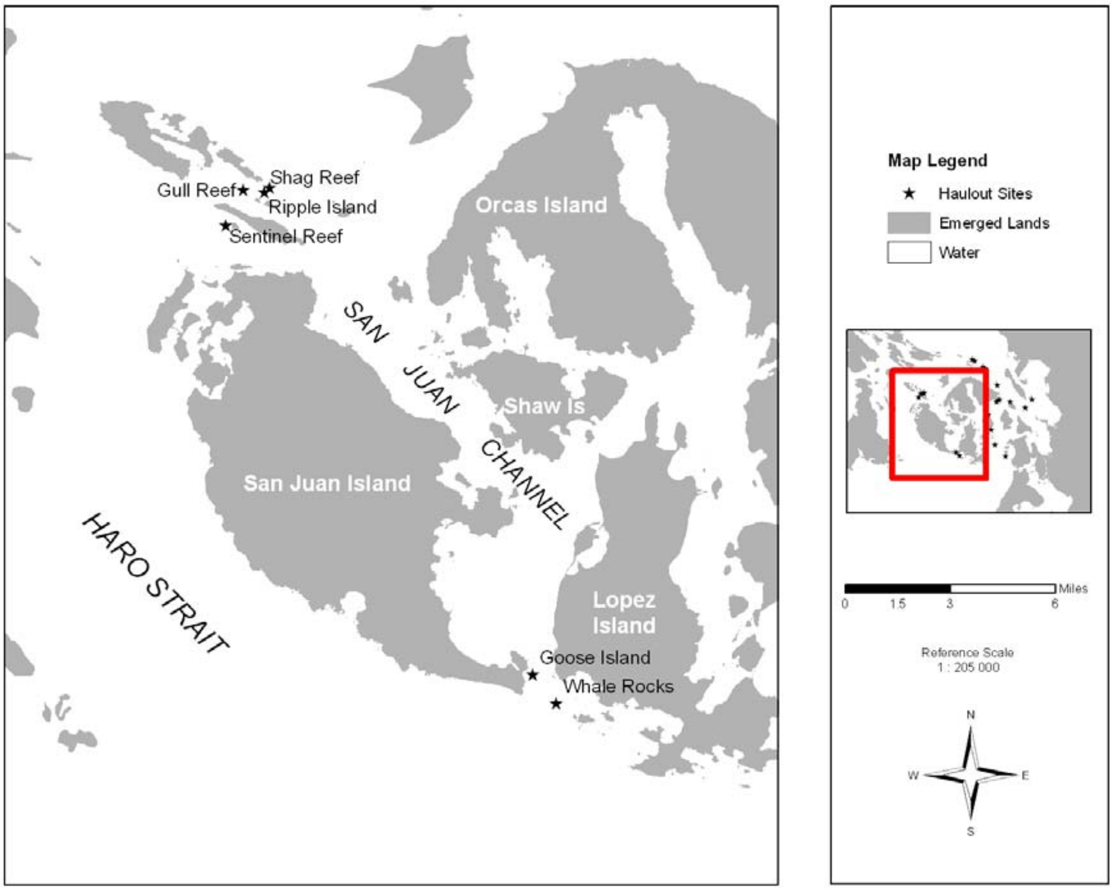


Table 1. Frequency of occurrence (FO; expressed as percent) and overall weighted average of prey species in the diet of harbor seals by season in the San Juan Islands, 2006-07

		Spring		Summer/Fall		Winter		Overall (wt)	
Scientific Name	Common Name	n=97	FO	n=239	FO	n=56	FO	n=392	FO
* All Clupeids		88	91	104	44	40	71	232	69
Clupea pallasi	Pacific herring	79	81	76	32	33	59	188	57
Clupeid spp.	herring spp.	6	6.2	22	9.2	7	13	35	9.5
Alosa sapidissima	American Shad	3	3.1	6	2.5	0	0	9	1.9
* All Gadids		22	23	64	27	25	45	111	32
Gadidae spp.	codfish spp.	12	12	15	6.3	5	8.9	32	9.1
Theragra chalcogramma	Walleye pollock	9	9.3	38	16	12	21	59	15
Merluccius productus	Pacific hake	0	0	6	2.5	5	8.9	11	3.8
Microgadus proximus	Pacific tomcod	1	1.0	5	2.1	3	5.4	9	2.8
* All Salmonids		7	7.2	159	67	7	13	173	29
Adult Salmonid spp.		6	6.2	106	44	4	7.1	116	19
Oncorhynchus gorbuscha	Pink Salmon (ad)	0	0	1	0.42	0	0	1	0.14
Oncorhynchus tshawytscha	Chinook Salmon (ad)	0	0	1	0.42	0	0	1	0.14
Oncorhynchus keta	Chum Salmon (ad)	0	0	13	5.4	0	0	13	1.8
Oncorhynchus nerka	Sockeye Salmon (ad)	0	0	6	2.5	1	1.8	7	1.4
Oncorhynchus kisutch	Coho Salmon (ad)	0	0	2	0.84	0	0	2	0.28
Juvenile Salmonid spp.		1	1.0	21	8.8	1	1.8	23	3.9
Oncorhynchus tshawytscha	Chinook Salmon (juv)	0	0	7	2.9	1	1.8	8	1.6
Oncorhynchus kisutch	Coho Salmon (juv)	0	0	1	0.42	0	0	1	0.14
Oncorhynchus nerka	Sockeye Salmon (juv)	0	0	1	0.42	0	0	1	0.14
Ammodytes hexapteras	Pacific sand lance	12	12	34	14	3	5.4	49	10
Engraulis mordax	Northern anchovy	20	21	4	1.7	1	1.8	25	8.2
Squalus acanthias	Spiny dogfish	1	1.0	1	0.42	0	0	2	0.47
* All Cottids		4	4.1	22	9.2	11	20	37	11
Cottid spp.	sculpin spp.	2	2.1	10	4.2	7	13	19	6.4
Leptocottus armatus	Pacific staghorn sculpin	0	0	9	3.8	4	7.1	13	3.6
Hemilepidotus spp.	irish lord spp.	2	2.1	3	1.3	0	0	5	1.1
* All Flatfish		1	1.0	15	6.3	1	1.8	17	3.0
Pleuronectid spp.	righteye flounder spp.	1	1.0	10	4.2	1	1.8	12	2.3
Pleuronectes vetulus	English Sole	0	0	4	1.7	0	0	4	0.57
Bothid spp.	lefteye flounder spp.	0	0	1	0.42	0	0	1	0.14
* All Cephalopods		4	4.1	34	14	9	16	47	11
Octopus rubescens		2	2.1	5	2.1	3	5.4	10	3.2
Berryteuthis magister		1	1.0	11	4.6	1	1.8	13	2.5
Loligo opalescens	Market squid	0	0	5	2.1	0	0	5	0.7
Gonatidae spp.		0	0	1	0.42	3	5.4	4	1.9
Not identifiable ceph. spp.	statolith only	1	1.0	12	5.0	2	3.6	15	3.2
Rajid spp.	skate spp.	5	5.2	2	0.84	7	13	14	6.3
Liparidid spp.	snailfish spp.	4	4.1	3	1.3	4	7.1	11	4.2
Cymatogaster aggregata	Shiner perch	3	3.1	7	2.9	15	27	25	11
Osmerid spp.	smelt spp.	2	2.1	5	2.1	3	5.4	10	3.2
Osmerus mordax dentex	Rainbow smelt	1	1.0	1	0.42	0	0	2	0.47
Hypomesus pretiosus	Surf smelt	0	0	1	0.42	0	0	1	0.14
Thaleichthys pacificus	Eulachon	1	1.0	5	2.1	1	1.8	7	1.6
Gasteroseus aculeatus	Threespine stickleback	5	5.2	4	1.7	0	0	9	2.3
Scorpaenid spp.	rockfish spp.	3	3.1	22	9.2	13	23	38	12
Porichthys notatus	Plainfin midshipmen	1	1.0	10	4.2	5	8.9	16	4.7
Pholid spp.	gunnel spp.	0	0	7	2.9	0	0	7	0.97
Hexagrammid spp.	greenling spp.	0	0	1	0.42	0	0	1	0.14
Diaphus theta	California headlight fish	2	2.1	0	0	1	1.8	3	1.3
Zoarcid spp.	eelpout spp.	1	1.0	18	7.5	4	7.1	23	5.2
Petromyzontid spp.	lamprey spp.	0	0	9	3.8	0	0	9	1.3
Stenobrachius leucopsarus	Northern lampfish	1	1.0	0	0	0	0	1	0.33
Not identifiable fish spp.		3	3.1	4	1.7	3	5.4	10	3.4
Unidentifiable fish spp.		1	1.0	2	0.84	3	5.4	6	2.4

Table 2. Frequency of occurrence (FO; expressed as percent) of prey species in the Eastern Bays by season, 2006-2007

		Spring		Summer/Fall		Winter	
Scientific Name	Common Name	n=17	FO	n=51	FO	n=29	FO
* All Clupeids		12	71	25	49	18	62
Clupea pallasi	Pacific herring	7	41	20	39	17	59
Clupeid spp.	herring spp.	5	29	5	9.8	1	3.5
* All Gadids		1	5.9	12	24	14	48
Gadidae spp.	codfish spp.	0	0	3	5.9	4	14
Theragra chalcogramma	Walleye pollock	1	5.9	5	9.8	6	21
Merluccius productus	Pacific hake	0	0	0	0	2	6.9
Microgadus proximus	Pacific tomcod	0	0.0	4	7.8	2	6.9
* All Salmonids		2	12	23	45	1	3.5
Adult Salmonid spp.		2	12	11	22	1	3.5
Oncorhynchus keta	Chum Salmon (ad)	0	0	1	2.0	0	0
Oncorhynchus nerka	Sockeye Salmon (ad)	0	0	1	2.0	0	0
Juvenile Salmonid spp.		0	0.0	5	9.8	0	0
Oncorhynchus tshawytscha	Chinook Salmon (juv)	0	0	4	7.8	0	0
Oncorhynchus nerka	Sockeye Salmon (juv)	0	0	1	2.0	0	0
Ammodytes hexapteras	Pacific sand lance	2	12	5	9.8	0	0
Engraulis mordax	Northern anchovy	3	18	1	2.0	0	0
* All Cottids		2	12	10	20	9	31
Cottid spp.	sculpin spp.	1	5.9	3	5.9	5	17
Leptocottus armatus	Pacific staghorn sculpin	0	0	7	14	4	14
Hemilepidotus spp.	irish lord spp.	1	5.9	0	0	0	0
* All Flatfish		0	0.0	6	12	0	0
Pleuronectid spp.	righteye flounder spp.	0	0.0	5	9.8	0	0
Pleuronectes vetulus	English Sole	0	0	1	2.0	0	0
* All Cephalopods		1	5.9	3	5.9	5	17
Octopus rubescens		0	0	1	2.0	2	6.9
Berryteuthis magister		0	0.0	1	2.0	1	3.5
Gonatidae spp.		1	5.9	1	2.0	2	6.9
Not identifiable ceph. spp.	statolith only	0	0.0	0	0.0	2	6.9
Rajid spp.	skate spp.	2	12	0	0	5	17
Liparidid spp.	snailfish spp.	1	5.9	0	0	3	10
Cymatogaster aggregata	Shiner perch	3	18	3	5.9	14	48
Osmerid spp.	smelt spp.	1	5.9	5	9.8	3	10
Osmerus mordax dentex	Rainbow smelt	1	5.9	0	0	0	0
Thaleichthys pacificus	Eulachon	0	0.0	0	0	1	3.4
Gasteroseus aculeatus	Threespine stickleback	2	12	1	2.0	0	0
Scorpaenid spp.	rockfish spp.	1	5.9	6	12	12	41
Porichthys notatus	Plainfin midshipmen	0	0.0	8	16	5	17
Pholid spp.	gunnel spp.	0	0	1	2.0	0	0
Diaphus theta	California headlight fish	1	5.9	0	0	1	3.4
Zoarcid spp.	eelpout spp.	0	0.0	14	27	4	14
Petromyzontid spp.	lamprey spp.	0	0	2	3.9	0	0
Unidentifiable fish spp.		0	0.0	0	0	2	6.9

Table 3. Frequency of occurrence (FO; expressed as percent) of prey species in the Southern San Juan Channel by season, 2006-2007

		Spring		Summer/Fall		Winter	
Scientific Name	Common Name	n=61	FO	n=64	FO	n=16	FO
* All Clupeids		61	100	21	33	16	100
Clupea pallasi	Pacific herring	60	98	11	17	13	81
Clupeid spp.	herring spp.	0	0	9	14	3	19
Alosa sapidissima	American Shad	1	1.6	1	1.6	0	0
* All Gadids		10	16	17	27	9	56
Gadidae spp.	codfish spp.	5	8.2	4	6.3	1	6.3
Theragra chalcogramma	Walleye pollock	5	8.2	10	16	5	31
Merluccius productus	Pacific hake	0	0	3	4.7	2	13
Microgadus proximus	Pacific tomcod	0	0.0	0	0	1	6.3
* All Salmonids		5	8.2	59	92	3	19
Adult Salmonid spp.		4	6.6	43	67	2	13
Oncorhynchus tshawytscha	Chinook Salmon (ad)	0	0	1	1.6	0	0
Oncorhynchus keta	Chum Salmon (ad)	0	0	6	9.4	0	0
Oncorhynchus nerka	Sockeye Salmon (ad)	0	0	1	1.6	0	0
Oncorhynchus kisutch	Coho Salmon (ad)	0	0	1	1.6	0	0
Juvenile Salmonid spp.		1	1.6	7	11	1	6.3
Oncorhynchus tshawytscha	Chinook Salmon (juv)	0	0	0	0	1	6.3
Ammodytes hexapteras	Pacific sand lance	10	16	14	22	3	19
Engraulis mordax	Northern anchovy	16	26	3	4.7	1	6.3
Squalus acanthias	Spiny dogfish	0	0.0	1	1.6	0	0
* All Cottids		2	3.3	3	4.7	1	6.3
Cottid spp.	sculpin spp.	1	1.6	0	0	1	6.3
Hemilepidotus spp.	irish lord spp.	1	1.6	3	4.7	0	0
* All Flatfish		1	1.6	1	1.6	1	6.3
Pleuronectid spp.	righteye flounder spp.	1	1.6	1	1.6	1	6.3
* All Cephalopods		3	4.9	11	17	2	13
Octopus rubescens		2	3.3	0	0	1	6.3
Berryteuthis magister		1	1.6	5	7.8	0	0
Loligo opalescens	Market squid	0	0	2	3.1	0	0
Gonatidae spp.		0	0	0	0	1	6.3
Not identifiable ceph. spp.	statolith only	0	0.0	4	6.3	0	0
Rajid spp.	skate spp.	1	1.6	2	3.1	2	13
Liparidid spp.	snailfish spp.	3	4.9	2	3.1	1	6.3
Osmerid spp.	smelt spp.	1	1.6	1	1.6	0	0
Thaleichthys pacificus	Eulachon	1	1.6	0	0	0	0
Gasteroseus aculeatus	Threespine stickleback	2	3.3	3	4.7	0	0
Scorpaenid spp.	rockfish spp.	1	1.6	4	6.3	0	0
Pholid spp.	gunnel spp.	0	0	1	1.6	0	0
Diaphus theta	California headlight fish	1	1.6	0	0	0	0
Zoarcid spp.	eelpout spp.	0	0.0	2	3.1	0	0
Petromyzontid spp.	lamprey spp.	0	0	4	6.3	0	0
Stenobrachius leucopsarus	Northern lampfish	1	1.6	0	0	0	0
Not identifiable fish spp.		1	1.6	1	1.6	1	6.3
Unidentifiable fish spp.		1	1.6	0	0	2	13

Table 4. Rockfish and Hexagrammid species in harbor seal samples (n=39) by age (subadult and adult), region, and season, 2006-2007

	South Strait of Georgia	North Rosario Strait	Eastern Bays	South Rosario Strait	South San Juan Channel	North San Juan Channel
Spring						
Subadult rockfish, exact age unk.			1			
Adult rockfish, exact age unk.				1	1	
Summer/Fall						
Subadult rockfish, exact age unk.	1		6	4	1	2
Age 2 rockfish					1	
Age 1 and 3 rockfish						1
Adult rockfish spp., exact age unk.	1	1			2	
Age 6 and 7 rockfish	1					
Age 3, 4 and age 6, 7, 8 rockfish						1
Adult hexagrammid		1				
Winter						
Subadult rockfish, exact age unk.			8			
Age 2 rockfish			1			
Adult rockfish, exact age unk.			3	1		

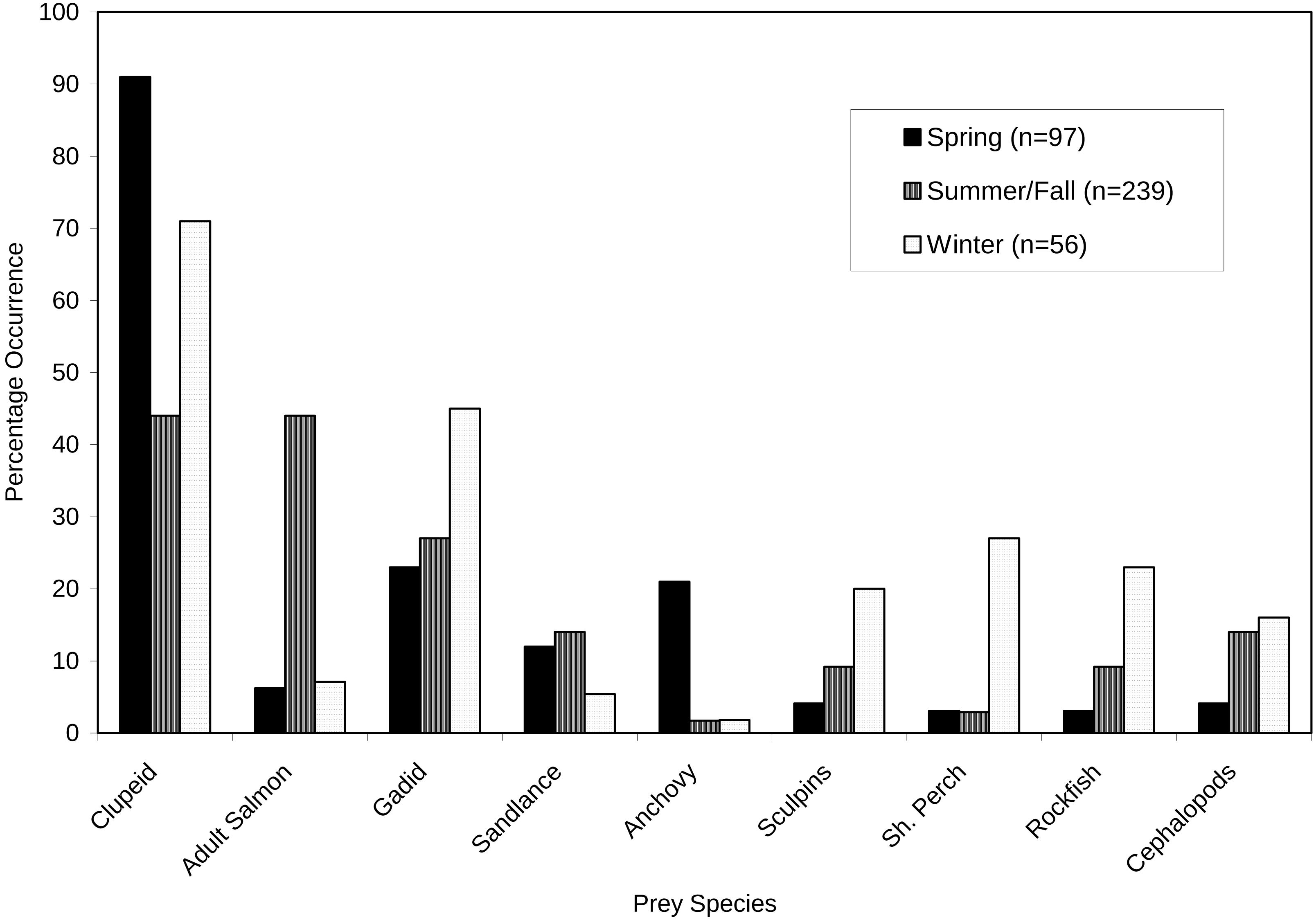
Table 5. Overall weighted average of prey species in the diet of harbor seals in the San Juan Islands, 2005-06 (n=507) and 2006-07 (n=392).

Scientific Name	Common Name	2005-2006 Overall (wt)		2006-2007 Overall (wt)	
* All Clupeids		236	61	232	69
Clupea pallasi	Pacific herring	219	57	188	57
Clupeid spp.	herring spp.	14	2.5	35	9.5
Alosa sapidissima	American Shad	3	1.5	9	1.9
* All Gadids		114	42	111	32
Gadidae spp.	codfish spp.	59	24	32	9.1
Theragra chalcogramma	Walleye pollock	53	17	59	15
Merluccius productus	Pacific hake	2	0.17	11	3.8
Microgadus proximus	Pacific tomcod	0	0	9	2.8
* All Salmonids		313	31	173	29
Adult Salmonid spp.		257	26	116	19
Oncorhynchus gorbuscha	Pink Salmon (ad)	25	2.2	1	0.14
Oncorhynchus tshawytscha	Chinook Salmon (ad)	1	0.43	1	0.14
Oncorhynchus keta	Chum Salmon (ad)	3	0.26	13	1.8
Oncorhynchus nerka	Sockeye Salmon (ad)	1	0.09	7	1.4
Oncorhynchus kisutch	Coho Salmon (ad)	0	0	2	0.28
Juvenile Salmonid spp.		22	1.9	23	3.9
Oncorhynchus tshawytscha	Chinook Salmon (juv)	4	0.43	8	1.6
Oncorhynchus kisutch	Coho Salmon (juv)	0	0	1	0.14
Oncorhynchus nerka	Sockeye Salmon (juv)	0	0	1	0.14
Ammodytes hexapteras	Pacific sand lance	66	20	49	10
Engraulis mordax	Northern anchovy	29	19	25	8.2
Squalus acanthias	Spiny dogfish	19	12	2	0.47
* All Cottids		35	9.2	37	11
Cottid spp.	sculpin spp.	17	5.7	19	6.4
Leptocottus armatus	Pacific staghorn sculpin	10	2.8	13	3.6
Hemilepidotus spp.	irish lord spp.	8	0.69	5	1.1
* All Flatfish		30	6.8	17	3.0
Pleuronectid spp.	righteye flounder spp.	9	1.8	12	2.3
Platichthys stellatus	Starry flounder	7	2.5	0	0
Pleuronectes vetulus	English Sole	7	0.61	4	0.57
Microstomus pacificus	Dover sole	5	1.1	0	0
Bothid spp.	lefteye flounder spp.	2	0.81	1	0.14
* All Cephalopods		22	6.8	47	11
Octopus rubescens		9	2.1	10	3.2
Berryteuthis magister		7	1.9	13	2.5
Loligo opalescens	Market squid	4	2.0	5	0.7
Gonatidae spp.		1	0.72	4	1.9
Not identifiable ceph. spp.	statolith only	1	0.09	15	3.2
Rajid spp.	skate spp.	10	6.0	14	6.3
Liparidid spp.	snailfish spp.	7	4.4	11	4.2
Cymatogaster aggregata	Shiner perch	14	3.8	25	11
Osmerid spp.	smelt spp.	0	0	10	3.2
Osmerus mordax dentex	Rainbow smelt	0	0	2	0.47
Hypomesus pretiosus	Surf smelt	17	3.5	1	0.14
Thaleichthys pacificus	Eulachon	0	0	7	1.6
Gasteroseus aculeatus	Threespine stickleback	13	3.3	9	2.3
Scorpaenid spp.	rockfish spp.	4	2.3	38	12
Argentinid spp.	Argentine	2	1.5	0	0
Porichthys notatus	Plainfin midshipmen	6	1.2	16	4.7
Pholid spp.	gunnel spp.	3	1.2	7	0.97
Hexagrammid spp.	greenling spp.	3	0.95	1	0.14
Genus Rathbunella	ronquil spp.	4	0.98	0	0
Diaphus theta	California headlight fish	7	0.61	3	1.3
Zoarcid spp.	eelpout spp.	6	0.52	23	5.2
Lycodopis pacifica	Blackbelly eelpout	2	0.17	0	0
Petromyzontid spp.	lamprey spp.	2	0.17	9	1.3
Anarrhichthys ocellatus	Wolf-eel	1	0.09	0	0
Stenobrachius leucopsarus	Northern lampfish	1	0.72	1	0.33
Scomber japonicus	mackerel spp.	1	0.72	0	0
Not identifiable fish spp.		6	2.4	10	3.4
Unidentifiable fish spp.		17	3.2	6	2.4

Table 6. Frequency of occurrence (FO; expressed as percent) of prey species in Steller sea lions samples (n=12) collected on Bird and Whale Rocks during winter and spring, 2006-07

Scientific Name	Common Name	n	FO
Clupea pallasi	Pacific herring	2	17
Clupeid spp.	herring spp.	4	33
Gadidae spp.	codfish spp.	2	17
Theragra chalcogramma	Walleye pollock	1	8.3
Ammodytes hexapteras	Pacific sand lance	1	8.3
Squalus acanthias	Spiny dogfish	10	83
Pleuronectid spp.	righteye flounder spp.	2	17
Octopus rubescens		1	8.3
Not identifiable ceph. spp.	statolith only	1	8.3
Rajid spp.	skate spp.	11	92
Liparidid spp.	snailfish spp.	1	8.3
Gasteroseus aculeatus	Threespine stickleback	5	42
Scorpaenid spp.	rockfish spp.	1	8.3
Not identifiable fish spp.		2	17
Unidentifiable fish spp.		2	17

Figure 4. Frequency of occurrence (expressed as percent) of Clupeids, adult Salmon, Gadids, Pacific sand lance, Northern Anchovy, sculpins, shiner perch, rockfish and cephalopods in the diet of harbor seals in the San Juan Islands by season, 2006-07



Appendix 1. Number of harbor seals (Pv) hauled out and number of samples collected (n) by region, season and haulout location in the San Juan Islands, 2006-2007

	Spring:1 March - 30 April								Summer/Fall:1 August - 30 September								Winter: 1 December - 31 January							
	04/13/06		04/14/06		04/27/06		04/28/06		07/24/06		07/25/06		08/24/06		08/25/06		02/08/07		02/09/07		02/22/07		02/23/07	
	Pv	n	Pv	n	Pv	n	Pv	n	Pv	n	Pv	n	Pv	n	Pv	n	Pv	n	Pv	n	Pv	n	Pv	n
South Strait of Georgia:																								
Clements Reef W	12	0			90	4			160	6			50	9			40	0					45	1
Clements Reef E	0	0			80	0			140	0			140	8			0	0					0	0
West Matia													5	0										
North Matia	12	5			62	0			30	1							35	0					65	2
Puffin reef + island					85	0			120	2			210	11			0	0					0	0
Reef at The Sisters									50	0														
North Rosario Strait:																								
Boulder Reef					120	0			120	5			35	2			0	0			22	0		
North Peapod													20	11										
Middle Peapod					80	0			120	0											20	0		
South Peapod									35	0			35	18							2	0		
Cypress Reef																								
Spindle Rock													20	0							15	0		
Eastern Bays:																								
Eliza Rock	0	2			44	3					90	7	140	20			0	0			1	0		
Viti Island																								
Vendovi E side	0	4			92	8					9	9	60	15			0	15			20	15	1	0
South Rosario Strait:									*Seabird breeding restrictions (15 April - 31 August)*															
Pointer Island															30	6								
Bird Rocks			0	4			0	0							0	14			35	0	90	7	60	2
Williamson rock							0	0											40	0	6	0		
Coville Island S side																								
South San Juan Channel:																								
Rks. East of Charles Is.																								
So. Side Long Is.																								
Whale Rock			0	0			280	0			200	17			45	26			0	5	1	0		
Goose Island			25	32			13	29			45	12			6	9			20	2	40	10		
Shark Reef																								
Turn Rock																								
North San Juan Channel:																								
Flattop															160	9								
Yellow Island W side																								
Jones Island E side																								
Sentinel Reef							100	6	80	18					30	12	30	0					92	2
Speiden Is S side																								
Shag Reef																								
Gull Reef															55	6								
Ripple Island							35	0							60	2	0	0					12	0
White Rock																							135	2
Bare Island																								