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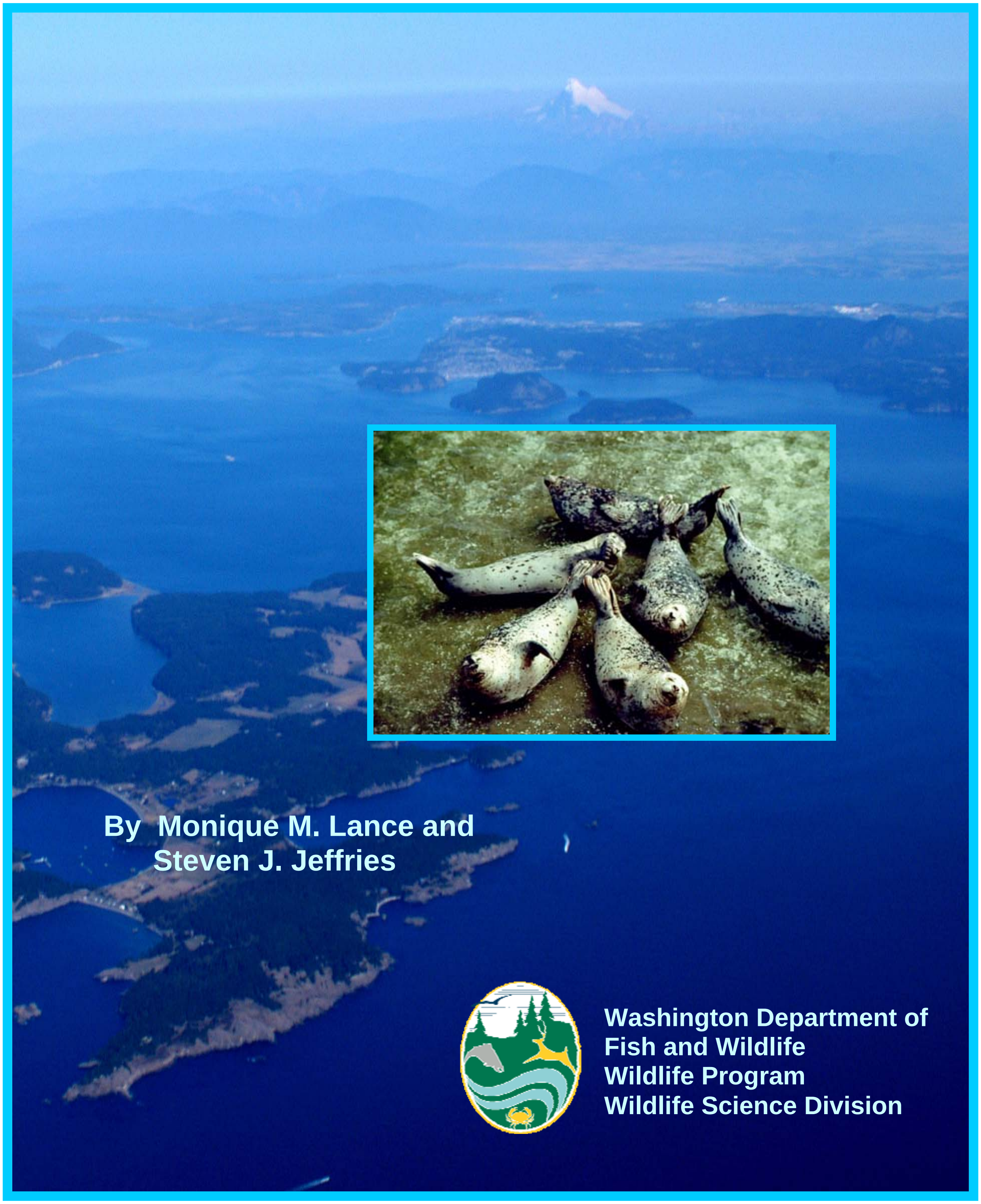
ESTIMATING IMPORTANCE OF ROCKFISH, LINGCOD AND OTHER BOTTOMFISH IN THE DIET OF HARBOR SEALS IN THE SAN JUAN ISLANDS



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Estimating importance of rockfish, lingcod and other bottomfish in the diet of harbor seals in the San Juan Islands

Final Report
U.C. Davis Wildlife Health Center
SeaDoc Society

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Abstract

Harbor seals are the most abundant pinniped species in the inland waters of Washington east of Cape Flattery, numbering nearly 15,000 animals and are important upper trophic level predators. In the San Juan Islands, harbor seals are the most commonly seen pinniped and use over 150 sites as haulout locations. This study uses percent frequency of occurrence of prey species in fecal samples (scats) collected from rocky habitat haul outs in the San Juan Islands to describe overall diet and determine importance of rockfish, lingcod and other bottom fish in the diet of harbor seals, a primarily piscivorous apex predator. 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%). Diet differed among seasons with Gadids, Pacific herring and Pacific sand lance important during spring, adult salmonids and Pacific herring during summer/fall and Pacific herring, Northern anchovy, Gadids, Pacific sand lance and Spiny dogfish during winter. Overall, Rockfish and Hexagrammid (lingcod and greenling) remains were found in only 2.3% and 1.0% of samples collected, respectively. Mean number of different prey species differed among seasons with winter diet the most diverse, 3.59 different prey species and summer/fall and spring less so with 1.72 and 2.14 different prey species, respectively. In general, species composition in harbor seal diet was comparable to fish abundance based on bottom trawl data and salmon return abundance timing in the San Juan Islands. We suggest these data are an important component for assessing how predator populations, specifically harbor seals, may impact fish populations and overall biodiversity in the San Juan Islands.

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Introduction

Harbor seals are the most abundant upper trophic level predator in the inland waters of Washington with an estimated population of nearly 15,000 animals (Jeffries et al. 2003). Diet studies using scat analysis have shown that harbor seals are opportunistic consumers, with the majority of their diet consisting of prey species that are seasonally and locally abundant. For example, harbor seal diet in the Strait of Georgia and Hood Canal, while diverse, was composed primarily of Pacific hake and Pacific herring (Calambokidis et al. 1989, Olesiuk et al. 1990, London et al. 2000). At Smith Island in the Strait of Juan de Fuca, Pacific herring and eelpouts were identified as important prey species of harbor seals (Calambokidis et al.1978). The fish species consumed at these sites were locally abundant during these studies. Harbor seals exhibit seasonally high site fidelity to both haul out sites and individual foraging locations (Olesiuk 1999, WDFW unpub. data). A study conducted in the San Juan Islands showed individual harbor seals typically used haulout sites that were less than 5.6 km from foraging areas (Suryan and Harvey 1998). Here, we use scat analysis as a reliable way to investigate relative importance (frequency of occurrence) of prey species in harbor seal diet over time and space throughout the San Juan Islands.

Scat analysis of harbor seal diet in the San Juan Islands based had not been investigated previously; however, harbor seals were observed feeding on Pacific herring and salmon in tiderips during the summer of 1992 (Suryan and Harvey 1998). In 1992, scat samples were collected north of the San Juan Islands during July-September from haulout sites in Drayton Harbor located near Blaine, Washington. Drayton Harbor is a relatively shallow, estuarine environment and consequently diet was composed primarily of staghorn sculpin, snake prickleback, shiner surfperch, three-spine stickleback and salmon (WDFW unpublished data).

The importance of rockfish species, lingcod and other bottomfish in the diet of harbor seals varies along the west coast by season, location and habitat type. In harbor seal scats collected from haulout sites located at the entrance to the Rogue River in southern Oregon, rockfish species ranged from 10–39 percent frequency of occurrence in 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 harbor seal diet and ranged from 4-7 percent and lingcod was less than 1 percent (Riemer et al. 1999). In the Strait of Georgia, the prevalence of rockfish (68 of 2917 samples) and hexagrammids (83 of 2917) in harbor seal diet year-round was relatively low, 2.3% and 2.8%, respectively (Olesiuk et al. 1990)

In this study, we assessed the importance of rockfish species, lingcod and other bottomfish in harbor seal diet using scat analysis. Scat analysis allowed us to describe all prey species in their diet using both bone and otolith identification and allowed us to obtain a large sample size from a large geographic area. Based on published literature, we assumed the following four statements were true: 1. harbor seals eat what is seasonally and locally abundant in the San Juan Islands; 2. 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; 3. hard parts (bones, otoliths, squid beaks) found in scats are representative of species being consumed by seals; and 4. Marine Protected Areas support a complex habitat structure and provide refuge for fish to grow and mature. Understanding the impact of predators like harbor seals to the recovery of fish stocks within Marine Protected Areas is important to understanding the 'success' of Marine Protected Areas in increasing biodiversity.

Hypotheses and Specific Aims

Hypotheses:

1. Harbor seal diet composition in the San Juan Islands reflects seasonally and locally abundant prey resources.

2. Prey species found in the diet of harbor seals overlaps species composition of Marine Protected Areas.

Assumptions:

1. Harbor seals are opportunistic predators and prey upon seasonally and locally abundant prey species in the San Juan Islands.
2. 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.
3. Marine Protected Areas support a complex habitat structure and provide refuge for fish to grow and mature and these fish are available to harbor seals.
4. Hard parts (bones, otoliths, squid beaks) found in scats are representative of species being consumed by harbor seals.

Specific Aims:

1. Describe the relative importance of each prey species or family in the diet of harbor seals in the San Juan Islands.
2. Estimate the size (age) of rockfish (to species if possible), lingcod and other bottom fish being consumed by harbor seals in the San Juan Islands.
3. Determine if there are significant differences in diet by season and how this compares to fish composition data.

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', 'East Rosario Strait', 'South Rosario Strait', 'South San Juan Channel', and 'North San Juan Channel' (Figs. 1-3). A scat collection goal was set at a minimum of 50 scat samples within a given season for each region. Effort was adjusted to ensure a minimum of 150 scats per season to allow for meaningful statistical analyses. Haulout locations on rocks or islands with important seabird colonies prohibited collections during critical seabird nesting and breeding periods at some sites from late April through August. Samples were collected in either plastic ‘Whirlpak’ bags if collected on sand or pebble beaches or in fine mesh paint strainer bags and frozen until processing.

Sample processing. Samples were washed 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 collection collected from Washington and Oregon, and published bone and 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.). Otoliths were identified and aged by interpreting growth patterns using methods consistent with ageing marine fish by WDFW Marine Fish Ageing 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 the 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). We report diet diversity (average number of prey species per sample) and we compared 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 WDFW, Puget Sound Salmon Management.

Results

Diet composition. During three collection periods (‘spring’, ‘summer/fall’ and ‘winter’), a total of 509 scats were collected from 18 sites distributed throughout the San Juan Islands (Figs. 1-3, Appendix 1). Data analyses were based on the 99.6% of harbor seal scats (507 of 509 collected) that contained identifiable prey. Marine and anadromous fishes were found in all samples analyzed and cephalopods occurred in 6.8% of samples. Diet included 35 species from 25 different families. Individual samples typically contained one to three (mean = 1.95) different prey species, but occasionally contained as many as eleven.

Overall, harbor seals fed primarily on Pacific herring (57% occurrence), adult Salmonid species (26%), Gadid species (24%), and Pacific sand lance (20%) in the San Juan Islands (Table 1). Other important species that occurred in greater than three percent of samples were, in decreasing order of importance, Northern anchovy, Walleye pollock, Spiny dogfish, sculpin species, flatfish species, cephalopods (octopus and squids), skate species, snailfish species, Shiner perch, Surf smelt, and Threespine stickleback (Table 1). Scientific names of marine fish species 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 3.59 different prey species. Mean number of different prey species in samples collected during winter and summer/fall were 2.14 and 1.72, respectively.

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 from scats because the bones recovered are not species specific. Of the 287 samples that contained adult salmonid remains, 30 otoliths were identifiable to species and of those 25 (83%) were identified as Pink salmon (Table 1). Otoliths from other adult salmon species were found in different samples and included chinook (1 otolith), sockeye (1 otolith) and chum (3 otoliths).

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

Gadid species were important prey species in the San Juan Islands primarily during winter and spring. 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 species because bones recovered were not species specific. Walleye pollock occurred in over 40% of harbor seal samples collected during spring and was also present in samples collected during both summer/fall and winter collection periods (Table 1).

Seasonal changes in diet composition in the San Juan Islands are shown in Figures 4 and 5. Gadids (Gadid species, Walleye pollock and Pacific hake), Clupeids (Pacific herring and Clupeid species), and Pacific sand lance were the three most important prey species in seal diet during spring (Table 1, Fig. 4). Pacific herring remained important during summer/fall, but summer/fall diet was dominated by returning adult salmonid species. Clupeids were found in over 65% of samples collected during the winter, but harbor seal diet also became more varied with Northern anchovy, Gadid species, Pacific sand lance, Spiny dogfish, skates, cottid species, flatfish species, snailfish species and cephalopods all found in greater than 13% of samples collected (Figs. 4 and 5).

A comparison among seasons of samples collected within the South San Juan Channel region illustrates a dramatic seasonal shift in diet. Over 80% of samples collected during winter and spring contained Pacific herring, whereas over 80% of samples collected during summer/fall contained adult salmon (Table 2). Both Gadids and Pacific sand lance were in greater than 30% of samples collected during winter and spring and almost absent during summer/fall collections. Northern anchovy and Spiny dogfish appeared in the winter diet and Walleye Pollock occurred more frequently in spring. Similar analyses in other regions were not possible because of inadequate 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 collection periods. This resulted in difficulty in collecting additional scat samples desired for analysis purposes. 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 (Appendix 1).

Rockfish, lingcod and other bottom fish. Overall, Rockfish remains were found in only four samples (2.3%, Table 1). Two samples collected at Goose Island during winter contained bones only and species identification was not possible. Two samples contained otoliths, one collected at Puffin Island during summer/fall was age 2 and most likely Yellowtail rockfish (*Sebastes flavidus*) and the other collected at Bird Rocks during winter was age 2 and most likely Black rockfish (*Sebastes melanops*). Both otoliths were whole, but eroded and this prevented complete confidence in rockfish species identification.

Hexagrammid species (greenling and lingcod) remains were found in three scat samples (1.0%). Two samples containing greenling were collected during spring, one from Clements Reef and one from Vendovi Island. The other sample containing greenling was collected during summer/fall from Bird Rocks.

Discussion

Diet composition. Harbor seals fed on adult salmonids, Pacific herring, Pacific sand lance and gadid species in the San Juan Islands during spring and summer/fall 2005, and winter 2006. These results are similar to other studies in close proximity to the San Juan Islands and elsewhere that show that harbor seals feed primarily on adult salmonids (when they are abundant), small schooling fish and gadid species (Calambokidis et al. 1989, Olesiuk et al. 1990, London et al. 2000).

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 WDFW in the San Juan Islands during May and June of 2001 (Palsson et al. 2003). While gadid species were found in harbor seal diet during all seasons and in a high percentage of samples collected in the spring and winter, Spotted ratfish did not appear in the diet. We speculate harbor seals do not consume this numerous species because they have a serrate, venomous dorsal spine (Hart 1973). English sole and Dover sole, as well as Pleuronectid species all 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 sample schooling forage fishes.

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. WDFW and others have conducted extensive surveys to map and protect spawning habitat for Pacific herring, Pacific sand lance and

Surf smelt. Despite the large proportion of Pacific herring found in harbor seal diet year round, North Puget Sound Pacific herring stock profiles indicate that three stocks are depressed (Fidalgo Bay, Interior San Juan Islands, Semiahmoo Bay), two stocks are critical (Northwest San Juan Island, Cherry Point) and only one is considered moderately healthy (Samish/Portage Bay) based on 25 year spawning biomass estimates (Stick 2005). Pacific sand lance occurred in approximately 25% of samples collected during winter and spring and is receiving more attention recently for its importance in the Puget Sound food web (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 WDFW 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 the winter 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 WDFW, 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 (Wilson and Manuwal 1985).

The predominance 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 at that time of year. In 2005, approximately 5.6 and 7.3 million sockeye and pink salmon, respectively were estimated to have passed through inland waters of Washington and British Columbia while returning to the Fraser River. Peak entry of sockeye salmon to the Fraser River occurred in mid-late August and peak entry of pink salmon occurred in early-mid September (K. Adicks, WDFW, pers. comm.). Sockeye and pink salmon far outnumbered other salmonid species in the San Juan Islands during early September when diet was sampled in this study and relative abundance of pink salmon in the San Juan Islands was considerably higher than sockeye salmon. These data indicate that although harbor seals may eat most, if not all, salmon species, pink salmon was the most important and preferred salmon species consumed during the summer/fall collection period. We suggest their preference for Pink salmon over Sockeye salmon may be driven by abundance or the slightly smaller size of Pink salmon (3-4 pounds) relative to Sockeye salmon (5-6 pounds) makes them easier for a harbor seal to consume. In Hood Canal, average handling time by harbor seals of Pink salmon (4.90 minutes) was nearly half that of Chum and Coho salmon (8.89 and 8.15, respectively) based on predation observations (London 2006).

Pink salmon return to their natal streams during only odd years (e.g. 2005). Investigating which prey species replaces the large proportion of Pink salmon in the diet in years when it is unavailable warrants examination. 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. 2000, Olesiuk et al. 1990, Orr et al. 2004). In this study, harbor seals are feeding on salmon in “open” areas as they funnel through the narrow passages in the San Juan Islands. A high proportion of salmon was found in harbor seal diet in Johnstone Strait (30% of diet in July and September), which is another area where salmon funnel through passes (Olesiuk et al. 1990). Interestingly, salmon moving through these areas also attract Killer whales (*Orcinus orca*).

Rockfish, lingcod and other bottom fish. We are not completely confidant in our Rockfish otolith identifications, however Black and Yellowtail rockfish are two of the nineteen species of rockfish that have been observed in the San Juan Islands. Black rockfish were abundant 15 years ago, but are considered rare today and no mature, adult Yellowtail rockfish have been reported in the San Juan Islands and young, sub-adult fish and their populations have declined in the past 10-15 years as well (Wyllie-Echeverria and Sato 2005). Both otoliths recovered were from juvenile (2 year old) fish.

Rockfish and lingcod did not constitute a large percentage of harbor seal diet overall, but we suggest this small amount of predation may be important when harbor seal and rockfish populations are put into context. When other prey species such as, adult salmon, clupeids and gadids are abundant, rockfish may be "buffered" from predation. During winter, harbor seal diet becomes more diverse and we suggest this may be a period of time when rockfish, lingcod and other bottom fish would be more likely to be consumed.

The 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, pers. comm.).

Several categories of Marine Protected Areas exist in the San Juan Archipelago. The San Juan County/Cypress Island Marine Biological Preserve was established in 1923 and encompasses all of the Marine Protected Areas in San Juan County, and the Cypress Island Natural Resources Conservation Area. There are voluntary and statutory Marine Refuges (no fishing), Conservation Areas (all harvest closed) and Marine Preserves (harvest of most species closed) designated within this preserve throughout the San Juan Islands with some established as recently as 1990 (Murray 1998). Marine Protected Areas provide an opportunity to examine how these management actions may influence seal foraging ecology and diet. Fishes such as rockfish and some lingcod have been shown to spend the majority of their life in very small areas on rocky reefs, and their populations have been shown to be in poor condition in many or all areas of Puget Sound including the San Juan Islands (PSAT 2002, W. Palsson, WDFW, pers. comm.). 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 fish species composition of Marine Protected Areas in the San Juan Islands are still being investigated, these no-take refuges have been established to protect bottomfish and other species and research on their effectiveness is ongoing.

Over time, protection of fish resources within and around Marine Protected Areas should result in an increase in fish abundance, diversity and size, which in turn would be reflected in harbor seal diet. This study investigated the importance of rockfish, lingcod and other bottom fish in the diet of harbor seals in the San Juan Islands during one year. If voluntary 'no take' zones around Marine Protected Areas allow fish to grow larger and increase fish diversity, over time harbor seals may forage preferentially in these areas. If this occurs, we would expect this change in prey abundance to influence harbor seal diet within and adjacent to Marine Protected Areas. We will continue to explore these questions with a second year of data and increased sampling.

Significance to SeaDoc Society

This SeaDoc funded study provides new information necessary to understand the role of upper trophic level predators (e.g. harbor seals) in the San Juan Islands ecosystem and in Marine Protected Areas designed to recover fish stocks. Harbor seals were shown to consume a wide variety of prey species, with adult salmon, gadids and clupeids dominating their diet. Seasonal abundance played a key role in these dynamic relationships. Overall, rockfish, lingcod and other bottom fish composed a small percentage of diet and our results suggest that either there were very few rockfish, lingcod and other bottomfish species in the area for harbor seals to consume or harbor seals were not a significant predator on these species during 2005-2006.

Understanding the role fish predators (e.g. harbor seals) play in Marine Protected Areas designed to recover fish stocks is an important component when evaluating their 'success'. Multi-year research efforts focusing on top-level predators are essential to examining and understanding ecosystem health as harbor seal populations in the San Juan Islands are robust and multiple marine fish populations including, Pacific herring, several rockfish species and Pacific hake are declining. SeaDoc has funded an additional year to examine interannual variation in harbor seal diet and increase sample sizes to allow for statistical comparisons among seasons and regions. We believe these data will provide insight into multispecies and community effects outside of Marine Protected Area boundaries by examining changes in fish composition and size 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 2005-2006 (this grant) and 2006-2007 (current SeaDoc grant). We anticipate submitting for review during summer/fall 2007.

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

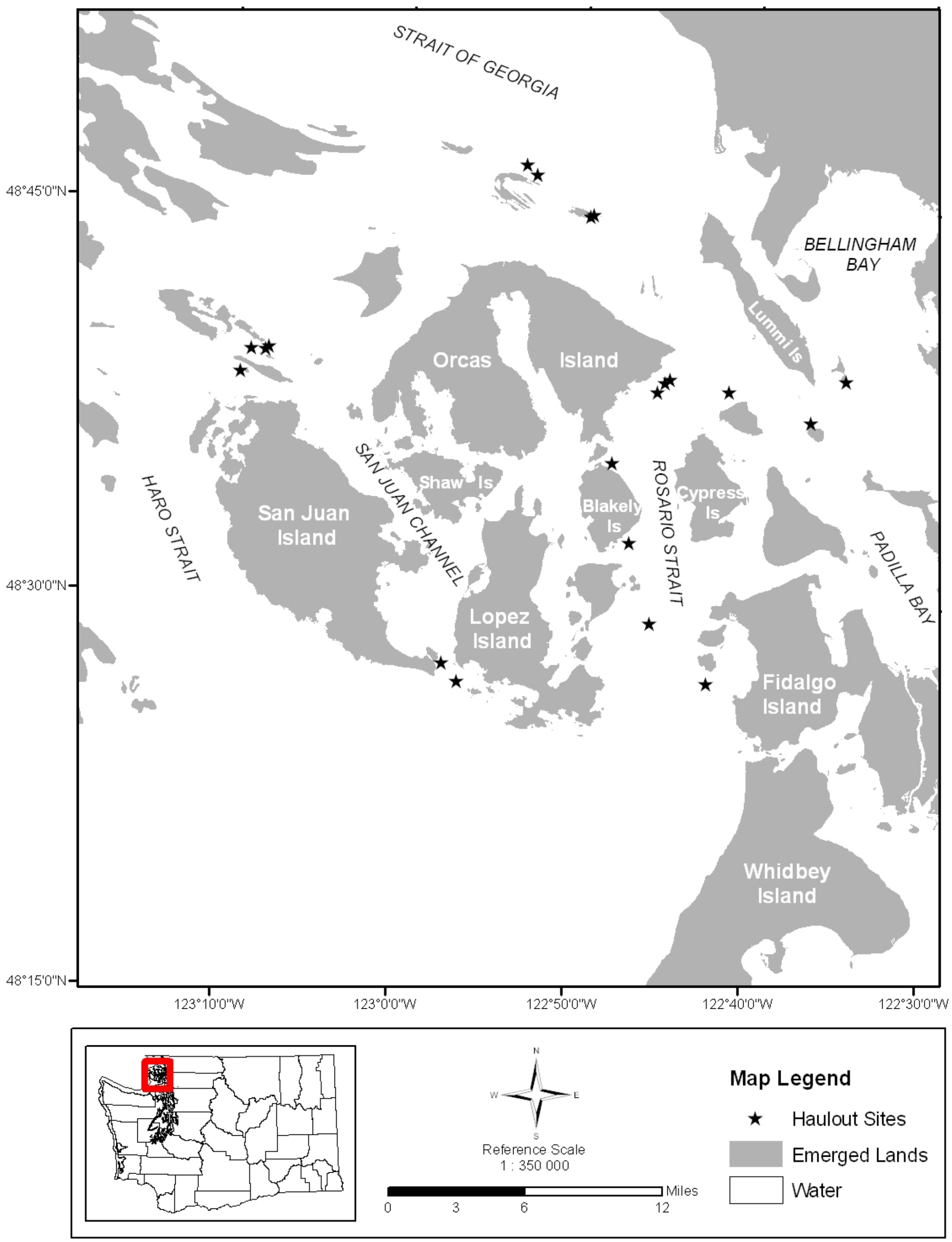


Figure 2. Map of the eastern portion of the San Juan Islands with names of reefs and islands where samples were collected

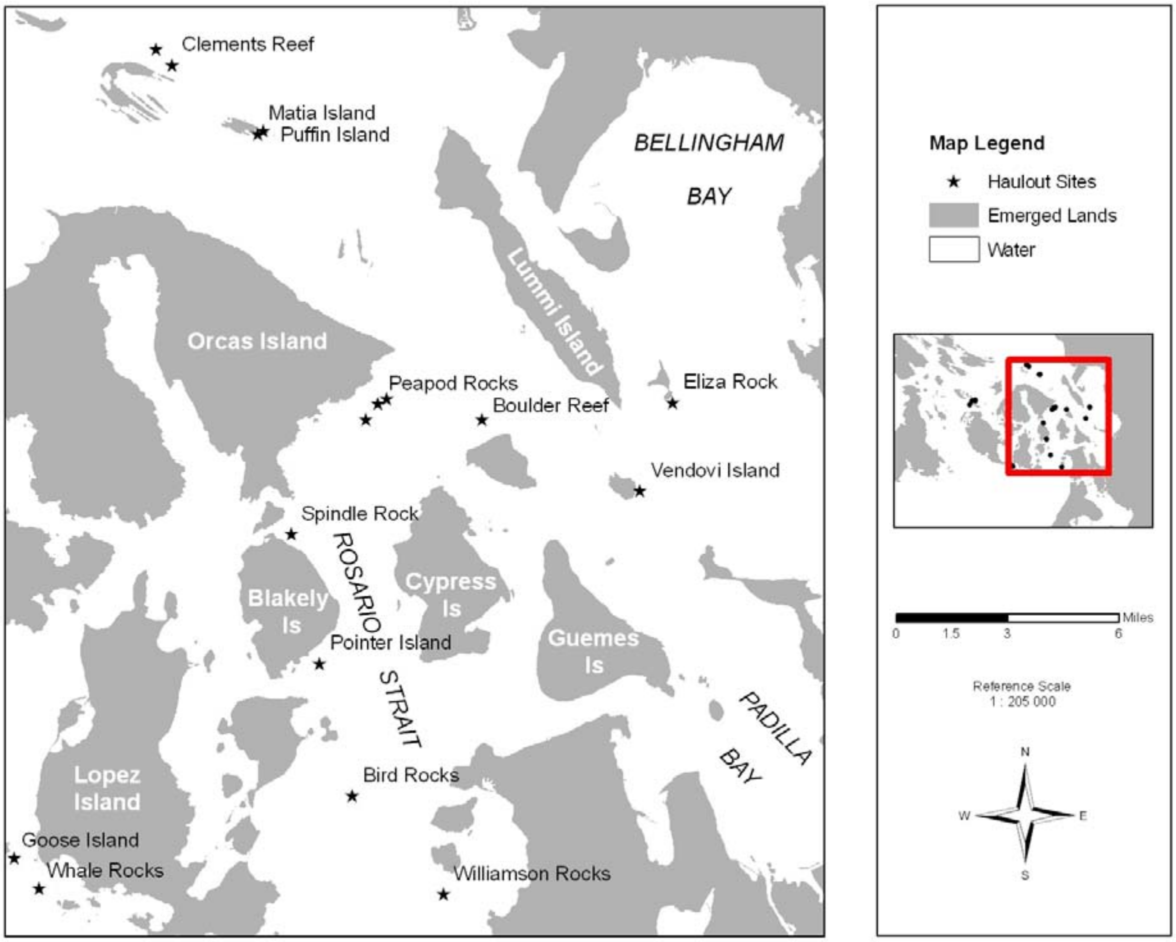


Figure 3. Map of the western portion of the San Juan Islands with names of reefs and islands where samples were collected

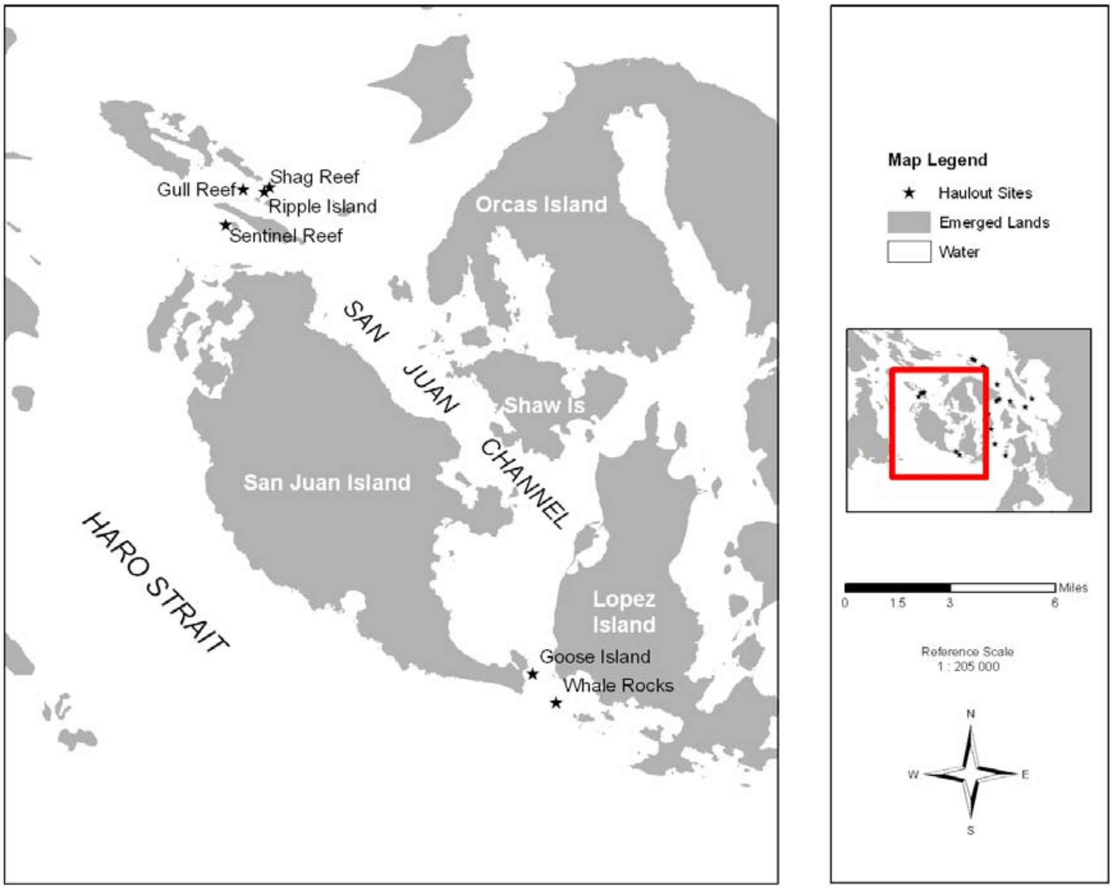


Table 1. Percentage occurrence (FO) and overall weighted average of prey species in the diet of harbor seals by season in the San Juan Islands, 2005-06

		Spring		Summer/Fall		Winter		Overall (wt)	
Scientific Name	Common Name	n=77	FO	n=384	FO	n=46	FO	n=507	FO
* All Clupeids		57	74	147	38	32	70	236	61
Clupea pallasi	Pacific herring	55	71	135	35	29	63	219	57
Clupeid spp.	herring spp.	2	2.6	11	2.9	1	2.2	14	2.5
Alosa sapidissima	American Shad	0	0	1	0.26	2	4.35	3	1.5
* All Gadids		60	78	37	10	17	37	114	42
Gadidae spp.	codfish spp.	29	38	16	4	14	30	59	24
Theragra chalcogramma	Walleye pollock	31	40	19	5	3	7	53	17
Merluccius productus	Pacific hake	0	0	2	0.52	0	0	2	0.2
* All Salmonids		0	0	307	80	6	13	313	31
Adult Salmonid spp.		0	0	251	65	6	13	257	26
Oncorhynchus gorbuscha	Pink Salmon	0	0	25	6.51	0	0	25	2.2
Oncorhynchus tshawytscha	Chinook Salmon (ad)	0	0	1	1.3	0	0	1	0.4
Oncorhynchus keta	Chum Salmon	0	0	3	0.78	0	0	3	0.3
Oncorhynchus nerka	Sockeye Salmon	0	0	1	0.26	0	0	1	0.1
Juvenile Salmonid spp.		0	0	22	5.73	0	0	22	1.9
Oncorhynchus tshawytscha	Chinook Salmon (juv)	0	0	4	1.3	0	0	4	0.4
Ammodytes hexapteras	Pacific sand lance	17	22	36	9	13	28	66	20
Engraulis mordax	Northern anchovy	4	5.2	2	0.5	23	50.0	29	19
Squalus acanthias	Spiny dogfish	0	0	2	0.52	17	37	19	12
* All Cottids		3	3.9	24	6.3	8	17.4	35	9.2
Cottid spp.	sculpin spp.	1	1.3	10	2.6	6	13.0	17	5.6
Leptocottus armatus	Pacific staghorn sculpin	2	2.6	6	1.6	2	4.4	10	2.8
Hemilepidotus spp.	irish lord spp.	0	0	8	2.08	0	0	8	0.7
* All Flatfish		1	1.3	23	6.0	6	13.0	30	6.8
Pleuronectid spp.	righteye flounder spp.	1	1.3	7	1.8	1	2.2	9	1.8
Platichthys stellatus	Starry flounder	0	0	4	1.04	3	6.52	7	2.5
Pleuronectes vetulus	English Sole	0	0	7	1.82	0	0	7	0.6
Microstomus pacificus	Dover sole	0	0	4	1.04	1	2.17	5	1.1
Bothid spp.	lefteye flounder spp.	0	0	1	0.26	1	2.17	2	0.8
* All Cephalopods		3	3.9	13	3.4	6	13.0	22	6.8
Octopus rubescens		2	2.6	6	1.6	1	2.2	9	2.1
Berryteuthis magister		0	0	5	1.3	2	4.35	7	1.9
Loligo opalescens	Market squid	1	1.3	1	0.3	2	4.4	4	2.0
Gonatidae spp.		0	0	0	0	1	2.17	1	0.7
Unknown cephalopod		0	0	1	0.26	0	0	1	0.1
Rajid spp.	skate spp.	2	2.6	1	0.3	7	15.2	10	6.0
Liparidid spp.	snailfish spp.	0	0	1	0.26	6	13	7	4.4
Cymatogaster aggregata	Shiner perch	2	2.6	9	2.3	3	6.5	14	3.8
Hypomesus pretiosus	Surf smelt	2	2.6	13	3.4	2	4.4	17	3.4
Gasteroseus aculeatus	Threespine stickleback	5	0	4	1.04	4	8.7	13	3.2
Scorpaenid spp.	rockfish spp.	0	0	1	0.26	3	6.52	4	2.3
Argentinid spp.	Argentine	0	0	0	0	2	4.35	2	1.5
Porichthys notatus	Plainfin midshipmen	2	2.6	4	1.0	0	0.0	6	1.2
Pholid spp.	gunnel spp.	1	1.3	1	0.3	1	2.2	3	1.2
Hexagrammid spp.	greenling spp.	2	2.6	1	0.3	0	0.0	3	1.0
Genus Rathbunella	ronquil spp.	0	0	3	0.78	1	2.17	4	1.0
Diaphus theta	California headlight fish	0	0	7	1.82	0	0	7	0.6
Zoarcid spp.	eelpout spp.	0	0	6	1.56	0	0	6	0.5
Lycodopis pacifica	Blackbelly eelpout	0	0	2	0.52	0	0	2	0.2
Petromyzontid spp.	lamprey spp.	0	0	2	0.52	0	0	2	0.2
Anarrhichthys ocellatus	Wolf-eel	0	0	1	0.26	0	0	1	0.1
Stenobrachius leucopsarus	Northern lampfish	0	0	0	0	1	2.17	1	0.7
Scomber japonicus	mackerel spp.	0	0	0	0	1	2.17	1	0.7
Not identifiable fish spp.		0	0	3	0.78	3	6.52	6	2.4
Unidentifiable fish spp.		3	3.9	13	3.4	1	2.2	17	3.2

Table 2. Percentage occurrence (FO) of prey species in the South San Juan Channel by season, 2005-2006

		Spring		Summer/Fall		Winter	
Scientific Name	Common Name	n = 42	FO	n = 56	FO	n = 32	FO
* All Clupeids		37	88	13	23	29	91
Clupea pallasi	Pacific herring	37	88	13	23	26	81
Clupeid spp.	herring spp.	0	0	0	0	1	3.1
Alosa sapidissima	American Shad	0	0	0	0	2	6.3
* All Gadids		31	74	3	5.4	15	47
Gadidae spp.	codfish spp.	13	31	2	3.6	13	41
Theragra chalcogramma	Walleye pollock	18	43	1	1.8	2	6.3
* All Salmonids		0	0	54	96	4	13
Salmonid spp.	adult salmonid spp.	0	0	47	84	4	13
Oncorhynchus gorbuscha	Pink Salmon	0	0	5	8.9	0	0
Oncorhynchus nerka	Sockeye Salmon	0	0	1	1.8	0	0
Salmonid spp.	juvenile salmonid spp.	0	0	1	1.8	0	0
Ammodytes hexapteras	Pacific sand lance	15	36	8	14	12	38
Engraulis mordax	Northern anchovy	3	7.1	0	0	22	69
Squalus acanthias	Spiny dogfish	0	0	0	0	7	22
Cottid spp.	sculpin spp.	0	0	0	0	3	9.4
* All Flatfish		0	0	0	0	4	13
Platichthys stellatus	Starry flounder	0	0	0	0	2	6.3
Microstomus pacificus	Dover sole	0	0	0	0	1	3.1
Bothid spp.	lefteye flounder spp.	0	0	0	0	1	3.1
* All cephalopods		3	7.1	0	0	4	13
Octopus rubescens		2	4.8	0	0	0	0
Berryteuthis magister		0	0	0	0	2	6.3
Loligo opalescens	Market squid	1	2.4	0	0	2	6.3
Rajid spp.	skate spp.	1	2.4	0	0	1	3.1
Liparidid spp.	snailfish spp.	0	0	0	0	3	9.4
Cymatogaster aggregata	Shiner perch	0	0	1	1.8	1	3.1
Hypomesus pretiosus	Surf smelt	0	0	1	1.8	2	6.3
Gasteroseus aculeatus	Threespine stickleback	3	7.1	1	1.8	3	9.4
Scorpaenid spp.	rockfish spp.	0	0	0	0	2	6.3
Argentinid spp.	Argentine	0	0	0	0	2	6.3
Pholid spp.	gunnel spp.	0	0	0	0	1	3.1
Genus Rathbunella	ronquil spp.	0	0	0	0	1	3.1
Stenobrachius leucopsarus	Northern lampfish	0	0	0	0	1	3.1
Scomber japonicus	mackerel spp.	0	0	0	0	1	3.1
Not identifiable fish spp.		0	0	0	0	2	6.3
Unidentifiable fish spp.		2	4.8	0	0	0	0

Figure 4. Percentage occurrence of Salmon, Gadids, Clupeids, Pacific Sand lance, Northern Anchovy and Spiny dogfish in the diet of harbor seals in the San Juan Islands by season, 2005-06

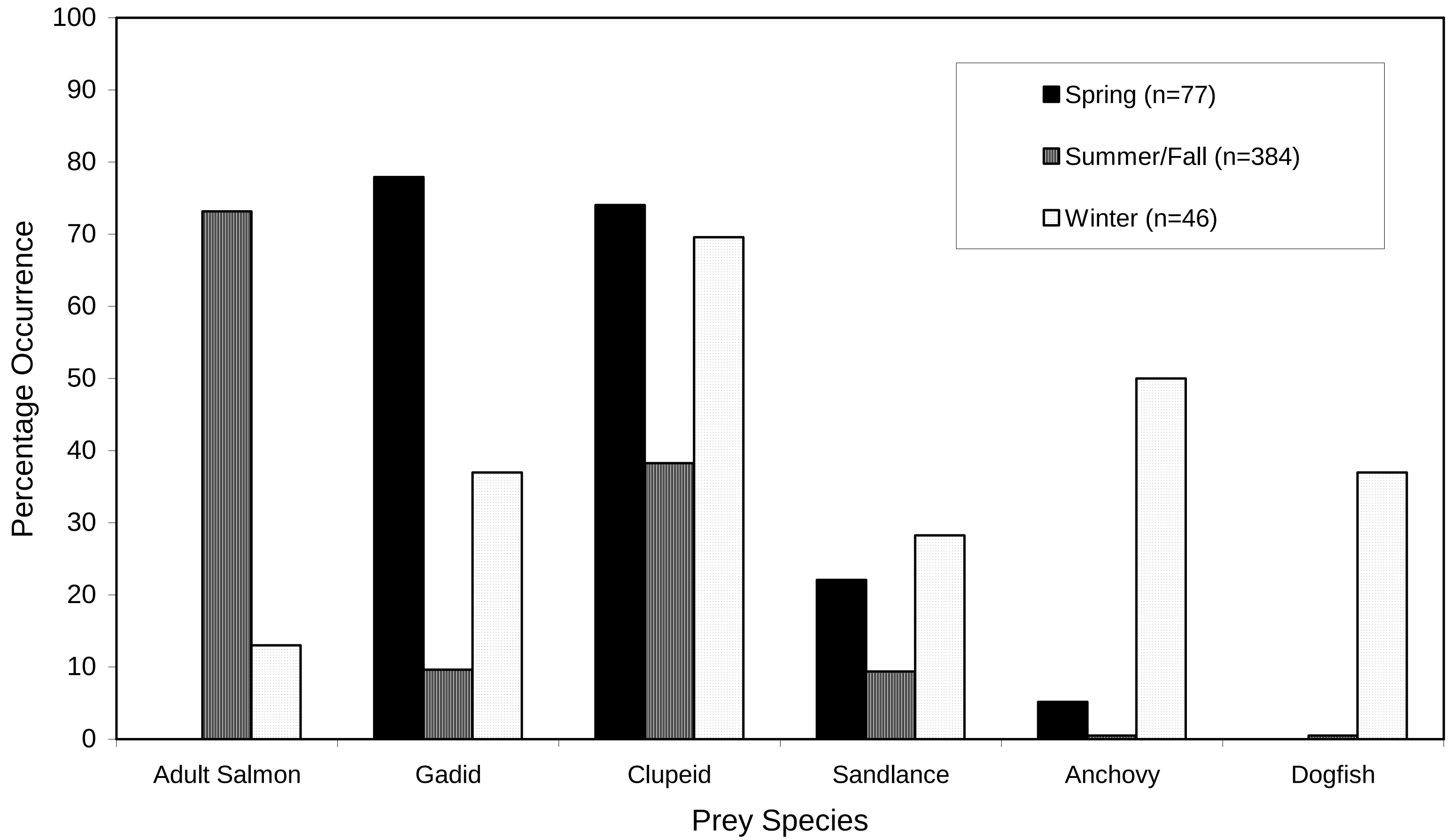
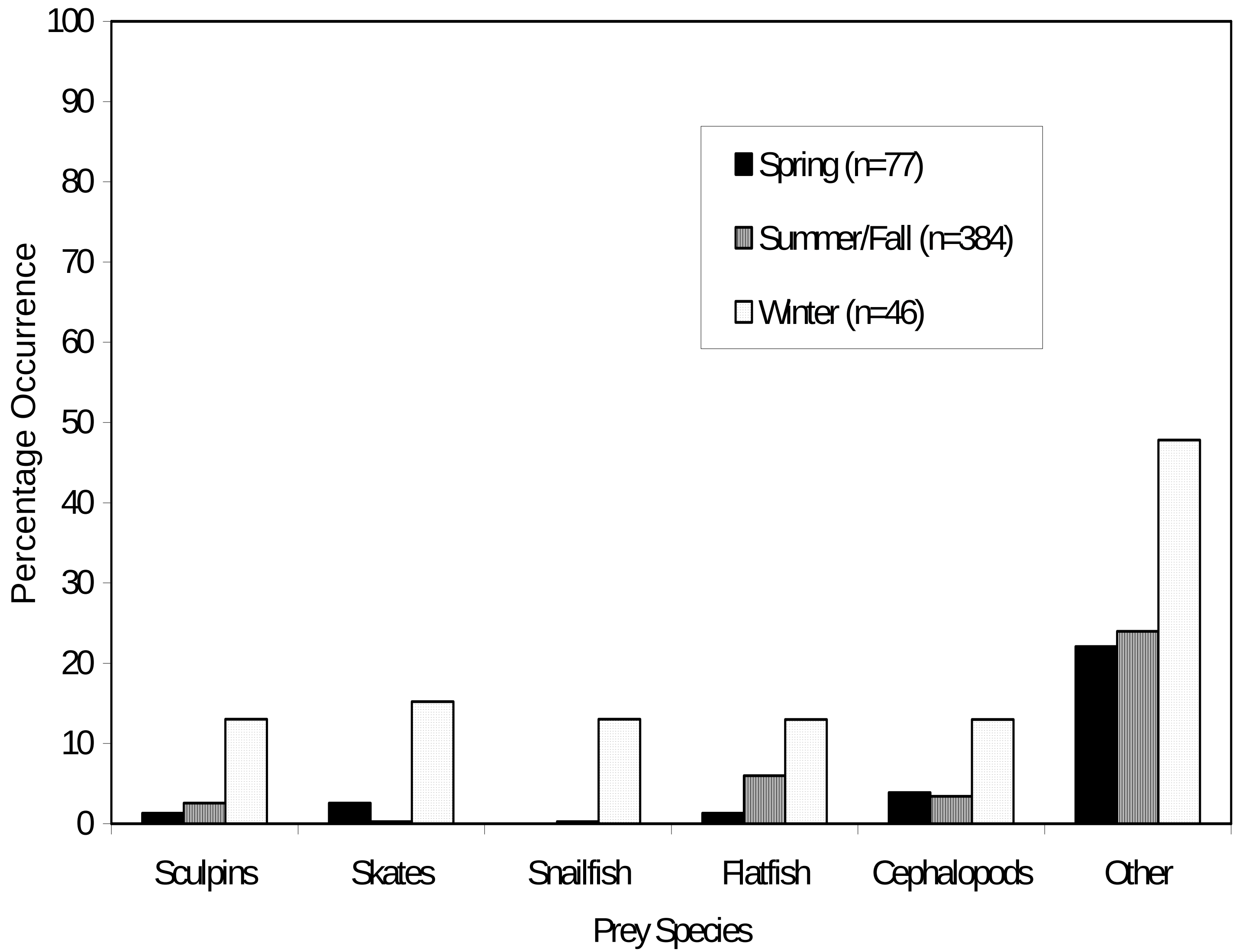


Figure 5. Percentage occurrence of Sculpins, Skates, Snailfish, Flatfish, Cephalopods and other species in the diet of harbor seals in the San Juan Islands by season, 2005-06



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, 2005-2006

	Spring:1 March - 30 April								Summer/Fall:1 August - 30 September						WINTER: 1 December - 31 January							
	04/01/05		04/02/05		04/10/05		04/11/05		09/01/05		09/02/05		09/03/05		02/02/06		02/03/06		02/16/06		02/17/06	
	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			85	20	47	2	145	0	145	31							6	0				
Clements Reef E							15	0									0	0				
West Matia			50	1	0	0	13	0														
North Matia			150	8	75	0	81	0	18	9							6	4				
Puffin reef + island							46	0	145	34												
Reef at The Sisters																						
North Rosario Strait:																						
Boulder Reef	40	0			0	0			40	28									0	0		
North Peapod	40	0																				
Middle Peapod	100	0																				
South Peapod					0	0							55	41	0	0			0	0		
Cypress Reef	30	0																				
Spindle Rock	70	0											62	5	0	0			0	0		
Eastern Rosario Strait:																						
Eliza Rock											145	34					0	0	0	0		
Viti Island											75	0										
Vendovi E side	40	0			25	4			120	25							0	0	0			
South Rosario Strait:			*Seabird breeding restrictions*																			
Pointer Island													40	10							0	0
Bird Rocks											80	28			50	1					25	10
Williamson rock													85	21	10	0						
Coville Island S side											50	0			15	0						
South San Juan Channel:																						
Rks. East of Charles Is.							10	0														
So. Side Long Is.															12	0						
Whale Rock							6	0			93	40			0	7					0	0
Goose Island							25	42			0	16			60	25					60	2
Shark Reef							25	0														
Turn Rock							0	0			0	0										
North San Juan Channel:																						
Yellow Island W side					30	0																
Jones Island E side							35	0														
Sentinel Reef					40	0							40	34			4	0			30	0
Speiden Is S side													30	0			0	0				
Shag Reef					40	0							0	1			0	0			15	0
Gull Reef					80	0							1	1			0	0				
Ripple Island													0	27			0	0			0	0
White Rock					100	0																
Bare Island																	1	0				