

Harbor seal diet in Hood Canal, South Puget Sound and the San Juan Island archipelago

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**Final Report
Studies of Expanding Pinniped Populations
Pacific States Marine Fisheries Commission**

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Abstract

Harbor seals are the most abundant resident pinniped species in Puget Sound. 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 river mouths in Hood Canal, sandy haulouts in South Puget Sound and rocky island and reef haul outs in the San Juan Islands to describe diet seasonally and regionally and to examine potential changes in diet over time.

In Hood Canal during fall (1998-2001 and 2003-2005), harbor seals fed mainly on Pacific hake (occurring in 79% of samples), Pacific herring (30%) and adult salmonids (26%). Diet shifted during spring (1999 and 2005) with Pacific hake (85%) and Pacific herring (26%) remaining important, but Northern anchovy (35%) increasing significantly and adult salmonids (8%) decreasing significantly.

South Puget Sound diet was dominated by gadids (99%), both Pacific tomcod and Pacific hake. Clupeid species (69%) also composed a large proportion of the diet, but unlike the other regions, plainfin midshipman (47%) and flat fish (33%) were primarily primary prey for harbor seals. Minor seasonal fluctuations in occurrence were observed for cephalopods, shiner surfperch, juvenile salmonids and rockfish. Prey assemblages in south Puget Sound seal diet are likely due to differences in habitat and the predominance of relatively shallow and calm inlets and bays.

In the San Juan Islands, Pacific herring was the most important prey species overall (57%). Gadid species (winter and spring), adult salmon (summer/fall), Pacific sand lance (winter and spring), and Northern anchovy (winter) were important more seasonally. The San Juan Islands are influenced by the Strait of Juan de Fuca and Strait of Georgia and seal diet reflects this dynamic region.

In comparing these three very different regions, clupeids (primarily herring) were a significant component of seal diet in each region. Adult salmonids are important seasonally in Hood Canal and the San Juan Islands and a gadid species and Pacific herring dominate the diet year round. As adult salmon migrate into the region and become abundant, harbor seals forage primarily on salmon (range 25–67% frequency of occurrence). For gadids, seals preyed primarily on Pacific hake in Hood Canal, Pacific tomcod and Pacific hake in south Puget Sound, and walleye pollock in North Puget Sound/San Juan Islands. Northern anchovy were important in Hood Canal and the San Juan Islands during winter, but not in South Puget Sound. High proportions of midshipman and flat fish in seal diet were unique to South Puget Sound. Many of the other important prey species were similar among regions including shiner surfperch, cephalopods, sand lance and sculpins. These data correlate well with species composition in each region and suggest that harbor seal diet provides a good indicator of fish availability and can be used to detect localized changes in prey availability.

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Introduction

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). Gadids (cod species) and forage fish in general, and herring specifically, are vital components of the marine food web and are an important indicator of the overall health of the marine environment. Pacific herring form the base of the Puget Sound 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, Stick 2005, Lance and Jeffries 2006, Lance and Jeffries 2007). 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). 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). Healthy and sustaining populations of native species in Puget Sound, including a robust food web is one of the Puget Sound Partnership's ecosystem recovery goals (Puget Sound Partnership 2008)

The harbor seal is the most abundant resident pinniped species in the inland waters of Washington. In Hood Canal they use five primary haulouts located at the major river mouths as well as on oyster rafts in Quilcene Bay and number over 1,000 animals (Jeffries et al. 2003). In south Puget Sound they use five primary haulouts located on reefs, islands, private floats, and log booms, and number approximately 1,200 animals (Jeffries et al. 2003). In the San Juan Islands they use over 150 intertidal haulout locations 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, Skagit, 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 ecosystem.

In Washington, harbor seal diet data is generally composed of small schooling forage (primarily herring) and various groundfish species. The status of Puget Sound herring stocks varies by region. South and central Puget Sound herring stocks have maintained a healthy population status since first evaluated in 1994, however north Puget Sound region herring stocks have moved progressively to depressed in recent years in large part due to the decrease in spawning biomass for the Cherry Point stock. The Strait of Juan de Fuca region stock status has been consistently classified as critical since 1994, primarily due to the condition of the Discovery Bay stock, which has remained at a very low level of abundance (Stick 2005). For groundfish, the Georgia Basin Pacific hake stock at one time comprised the largest fishery in central and north 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, Hood Canal and the Strait of Georgia.

Harbor seals are known to consume a wide range of prey sizes including adult salmonids returning to rivers to spawn, out-migrating salmon smolts, gadids, flatfishes, 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, Lance and Jeffries 2007). Seasonal abundance of prey species undoubtedly plays a key role in the foraging ecology and diet of harbor seals. Determining harbor seal diet in Puget Sound, 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 salmon) and consequently has significant population effects on the prey base. Harbor seal diet comparisons are also useful in addressing the question of multispecies and community effects by examining changes in fish size and composition over time.

In this study, we present harbor seal diet data from three distinct regions in Puget Sound: Hood Canal, south Puget Sound and San Juan Island archipelago. This report collates these data to allow for comparison among years, between seasons and among regions. Different project goals and study designs were employed in each region. Hood Canal diet data were collected as part of the west coast pinniped predation study focused on threatened and endangered salmon consumption by pinnipeds (London et al. 2001). South Puget Sound diet data were collected opportunistically during captures and observations at WDFW long term monitoring locations at Gertrude Island and Eagle Island (Lambourn et al. 2008). San Juan Island diet data were collected to examine the dependence of harbor seals on forage fish and rockfish communities, to strive to understand how they integrate into and impact the marine food web and to investigate the role of harbor seals in Marine Protected Areas designed to recover fish stocks (Lance and Jeffries 2006, Lance and Jeffries 2007). We obtained a large sample size of fecal samples (scats) 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 species. We believe this assumption is reasonable because, harbor seals have been shown to 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, Lance and Jeffries 2007), they 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. In Hood Canal, scat collections were attempted at roughly 10-14 day intervals during fall and spring. Fall collections were made from mid July to early December at

harbor seal haulout areas near Quilcene Bay (1998-2001, 2003, 2005), Dosewallips River (1998-2001 and 2003-2005), Duckabush River (1998-2001, 2003, 2005), Hamma Hamma River (1998-2000 and 2005) and the Skokomish River in 1998-1999 and 2004-2005) (Table 1, Figure 2). Spring collections were made from March to June at harbor seal haulout areas near Quilcene Bay, Dosewallips River and Skokomish River (1999 and 2005) and Duckabush River and Hamma Hamma River (2005) (Table 2, Figure 2).

In south Puget Sound, scats were collected opportunistically during captures and observations at Gertrude Island during fall 1995, spring 1997, summer 1997, winter 1997 and fall 2004 and at Eagle Island during spring 1997, summer 1997 and winter 1997 (Table 3, Figure 3).

In the San Juan Islands, scats were collected seasonally over three “collection windows” delineated as: 1 March-30 April (‘spring’), 1 August-30 September (‘summer/fall’) and 1 December-30 January (‘winter’) 2005-2007 (Table 4, Figure 4). 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’ (Figure 4). 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. 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). Data were entered into an Access database.

Data analyses. Diet data are presented as percent frequency of occurrence. 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). Scientific fish names are from Hart 1973.

Results

Hood Canal.

In Hood Canal, a total of 2,578 scats were collected during fall (Fig 3, Table 1) and 314 scats were collected during spring (Fig 3, Table 2). Data analyses were based on 98% and 99% of harbor seal scats that contained identifiable prey during fall and spring, respectively. Marine and

anadromous fishes were found in all samples analyzed and cephalopods occurred in 7-12% of samples.

Overall, harbor seals in Hood Canal fed primarily on Pacific hake (63% occurrence, hereafter hake), clupeids (primarily Pacific herring, 49%, hereafter herring), and adult salmonid species (26%) during fall (Table 2). Frequency of occurrence of hake, herring and adult salmonids fluctuated slightly from year to year, however; their importance in the diet remained relatively constant. The adult “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. Two other important species that occurred in greater than five percent of samples were, shiner surfperch (9%) and cephalopods (octopus and squids) (6%). Overall, fall diet was reasonably consistent among river systems with hake, herring and salmon dominating each year and shiner surfperch and cephalopods present in smaller proportions (Table 3). One small difference was the presence of threespine stickleback in Quilcene Bay, particularly during fall 2000. During spring 1999 and 2005, hake remained the most common prey species consumed, however; herring decreased in importance and shiner surfperch and northern anchovy increased (Table 7).

South Puget Sound.

In south Puget Sound, a total of 314 scats were collected during fall (Figure 3, Table 3). Data analyses were based on 98% of harbor seal scats that contained identifiable prey. Marine and anadromous fishes were found in all samples analyzed and cephalopods occurred in 19% of samples.

Overall, almost all samples (99%) collected at Gertrude Island and Eagle Island in south Puget Sound contained gadids (primarily Pacific tomcod and Pacific hake, 43% and 34% respectively) (Table 8). Three other primary prey species included clupeid species (69%), plainfin midshipman (47%), and flat fish (33%) that were primarily starry flounder and English sole. 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). Similarly, the “gadid species” category could include those species of gadid found in Puget Sound including Walleye pollock, Pacific tomcod, Pacific hake and Pacific cod, but which cannot be assigned species because bones recovered were not species specific. Other important species that occurred in greater than five percent of samples were, in decreasing order of importance, cephalopods (19%), shiner surfperch (14%), juvenile salmonids (13%), and rockfish species (9%) (Table 8). There were not large seasonal differences in diet observed. Gadids, clupeids, midshipman, and flatfish were relatively consistent in the diet year round. The following minor fluctuations in occurrence were observed: cephalopods were most common during fall and spring; shiner surfperch were most common during spring; juvenile salmonids were more common during spring and summer; and rockfish were most common during summer (Table 8).

San Juan Islands.

During three collection periods (‘spring’, ‘summer/fall’ and ‘winter’), a total of 899 scats were collected from sites distributed throughout the San Juan Islands during both years (Figure 4, Tables 9 and 10). Data analyses were based on 99% (507 of 509 collected) and 98% (392 of 398

collected) of harbor seal scats that contained identifiable prey during 2005-2006 and 2006-2007, respectively. Marine and anadromous fishes were found in all samples analyzed and cephalopods occurred in 7-11% of samples.

Overall, in 2005-2006 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 9). Other important species that occurred in greater than five percent of samples were, in decreasing order of importance, Northern anchovy, Walleye pollock, Spiny dogfish, sculpin species, flatfish species, cephalopods and skate species (Table 9).

Seasonal changes in diet composition were observed during 2005-2006 in the San Juan Islands. Clupeid species, primarily Pacific herring, were important prey for San Juan Islands harbor seals year round. Gadid species were important prey species in the San Juan Islands primarily during winter and spring. 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 9). 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 (Table 9).

Overall, in 2006-2007 harbor seals fed primarily on Pacific herring (57% occurrence), adult salmonid species (19%), and walleye pollock (15%) in the San Juan Islands (Table 10). 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).

Seasonal changes in diet composition were observed during 2006-2007 in the San Juan Islands. Clupeid species, primarily Pacific herring, were important prey for San Juan Islands harbor seals year round, but primarily during spring (91%) and winter (71%). Adult salmonid species were the dominant prey species during the summer/fall collection period. Gadid species were important prey species in the San Juan Islands primarily during winter. 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 10). Northern anchovy was an important prey species in seal diet almost exclusively during spring (Table 10). 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 10).

Regional comparison.

In all three regions, clupeids (primarily herring) were important in harbor seal diet year round (Figure 5, Tables 5-10). In each region, gadids dominated the diet however the gadid species largely differed by region. In general, Hood Canal seals ate hake during fall and spring, in South

Puget Sound seals ate tomcod and also hake and in the San Juan Islands harbor seals ate walleye pollock. Adult salmon were important seasonally in Hood Canal and the San Juan Islands during summer/fall, but not in south Puget Sound. Similarly, northern anchovy were important seasonally in Hood Canal and the San Juan Islands during winter, but not in south Puget Sound. High proportions of midshipman and flat fish (primarily starry flounder and english sole) in seal diet were unique to south Puget Sound. Many of the other important prey species were similar among regions including shiner surfperch, cephalopods, sand lance and sculpins (Figure 5).

Discussion

Hood Canal.

Food habits data indicate that Hood Canal harbor seals are opportunistic predators feeding on a variety of prey species, primarily schooling fishes, adult salmonids, and cephalopods. Hake, herring, adult salmon, shiner surfperch, and cephalopod species were the five most commonly occurring species for all years combined. The frequency of each prey species did vary among location, most notably the large percentage cephalopod species and threespine stickleback in Quilcene Bay. A high frequency of shiner surfperch was also observed in Quilcene Bay, Dosewallips River and Duckabush River. Bottom trawl data collected during 2002 and 2005 by Washington Department of Fish and Wildlife indicate hake and tomcod in 2002 and hake in 2005 were the primary gadid species in Hood Canal (Wayne Palsson, pers. comm.).

Each Hood Canal River supports runs of various salmonid species including chinook, coho, chum and pink. Steelhead and sea run cutthroat are present as well. Many salmonid runs have declined sharply, with several (chinook, summer chum and Dosewallips pinks) listed in the 1992 Salmon and Steelhead Stock Inventory (WDF et al. 1992) as critical or depressed. Hood Canal summer chum and Puget Sound chinook (including some runs in Hood Canal) were recently listed as “Threatened” under the ESA. Salmonid consumption and impacts on specific salmon runs by pinnipeds were the drivers for this study. Salmon species are the third most frequently occurring species based on scat analysis. Identification of salmon to species is only possible with otoliths, however this only accounts for a small percentage of the samples collected. Development of molecular genetic techniques to identify salmon to species using bone recovered from fecal samples is an important tool for identifying salmon species and these data are currently being analyzed.

South Puget Sound.

Tomcod, hake and herring were important in south Puget Sound seal diet during all seasons and across years that were sampled (1995, 1997 and 2004). In addition to these schooling ground and forage fishes, midshipman, flat fishes and shiner surfperch were common. Relatively shallow bays with sandy substrate, such as Case Inlet, Carr Inlet and Nisqually Reach, dominate south Puget Sound. Gertrude Island in particular is located in Still Harbor, which is a relatively isolated sandy-bottomed bay on the north side of McNeil Island. In this type of habitat, it appears flat fish, midshipman and shiner surfperch compose a high proportion of the diet and this was reflected in samples collected at Gertrude Island and Eagle Island.

Bottom trawl data collected during 2002 and 2005 by Washington Department of Fish and Wildlife indicate tomcod were the primary gadid species in Puget Sound (Wayne Palsson, pers.

comm.). Additionally, previous diet data collected in south Puget Sound in 1988 at the Nisqually River and at Gertrude Island in 1979 and 1994-1995 were similar in composition and proportion (NMFS 1997).

San Juan Islands.

In the San Juan Islands, harbor seals fed predominantly on Pacific herring, adult salmonids, and walleye pollock 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 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, Lance and Jeffries 2006).

The peak of adult salmon in harbor seal diet during summer/fall coincides with high concentrations of returning adult salmon passing through 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 as they only return in odd years, 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.).

In general, diet composition data collected in the San Juan Islands 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 other 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 in fish species composition 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.).

Regional comparison.

Current population status and trends for juvenile and adult forage fish species throughout Puget Sound are not well known. Washington Department of Fish and Wildlife Fish Program and others have conducted extensive surveys to map and protect spawning habitat for Pacific herring, Pacific sand lance and surf smelt in Puget Sound. 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 stock) based on 25 year spawning biomass estimates (Stick 2005). Pacific sand lance occurred in approximately 10% of samples collected in the San Juan Islands 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 in both the San Juan Islands and Hood Canal. There have been no detailed spawning surveys for Northern anchovy in Puget Sound 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 Puget Sound. They are the two most important prey species for thousands of Common murrelets (*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 1986) and during the 2006, 2007 and 2008 breeding seasons on Protection Island (S. Pearson, WDFW, pers. comm.).

Midshipman and flat fish (starry flounder and english sole) were most frequent in south Puget Sound harbor seal diet (Figure 5). These species prefer sandy substrate that is prevalent near Gertrude Island and Eagle Island and likely explains this difference from other regions. Washington Department of Fish and Wildlife has conducted a series of bottom trawl surveys in the Strait of Georgia, San Juan Islands, eastern Strait of Juan de Fuca, Hood Canal and south Puget Sound and abundance estimates support this finding (W. Palsson, WDFW, pers. comm.). Market squid were also common in the diet. We found no published information on abundance or distribution of market squid in Puget Sound although winter tends to be an important period based on sport harvests.

The peak of adult salmon in harbor seal diet during summer/fall in both Hood Canal and the San Juan Islands coincides with high concentrations of returning adult salmon. 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). This was the case in Hood Canal, however in the San Juan Islands, harbor seals are routinely feeding on salmon in “open water” areas as they funnel

through narrow passages in the San Juan Islands. In Johnstone Strait in British Columbia, 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 southern resident killer whales (*Orcinus orca*) that focus predation on chinook salmon. Adult salmon were rare in south Puget Sound diet collected from Gertrude Island and Eagle Island despite salmon runs returning to nearby rivers. Perhaps this is due to other more numerous or easily attainable species found close to the haul out and the generally depressed nature salmon populations in south Puget Sound. Alternatively, if scat samples were collected from haulout sites located right off important river mouths such as the Nisqually River, harbor seal diet may show a greater importance of salmonids similar to what was found their diet in Hood Canal or the San Juan Islands.

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Figure 1. Study area showing Hood Canal, south Puget Sound and San Juan Islands, Washington.

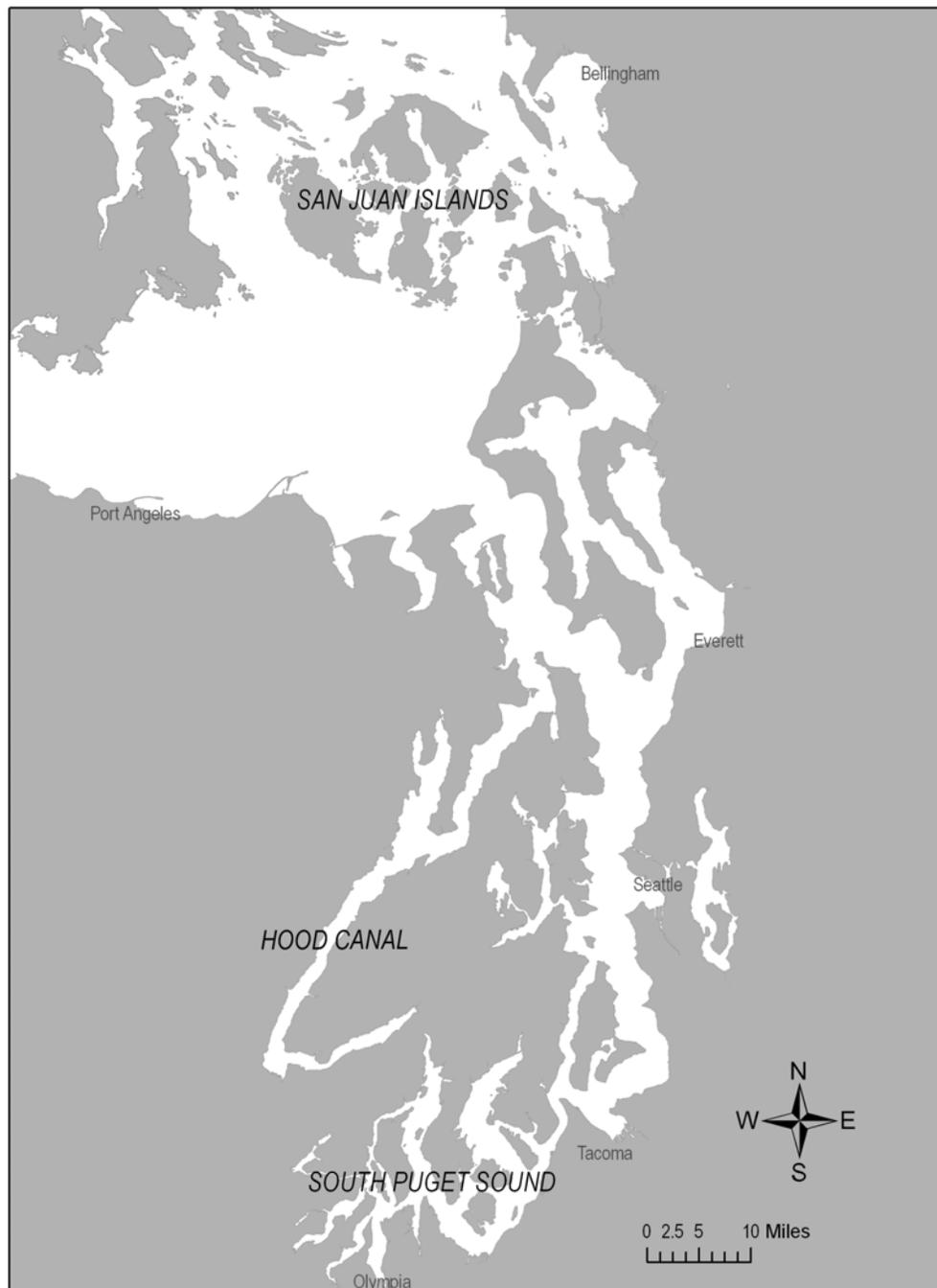


Figure 2. Map of Puget Sound and Hood Canal showing sample collection locations

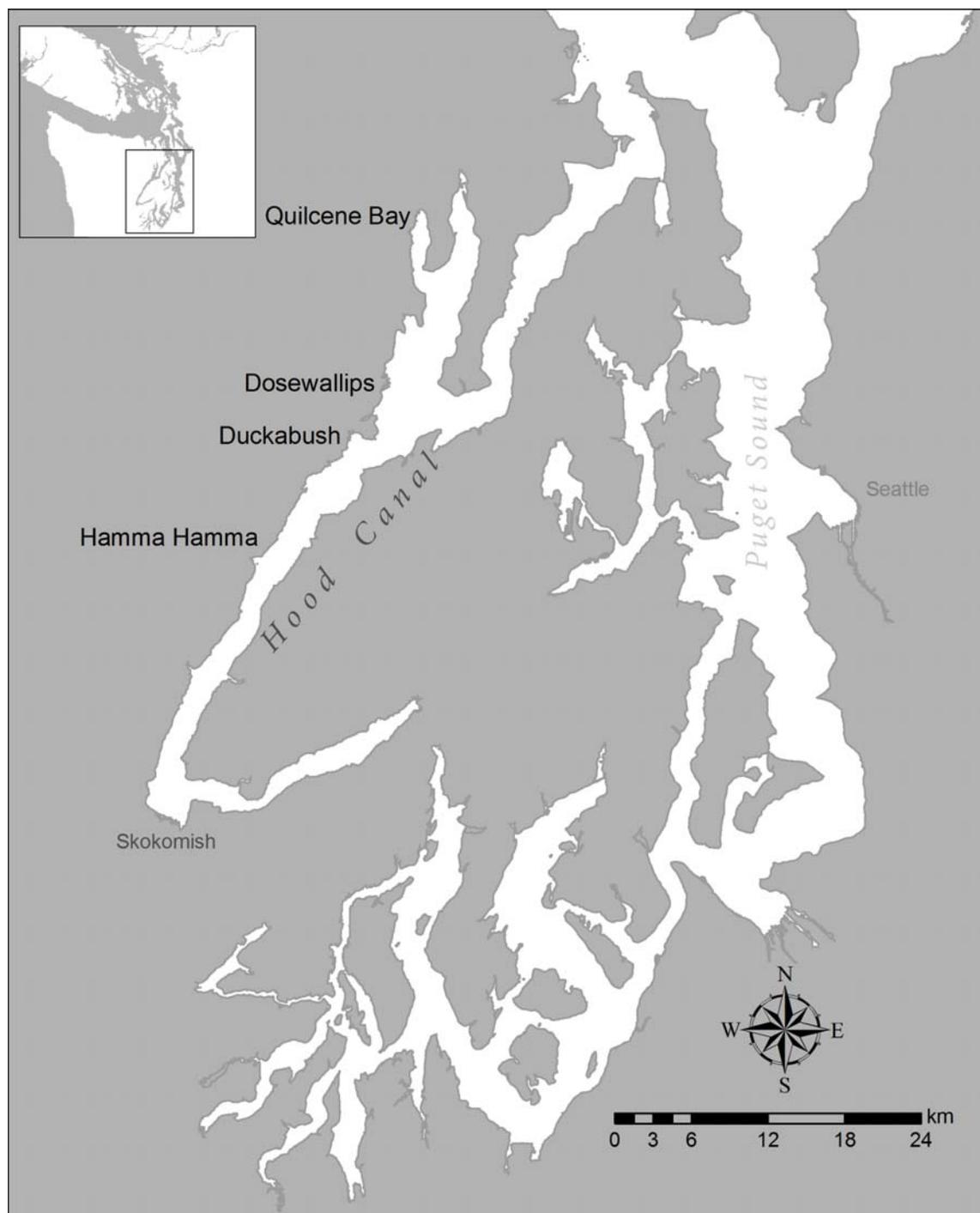


Figure 3. Map of south Puget Sound showing sample collection locations

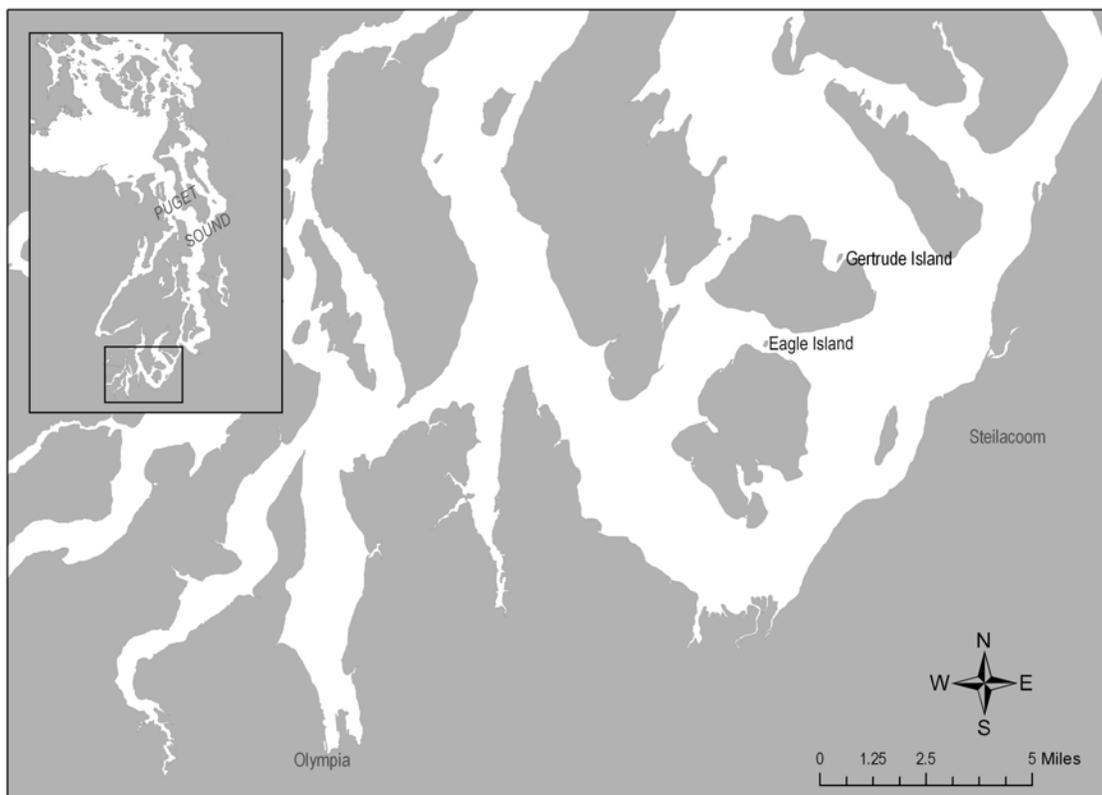


Figure 4. Map of the San Juan Islands showing sample collection locations

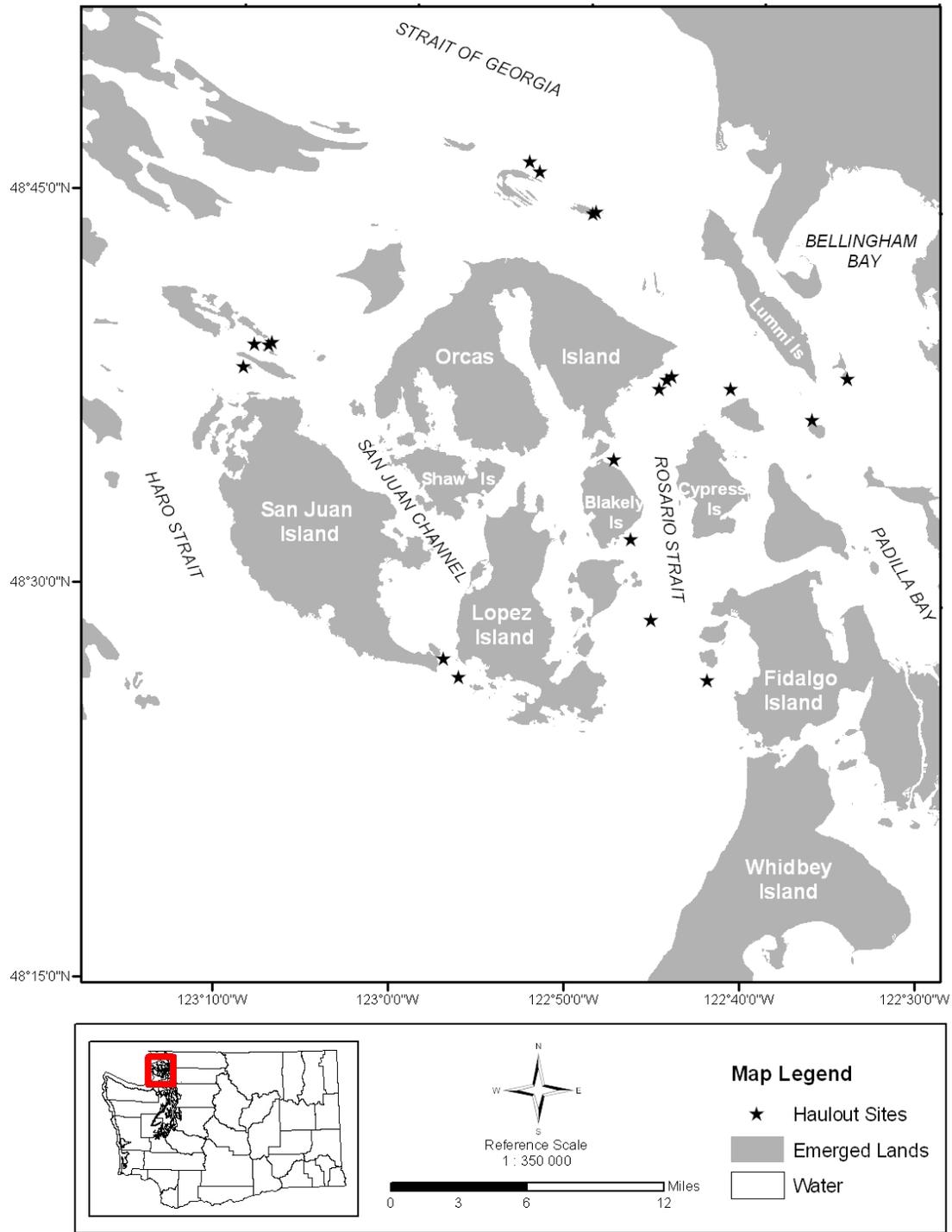


Figure 5. Overall weighted average of primary (>10%) prey species in the diet of harbor seals for all seasons and years combined in Hood Canal, south Puget Sound and the San Juan Islands

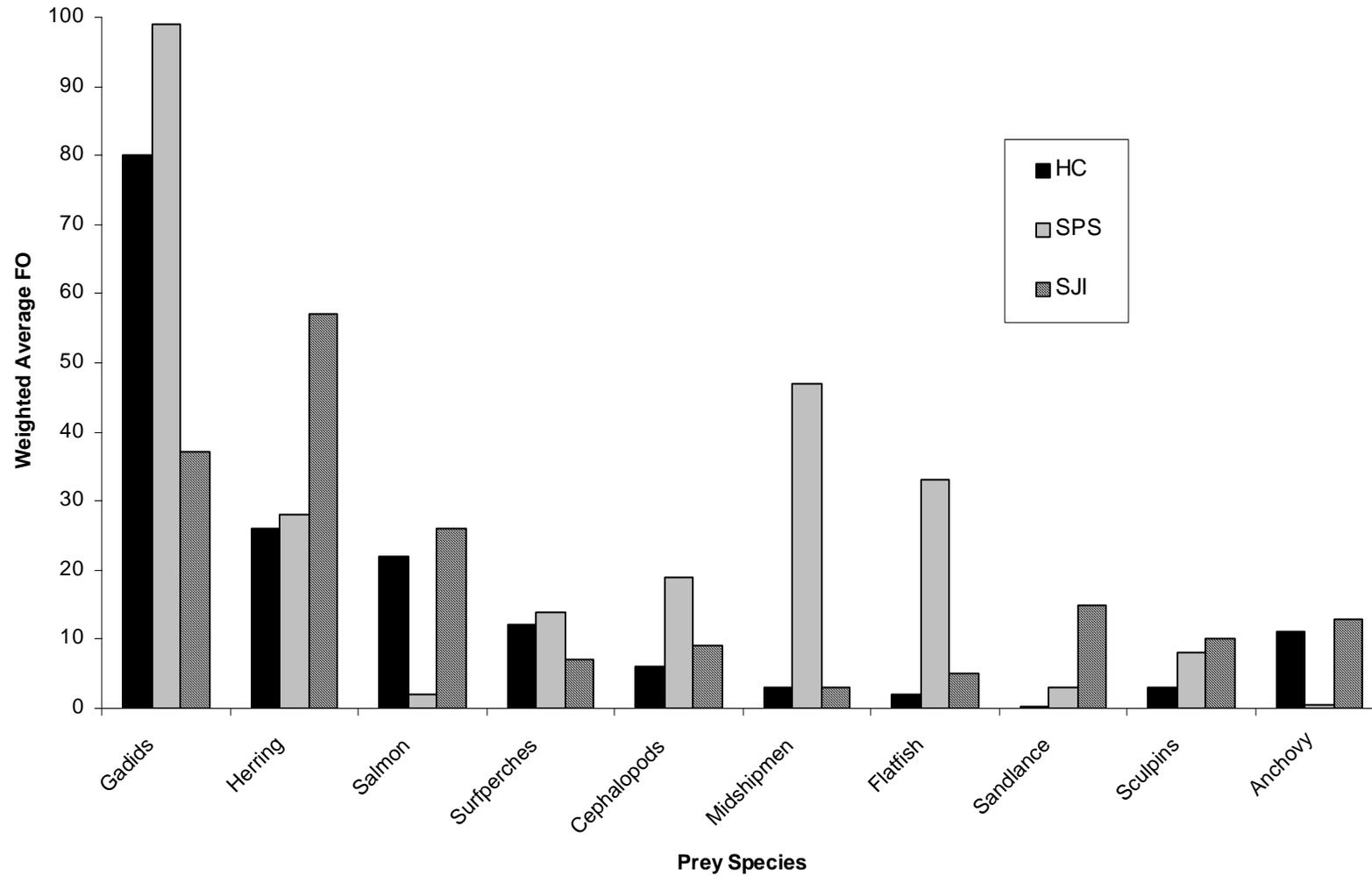


Table 1. Number of harbor seals scats collected (“C”) and with remains (“R”) by haul out site during fall (July – early December) 1998, 1999, 2000, 2001, 2003, 2004 and 2005 by year in Hood Canal, Washington.

	1998		1999		2000		2001		2003		2004		2005	
	C	R	C	R	C	R	C	R	C	R	C	R	C	R
Quilcene Bay	156	152	115	114	245	244	147	145	3	3	0	0	66	66
Dosewallips River	243	240	199	196	156	149	175	172	24	24	129	129	86	86
Duckabush River	7	7	9	9	127	125	102	100	93	92	0	0	2	2
Hamma Hamma River	68	67	40	38	80	78	0	0	0	0	0	0	40	40
Skokomish River	127	125	48	43	0	0	0	0	0	0	41	41	50	49
Total	601	591	411	400	608	596	424	417	120	119	170	170	244	243

Table 2. Number of harbor seals scats collected (“C”) and with remains (“R”) by haul out site during spring (March-June) 1999 and 2005 in Hood Canal, Washington.

	1999		2005	
	C	R	C	R
Quilcene Bay	10	10	0	0
Dosewallips River	170	170	82	82
Duckabush River	0	0	5	5
Hamma Hamma River	0	0	13	12
Skokomish River	17	15	105	105
Total	197	195	205	204

Table 3. Number of harbor seals scats collected (“C”) and with remains (“R”) by haul out site by season in 1995, 1997, 2004 in south Puget Sound, Washington.

	Fall 1995 (October)		Spring 1997 (April-May)		Summer 1997 (June-August)		Winter 1997 (October-Dec)		Fall 2004 (September)	
	C	R	C	R	C	R	C	R	C	R
Gertrude Island	20	20	121	118	18	18	45	45	64	64
Eagle Island	0	0	5	5	3	3	38	38	0	0
Total	20	20	126	123	21	21	83	83	64	64

Table 4. Number of harbor seal scats collected by season and region in the San Juan Islands 2005-2007. Collection location details found in Lance and Jeffries 2007.

	2005			2006		2007
	Spring	Summer/Fall	Winter	Spring	Summer/Fall	Winter
South Strait of Georgia	31	74	4	9	37	3
North Rosario Strait	0	74	0	0	36	0
East Rosario Strait	4	59	0	17	51	31
South Rosario Strait	0	59	11	4	20	9
South San Juan Channel	42	56	34	61	64	17
North San Juan Channel	0	63	0	6	47	4

Table 5. Percent frequency of occurrence (FO) of prey species identified using all structures (bone and otoliths) in harbor seal scats during fall (July – early December) of 1998, 1999, 2000, 2001, 2003 and 2004 by year in Hood Canal, Washington

Scientific Name	Common Name	1998		1999		2000		2001		2003		2004		2005	
		n=591	n=400	n=596	n=417	n=119	n=170	n=243							
		n	FO	n	FO	n	FO	n	FO	n	FO	n	FO	n	FO
* All Gadids		518	88	304	76	511	86	312	75	81	68	123	72	207	85
Gadidae species	codfish species	0	0	7	1.8	14	2.3	58	14	18	15	50	29	58	24
<i>Merluccius productus</i>	Pacific hake	501	85	289	72	470	79	240	58	61	51	66	39	143	59
<i>Microgadus proximus</i>	Pacific tomcod	15	2.5	7	1.8	26	4.4	14	3.4	1	0.8	7	4.1	6	2.5
<i>Theragra chalcogramma</i>	Walleye pollock	2	0.3	1	0.3	1	0.2	0	0	0	0	0	0	0	0
<i>Gadus macrocephalus</i>	Pacific cod	0	0	0	0	0	0	8	1.9	1	0.8	0	0	0	0
* All Clupeids		258	44	198	50	314	53	219	53	81	68	85	50	67	28
<i>Clupea pallasii</i>	Pacific herring	258	44	164	41	23	3.9	80	19	19	16	62	37	45	19
Clupeid species	herring spp.	0	0	33	8.3	291	49	139	33	62	52	22	13	22	9.1
<i>Alosa sapidissima</i>	American Shad	0	0	1	0.3	0	0	0	0	0	0	1	0.6	0	0
* All Salmonids		152	26	114	29	163	27	145	35	29	24	58	34	50	21
Salmonid species	adult salmonid spp.	150	25	110	28	146	25	137	33	25	21	55	32	48	20
<i>Oncorhynchus tshawytscha</i>	Chinook Salmon	0	0	0	0	0	0	0	0	0	0	1	0.6	2	0.8
Salmonid species	juvenile salmonid spp.	2	0.3	8	2.0	17	2.9	8	1.9	4	3.4	2	1.2	0	0
* All Surfperch		43	7.3	33	8.4	85	14	50	12	3	2.5	25	15	29	12
<i>Cymatogaster aggregata</i>	Shiner perch	39	6.6	30	7.5	81	14	44	11	3	2.5	22	13	28	12
<i>Rhacochilus vacca</i>	Pile perch	4	0.7	3	0.8	4	0.7	6	1.4	0	0	3	1.8	1	0.4
* All cephalopods		23	3.9	32	8.0	59	9.9	25	6.0	7	5.9	10	5.9	8	3.3
Cephalopod species		9	1.5	24	6.0	25	4.2	25	6.0	7	5.9	2	1.2	3	1.2
<i>Octopus rubescens</i>		0	0	8	2.0	6	1.0	0	0	0	0	1	0.6	0	0
<i>Loligo opalescens</i>	Market squid	11	1.9	0	0	28	4.7	0	0	0	0	7	4.1	5	2.1
<i>Berryteuthis/Gonatopsis borealis</i> species		3	0.5	0	0	13	2.2	0	0	0	0	0	0	0	0
<i>Engraulis mordax</i>	Northern anchovy	14	2.4	19	4.8	8	1.3	1	0.2	0	0	7	4.1	36	15
<i>Porichthys notatus</i>	Plainfin midshipman	14	2.4	15	3.8	13	2.2	12	2.9	3	2.5	6	3.5	11	4.5

<i>Leptocottus armatus</i>	Staghorn sculpin	16	2.7	9	2.3	14	2.3	20	4.8	0	0	6	3.5	8	3.3
<i>Chitonotus pugetensis</i>	Roughback sculpin	1	0.2	0	0	0	0	0	0	0	0	0	0	0	0
Cottid species	sculpin species	0	0	0	0	0	0	0	0	0	0	2	1.2	1	0.4
<i>Gasteroseus aculeatus</i>	Three spine stickleback	7	1.2	6	1.5	53	8.9	12	2.9	2	1.7	0	0	6	2.5
Pleuronectid species	Righteye flounder	0	0	0	0	1	0.2	4	1.0	0	0	2	1.2	1	0.4
<i>Platichthys stellatus</i>	Starry flounder	0	0	0	0	1	0.2	0	0	0	0	1	0.6	0	0
<i>Lyopsetta exilis</i>	Slender sole	0	0	2	0.5	0	0	0	0	0	0	0	0	0	0
<i>Pleuronectes vetulus</i>	English Sole	2	0.3	2	0.5	0	0	0	0	0	0	0	0	2	0.8
Bothid species	Lefteye flounder.	0	0	0	0	0	0	0	0	0	0	0	0	1	0.4
Rajid species	skate species	3	0.5	3	0.8	9	1.5	4	1.0	1	0.8	1	0.6	3	1.2
Liparidid species	snailfish species	0	0	0	0	0	0	0	0	0	0	1	0.6	0	0
<i>Ammodytes hexapteras</i>	Pacific sand lance	0	0	2	0.5	2	0.3	2	0.5	0	0	1	0.6	1	0.4
Scorpaenid species	rockfish species	3	0.5	3	0.8	4	0.7	5	1.2	1	0.8	1	0.6	7	2.9
Unidentifiable fish spp.		29	4.9	18	4.5	15	2.5	40	9.6	3	2.5	5	2.9	6	2.5

Table 6. An annual comparison of the percent frequency of occurrence (FO) of primary prey species identified using all structures (bone and otoliths) in harbor seal scats by river system in Hood Canal, Washington during fall (late July – early December) of 1998, 1999, 2000, 2001, 2003 and 2004.

Quilcene Bay

	1998		1999		2000		2001		2003		2005	
	n	FO	n	FO	n	FO	n	FO	n	FO	n	FO
	n = 152		n = 114		n = 244		n = 145		n = 3		n = 66	
Common Name	n	FO	n	FO	n	FO	n	FO	n	FO	n	FO
Pacific hake	135	89	89	78	210	86	88	61	3	100	40	61
Pacific herring	59	39	50	44	107	44	27	19	2	67	13	20
Adult salmonid species	37	24	41	36	66	27	59	41	0	0	10	15
Shiner perch	15	9.9	8	7.0	38	16	18	12	0	0	12	18
Cephalopod species	9	5.9	12	11	31	13	12	8.3	0	0	2	3.0
Threespine stickleback	7	4.6	5	4.4	52	21	5	3.4	0	0	4	6.1

Dosewallips River

	1998		1999		2000		2001		2003		2004		2005	
	n	FO	n	FO	n	FO	n	FO	n	FO	n	FO	n	FO
	n = 240		n = 196		n = 149		n = 172		n = 92		n = 129		n = 86	
Common Name	n	FO	n	FO	n	FO	n	FO	n	FO	n	FO	n	FO
Pacific hake	204	85	156	80	119	80	123	72	49	53	52	40	54	63
Pacific herring	113	47	75	38	68	46	76	44	41	45	49	38	17	20
Adult salmonid species	51	21	42	21	27	18	33	19	24	26	53	41	15	17
Shiner perch	15	6.3	14	7.1	12	8.1	2	1.2	2	2.2	15	12	6	7.0
Cephalopod species	0	0	0	0	0	0	6	3.5	6	6.5	8	6.2	3	3.5

Duckabush River

	1998		1999		2000		2001		2003		2005	
	n	FO	n	FO	n	FO	n	FO	n	FO	n	FO
	n = 7		n = 9		n = 125		n = 100		n = 24		n = 2	
Common Name	n	FO	n	FO	n	FO	n	FO	n	FO	n	FO
Pacific hake	7	100	5	56	83	66	29	29	9	38	1	50
Pacific herring	3	43	6	67	81	65	36	36	19	79	0	0
Adult salmonid species	1	14	0	0	24	19	45	45	4	17	0	0
Shiner perch	0	0	1	11	27	22	24	24	1	4.2	0	0
Cephalopod species	2	29	0	0	2	0.8	7	7.0	1	4.2	0	0

Hamma Hamma River

	1998		1999		2000		2005	
	n = 67		n = 38		n = 78		n = 40	
Common Name	n	FO	n	FO	n	FO	n	FO
Pacific hake	56	84	26	68	58	74	27	68
Pacific herring	27	40	16	42	35	45	7	18
Adult salmonid species	16	24	13	34	29	37	4	10
Shiner perch	3	4.5	2	5.3	4	5.1	3	7.5
Cephalopod species	2	3.0	6	16	11	14	1	2.5

Skokomish River

	1998		1999		2004		2005	
	n = 125		n = 43		n =		n = 49	
Common Name	n	FO	n	FO	n	FO	n	FO
Pacific hake	99	79	14	33	15	37	21	43
Pacific herring	56	45	16	37	14	34	8	16
Adult salmonid species	45	36	18	42	4	9.8	19	39
Shiner perch	6	4.8	5	12	7	17	7	14
Cephalopod species	0	0	0	0	1	2.4	2	4.1

Table 7. Percent frequency of occurrence (FO) of prey species identified using all structures (bone and otoliths) in harbor seal scats during spring (March-June) 1999 and 2005 in Hood Canal, Washington.

Scientific Name	Common Name	1999		2005	
		n=195	FO	n=204	FO
* All Gadids		171	88	168	82
Gadidae species	codfish species	7	3.6	57	28
<i>Merluccius productus</i>	Pacific hake	157	81	108	53
<i>Microgadus proximus</i>	Pacific tomcod	5	2.6	3	1.5
<i>Theragra chalcogramma</i>	Walleye pollock	2	1.0	0	0
* All Clupeids		86	44	46	23
<i>Clupea pallasii</i>	Pacific herring	78	40	24	12
Clupeid species	herring species	8	4.1	17	8.3
<i>Alosa sapidissima</i>	American Shad	0	0	5	2.5
* All Salmonids		31	16	27	13
Salmonid species	adult salmonid species	9	4.6	22	11
<i>Oncorhynchus tshawytscha</i>	Chinook Salmon	0	0	5	2.5
Salmonid species.	juvenile salmonid species	20	10	0	0
* All Surfperch		18	9.2	56	28
Embiotocid species	Surfperch species	0	0	2	1.0
<i>Cymatogaster aggregata</i>	Shiner perch	18	9.2	54	27
* All cephalopods		2	1.0	15	7.4
Cephalopod species	Squid or octopus species	2	1.0	12	5.9
<i>Loligo opalescens</i>	Market squid	0	0	3	1.5
<i>Engraulis mordax</i>	Northern anchovy	53	27	88	43
<i>Porichthys notatus</i>	Plainfin midshipman	9	4.6	6	2.9
<i>Leptocottus armatus</i>	Staghorn sculpin	0	0	4	2.0
<i>Gasteroseus aculeatus</i>	Three spine stickleback	29	15	9	4.4
Pleuronectid species	righteye flounder spp.	2	1.0	7	3.4
<i>Lyopsetta exilis</i>	Slender sole	7	3.6	0	0
<i>Pleuronectes vetulus</i>	English Sole	1	0.5	2	1.0
Rajid species	skate species	12	6.2	3	1.5
Scorpaenid species	rockfish species	4	2.1	9	4.4
<i>Hypomesus pretiosus</i>	Surf smelt	1	0.5	0	0
Unidentifiable fish species		9	4.6	12	5.9

Table 8. Percent frequency of occurrence (FO) of prey species identified using all structures (bone and otoliths) in harbor seal scats during fall 1995, spring 1997, summer 1997, winter 1997 and fall 2004 in south Puget Sound, Washington.

Scientific Name	Common Name	Fall 1995		Spring 1997		Summer 1997		Winter 1997		Fall 2004	
		n	FO	n	FO	n	FO	n	FO	n	FO
* All Gadids		23	100	137	100	20	95	97	100	69	100
<i>Microgadus proximus</i>	Pacific tomcod	7	35	62	50	8	38	43	52	26	41
<i>Merluccius productus</i>	Pacific hake	4	20	34	28	8	38	39	47	23	36
Gadidae species	codfish	9	45	38	31	3	14	15	18	10	16
<i>Theragra chalcogramma</i>	Walleye pollock	2	10	3	2.4	1	4.8	0	0	9	14
<i>Gadus macrocephalus</i>	Pacific cod	1	0.32	0	0	0	0	0	0	1	1.6
<i>Porichthys notatus</i>	Plainfin midshipman	12	60	53	43	6	29	39	47	33	55
* All Clupeids		11	55	55	45	13	62	45	54	56	88
<i>Clupea pallasii</i>	Pacific herring	6	30	13	11	5	24	18	22	34	53
Clupeid species	herring species	5	25	37	30	8	38	27	33	21	33
<i>Alosa sapidissima</i>	American Shad	0	0	5	4.1	0	0	0	0	1	1.6
* All Surfperch		2	10	34	28	2	9.5	12	14	5	7.8
<i>Cymatogaster aggregata</i>	Shiner perch	2	10	32	26	2	9.5	12	14	5	7.8
Embiotocid species.	Surfperch	0	0	1	0.8	0	0	0	0	0	0
<i>Rhacochilus vacca</i>	Pile perch	0	0	1	0.8	0	0	0	0	0	0
* All Salmonids		0	0	34	28	5	24	9	11	10	16
Salmonid species	adult salmonid	0	0	2	1.6	0	0	3	3.6	4	6.3
Salmonid species	juvenile salmonid	0	0	32	26	5	24	6	7.2	6	9.4
* All Flatfish		7	35	47	38	7	33	33	40	11	17
<i>Pleuronectes vetulus</i>	English Sole	2	10	18	15	3	14	11	13	4	6.3
Pleuronectid species	Righteye flounder	3	15	8	6.5	3	14	7	8.4	0	0
<i>Lyopsetta exilis</i>	Slender sole	1	5.0	10	8.1	1	4.8	2	2.4	0	0
<i>Platichthys stellatus</i>	Starry flounder	1	5.0	4	3.3	0	0	4	4.8	3	4.7
<i>Errex zachirus</i>	Rex sole	0	0	1	0.8	0	0	1	1.2	3	4.7
<i>Lepidopsetta bilineata</i>	Rock sole	0	0	2	1.6	0	0	2	2.4	0	0
Bothidae/Pleuronectidae	Unidentified flat fish	0	0	2	1.6	0	0	2	2.4	0	0
<i>Microstomus pacificus</i>	Dover sole	0	0	0	0	0	0	2	2.4	1	1.6
Bothid species	Lefteye flounder	0	0	1	0.8	0	0	0	0	0	0

<i>Isopsetta isolepis</i>	Butter sole	0	0	1	0.8	0	0	0	0	0	0
<i>Psettichthys melanostictus</i>	Sand sole	0	0	0	0	0	0	1	1.2	0	0
<i>Pleuronichthys coenosus</i>	C-O sole	0	0	0	0	0	0	1	1.2	0	0
* All Cottids		0	0	13	11	2	9.5	8	9.6	6	9.4
<i>Leptocottus armatus</i>	Staghorn sculpin	0	0	5	4.1	2	9.5	2	2.4	0	0
Cottid species	Sculpin	0	0	7	5.7	0	0	6	7.2	6	9.4
Hemilepidotus species	Irish lord	0	0	1	0.8	0	0	0	0	0	0
* All cephalopods		11	55	13	10.6	2	9.5	7	8.4	8	13
<i>Loligo opalescens</i>	Market squid	7	35	8	6.5	1	4.8	4	4.8	5	7.8
<i>Octopus rubescens</i>		1	5.0	2	1.6	1	4.8	2	2.4	1	1.6
Cephalopod species		3	15	3	2.4	0	0	1	1.2	2	3.1
Scorpaenid species	Rockfish	1	5.0	12	9.8	5	24	4	4.8	0	0
Petromyzontidae species	Lamprey	1	5.0	12	9.8	1	4.8	1	1.2	1	1.6
<i>Ammodytes hexapteras</i>	Pacific sand lance	0	0	6	4.9	1	9.5	0	0	1	1.6
Rajid species	Skate	0	0	7	5.7	0	0	1	1.2	0	0
Zoarcid species	Eelpout	0	0	4	3.3	1	4.8	0	0	0	0
Liparidid species	Snailfish	1	5.0	1	0.8	0	0	1	1.2	1	1.6
<i>Engraulis mordax</i>	Northern anchovy	0	0	3	2.4	0	0	0	0	0	0
Hexagrammid species	Greenling	0	0	2	1.6	0	0	0	0	0	0
Pholid species	Gunnel	0	0	1	0.8	0	0	1	1.2	0	0
<i>Gasteroseus aculeatus</i>	Three spine stickleback	0	0	1	0.8	0	0	0	0	0	0
Unidentified fish spp.		1	5.0	9	7.3	2	9.5	0	0	0	0
Unidentifiable fish spp		1	5.0	3	2.4	0	0	1	1.2	1	1.6

Table 9. 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, 2005-06

Scientific Name	Common Name	Spring		Summer/Fall		Winter		Overall (wt)	
		n = 77	FO	n = 384	FO	n = 46	FO	n = 507	FO
* All Clupeids		57	74	147	38	32	70	236	61
<i>Clupea pallasii</i>	Pacific herring	55	71	135	35	29	63	219	57
Clupeid species	herring species	2	2.6	11	2.9	1	2.2	14	2.5
<i>Alosa sapidissima</i>	American Shad	0	0	1	0.26	2	4.35	3	1.5
* All Gadids		60	78	37	10	17	37	114	42
Gadidae species	codfish species	29	38	16	4	14	30	59	24
<i>Theragra chalcogramma</i>	Walleye pollock	31	40	19	5	3	7	53	17
<i>Merluccius productus</i>	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
<i>Oncorhynchus gorbuscha</i>	Pink Salmon	0	0	25	6.51	0	0	25	2.2
<i>Oncorhynchus tshawytscha</i>	Chinook Salmon (ad)	0	0	1	1.3	0	0	1	0.4
<i>Oncorhynchus keta</i>	Chum Salmon	0	0	3	0.78	0	0	3	0.3
<i>Oncorhynchus nerka</i>	Sockeye Salmon	0	0	1	0.26	0	0	1	0.1
Juvenile Salmonid species		0	0	22	5.73	0	0	22	1.9
<i>Oncorhynchus tshawytscha</i>	Chinook Salmon (juv)	0	0	4	1.3	0	0	4	0.4
<i>Ammodytes hexapterus</i>	Pacific sand lance	17	22	36	9	13	28	66	20
<i>Engraulis mordax</i>	Northern anchovy	4	5.2	2	0.5	23	50.0	29	19
<i>Squalus acanthias</i>	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 species	sculpin species	1	1.3	10	2.6	6	13.0	17	5.6
<i>Leptocottus armatus</i>	Pacific staghorn sculpin	2	2.6	6	1.6	2	4.4	10	2.8
Hemilepidotus species.	Irish lord species	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 species	righteye flounder species	1	1.3	7	1.8	1	2.2	9	1.8
<i>Platichthys stellatus</i>	Starry flounder	0	0	4	1.04	3	6.52	7	2.5
<i>Pleuronectes vetulus</i>	English Sole	0	0	7	1.82	0	0	7	0.6
<i>Microstomus pacificus</i>	Dover sole	0	0	4	1.04	1	2.17	5	1.1
Bothid species	lefteye flounder species	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
<i>Octopus rubescens</i>		2	2.6	6	1.6	1	2.2	9	2.1
<i>Berryteuthis magister</i>		0	0	5	1.3	2	4.35	7	1.9
<i>Loligo opalescens</i>	Market squid	1	1.3	1	0.3	2	4.4	4	2.0
Gonatidae species		0	0	0	0	1	2.17	1	0.7
Unknown cephalopod		0	0	1	0.26	0	0	1	0.1
Rajid species	skate species	2	2.6	1	0.3	7	15.2	10	6.0
Liparidid species	snailfish species	0	0	1	0.26	6	13	7	4.4
<i>Cymatogaster aggregata</i>	Shiner perch	2	2.6	9	2.3	3	6.5	14	3.8
<i>Hypomesus pretiosus</i>	Surf smelt	2	2.6	13	3.4	2	4.4	17	3.4
<i>Gasteroseus aculeatus</i>	Threespine	5	0	4	1.04	4	8.7	13	3.2

	stickleback								
Scorpaenid species	rockfish species	0	0	1	0.26	3	6.52	4	2.3
Argentinid species	Argentine	0	0	0	0	2	4.35	2	1.5
<i>Porichthys notatus</i>	Plainfin midshipmen	2	2.6	4	1.0	0	0.0	6	1.2
Pholid species	gunnel species	1	1.3	1	0.3	1	2.2	3	1.2
Hexagrammid species	greenling species	2	2.6	1	0.3	0	0.0	3	1.0
Genus Rathbunella	ronquil species	0	0	3	0.78	1	2.17	4	1.0
<i>Diaphus theta</i>	California headlight fish	0	0	7	1.82	0	0	7	0.6
Zoarcid species	eelpout species	0	0	6	1.56	0	0	6	0.5
<i>Lycodopsis pacifica</i>	Blackbelly eelpout	0	0	2	0.52	0	0	2	0.2
Petromyzontid species	lamprey species	0	0	2	0.52	0	0	2	0.2
<i>Anarrhichthys ocellatus</i>	Wolf-eel	0	0	1	0.26	0	0	1	0.1
<i>Stenobranchius leucopsarus</i>	Northern lampfish	0	0	0	0	1	2.17	1	0.7
<i>Scomber japonicus</i>	mackerel species	0	0	0	0	1	2.17	1	0.7
Not identifiable fish species		0	0	3	0.78	3	6.52	6	2.4
Unidentifiable fish species		3	3.9	13	3.4	1	2.2	17	3.2

Table 10. 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

Scientific Name	Common Name	Spring		Summer/Fall		Winter		Overall (wt)	
		n = 97	FO	n = 239	FO	n = 56	FO	n = 392	FO
* All Clupeids		88	91	104	44	40	71	232	69
<i>Clupea pallasii</i>	Pacific herring	79	81	76	32	33	59	188	57
Clupeid spp.	herring species	6	6.2	22	9.2	7	13	35	9.5
<i>Alosa sapidissima</i>	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 species	12	12	15	6.3	5	8.9	32	9.1
<i>Theragra</i> <i>chalcogramma</i>	Walleye pollock	9	9.3	38	16	12	21	59	15
<i>Merluccius productus</i>	Pacific hake	0	0	6	2.5	5	8.9	11	3.8
<i>Microgadus proximus</i>	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
<i>Oncorhynchus</i> <i>gorbuscha</i>	Pink Salmon (ad)	0	0	1	0.42	0	0	1	0.14
<i>Oncorhynchus</i> <i>tshawytscha</i>	Chinook Salmon (ad)	0	0	1	0.42	0	0	1	0.14
<i>Oncorhynchus keta</i>	Chum Salmon (ad)	0	0	13	5.4	0	0	13	1.8
<i>Oncorhynchus nerka</i>	Sockeye Salmon (ad)	0	0	6	2.5	1	1.8	7	1.4
<i>Oncorhynchus kisutch</i>	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
<i>Oncorhynchus</i> <i>tshawytscha</i>	Chinook Salmon (juv)	0	0	7	2.9	1	1.8	8	1.6
<i>Oncorhynchus kisutch</i>	Coho Salmon (juv)	0	0	1	0.42	0	0	1	0.14
<i>Oncorhynchus nerka</i>	Sockeye Salmon (juv)	0	0	1	0.42	0	0	1	0.14
<i>Ammodytes hexapteras</i>	Pacific sand lance	12	12	34	14	3	5.4	49	10
<i>Engraulis mordax</i>	Northern anchovy	20	21	4	1.7	1	1.8	25	8.2
<i>Squalus acanthias</i>	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 species	2	2.1	10	4.2	7	13	19	6.4
<i>Leptocottus armatus</i>	Pacific staghorn sculpin	0	0	9	3.8	4	7.1	13	3.6
Hemilepidotus spp.	irish lord species	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 species	1	1.0	10	4.2	1	1.8	12	2.3
<i>Pleuronectes vetulus</i>	English Sole	0	0	4	1.7	0	0	4	0.57
Bothid spp.	lefteye flounder species	0	0	1	0.42	0	0	1	0.14
* All Cephalopods		4	4.1	34	14	9	16	47	11
<i>Octopus rubescens</i>		2	2.1	5	2.1	3	5.4	10	3.2
<i>Berryteuthis magister</i>		1	1.0	11	4.6	1	1.8	13	2.5
<i>Loligo opalescens</i>	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
Cephalopod species	statolith only	1	1.0	12	5.0	2	3.6	15	3.2
Rajid spp.	skate species	5	5.2	2	0.84	7	13	14	6.3
Liparidid spp.	snailfish species	4	4.1	3	1.3	4	7.1	11	4.2
<i>Cymatogaster</i> <i>aggregata</i>	Shiner perch	3	3.1	7	2.9	15	27	25	11
Osmerid species	smelt species	2	2.1	5	2.1	3	5.4	10	3.2
<i>Osmerus mordax dentex</i>	Rainbow smelt	1	1.0	1	0.42	0	0	2	0.47
<i>Hypomesus pretiosus</i>	Surf smelt	0	0	1	0.42	0	0	1	0.14

<i>Thaleichthys pacificus</i>	Eulachon	1	1.0	5	2.1	1	1.8	7	1.6
<i>Gasteroseus aculeatus</i>	Threespine stickleback	5	5.2	4	1.7	0	0	9	2.3
Scorpaenid spp.	rockfish species	3	3.1	22	9.2	13	23	38	12
<i>Porichthys notatus</i>	Plainfin midshipmen	1	1.0	10	4.2	5	8.9	16	4.7
Pholid spp.	gunnel species	0	0	7	2.9	0	0	7	0.97
Hexagrammid spp.	greenling species	0	0	1	0.42	0	0	1	0.14
	California headlight								
<i>Diaphus theta</i>	fish	2	2.1	0	0	1	1.8	3	1.3
Zoarcid species	eelpout species	1	1.0	18	7.5	4	7.1	23	5.2
Petromyzontid species	lamprey species	0	0	9	3.8	0	0	9	1.3
<i>Stenobranchius</i>									
<i>leucopsarus</i>	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