Marine Mammals and the *Exxon Valdez*

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Chapter 11

Sea Otter Foraging Behavior and Hydrocarbon Levels in Prey

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INTRODUCTION

Following the *Exxon Valdez* oil spill (EVOS), Prudhoe Bay crude oil from the vessel spread on the sea surface and covered coastal shores from western Prince William Sound (PWS) to the Alaska Peninsula. In PWS alone, acute mortality of sea otters at the time of the spill was estimated to be greater than 2000 (Doroff et al. 1993; Garrott et al. 1993).

Shoreline oiling was observed on approximately 24% of the 1891 km of coastline surveyed within PWS (*Exxon Valdez* Oil Spill Damage Assessment Geoprocessing Group 1991). The effect of oil on the abundance of nearshore marine invertebrate populations is unclear, and the concentration and persistence of hydrocarbons present in tissues of most of these invertebrate species still remains unknown. What is known is that marine bivalves can accumulate petroleum hydrocarbons from both chronic and acute sources (Blumer et al. 1970; Ehrhardt 1972; Boehm and Quinn 1977). Potential long-term chronic effects of oiled intertidal and subtidal prey on the sea otter population are of concern.

Sea otters prey on a wide variety of benthic marine invertebrates (Riedman and Estes 1990) and forage in shallow coastal waters (Wild and Ames 1974), which vary widely in exposure to the open ocean, substrate type, and community composition. Sea otters have high metabolic demands relative to other marine mammals and can consume 20–25% of their body weight per day in invertebrate prey (Kenyon 1969; Costa and Kooyman 1984).

Sea otters have occupied southwestern PWS since at least the early 1950s (Lensink 1962; Garshelis et al. 1986). The sea otter population in the PWS spill region was likely near equilibrium density and limited by prey availability before the oil spill occurred (Estes et al. 1981; Garshelis et al. 1986; Johnson 1987). Sea otters in this region spent 59% of the daylight hours foraging, while otters in recently reoccupied habitats of eastern PWS spent only 27% (Garshelis et al. 1986). Therefore, small differences in abundance of prey or net caloric availability due to heavy oiling in portions of southwestern PWS may have led to reduced carrying capacity and delayed recovery for the sea otter population in this region.

Recovery of the PWS sea otter population may be influenced by several factors. Decreased food availability caused by oil-related prey mortality or consumption of contaminated prey may be detrimental. Prey availability in western PWS may have declined due to increased mortality of invertebrates at the time of shoreline oiling, or by oil-removal activities. In addition, relative prey availability may have been decreased by sea otters avoiding invertebrate prey contaminated with petroleum hydrocarbons. However, we lack the baseline data on abundance and distribution of nearshore invertebrates necessary to estimate a reduction in prey availability. In addition, the effects of ingesting prey contaminated with petroleum hydrocarbons on sea otters are unknown.

Our objectives were to determine if sea otter foraging success and prey composition differed between oiled and nonoiled areas and to assess hydrocarbon levels in sea otter prey between oiled and nonoiled areas.

METHODS

Study Sites

The study area included sea otter foraging sites at Squirrel, Green, and Montague Islands in western PWS (Fig. 11-1). Sites were selected on the basis of two criteria: (1) degree of shoreline oiling (based on Alaska Department of Environmental Conservation shoreline oiling maps) with Squirrel, Green, and Montague Islands representing heavy (>50% of the beach area covered or penetrated with oil), moderate (10–50% of the beach area covered or penetrated with oil), and no shoreline oiling, respectively; and (2) sufficient sea otter densities to obtain foraging data (determined by sea otter survey and capture data from other spill-related studies). In general, the study area was a female-occupied area where breeding and pup rearing occurred (Estes et al. 1981; Garshelis 1983; Riedman and Estes 1990). Sea otter foraging data were collected in the study area between mid-April and July 1991 and subtidal sea otter prey were collected during August 1991.

Foraging Observations

Visual observations of foraging sea otters were made with high-resolution telescopes (Questar Corporation, New Hope, PA) and 10X40 binoculars. Foraging behavior was documented using a focal animal sampling method (Altmann 1974). A foraging otter was located and observed until a maximum of 50 identifiable prey items were observed, or until visual contact with the animal was lost, or foraging ceased. When possible, data recorded for each focal animal on each dive included age (i.e., adult, juvenile, or unknown), sex, number of prey and relative prey size, dive interval (seconds), surface interval between foraging dives (seconds), and prey item to lowest identifiable taxon. Prey were classified into one of five size classes (<5 cm; ≥5 to <7 cm; ≥7 cm to <9 cm; ≥9 to <12 cm; and ≥12 cm). Size class of prey was estimated by observers based on the mean forepaw width (4.5 cm) and mean skull width (10 cm) for adult sea otters in this region (Johnson 1987; U.S. Fish and Wildlife Service, unpublished data). Adult animals were categorized as male, independent female, or female with a pup. Small (estimated at ≤18 kg), dark-headed otters were identified as juveniles. Foraging dives were classified as successful (prey item captured), unsuccessful (no prey item captured), or as producing an unknown result (observer could not determine if the dive was successful or unsuccessful). The locations of foraging sea otters were recorded on a Geographic Information System coverage map gridded with a Universal Transverse Mercator projection. Data were collected only during daylight hours and during all tidal cycles.

Scat Analysis

From 20 April to 3 May 1991, 253 sea otter scat samples were examined in the field along 8.5 km of beach within the Green Island study site (Fig. 11-1). For each scat sample encountered, the prey species (when possible) were recorded within each scat. The estimated percentage that each prey type (mussel, clam, crab, or other) contributed to the entire scat was categorized as follows: 100, 90, 75, 50, 25, 10, and 5%.

Collection and Hydrocarbon Analysis of Prey

At each study site, clam species identified as sea otter prey were collected and tissues were analyzed for hydrocarbon content. Coordinates of foraging observations were plotted for each study site. The outermost coordinate locations delineated a polygon over which a grid of 100-m^2 plots was laid. Ten 100-m^2 plots were chosen randomly within each study site, and SCUBA divers searched for prey within each plot, beginning at the boat anchor. The boat anchor location was haphazard within each of the plot boundaries. Clams were recovered using a venturi dredge (Keene Engineering, Northridge, California). Water depth averaged 8 m (range 5–12 m). Clams were brought to the surface in nylon-mesh dive bags, wrapped in chemically cleaned aluminum foil (acetone and hexane washed), and frozen whole. During prey collection, divers attempted to obtain three *Saxidomus giganteus* within each plot. However, this could not be accomplished in all plots and, where possible, three of each clam species encountered were submitted for

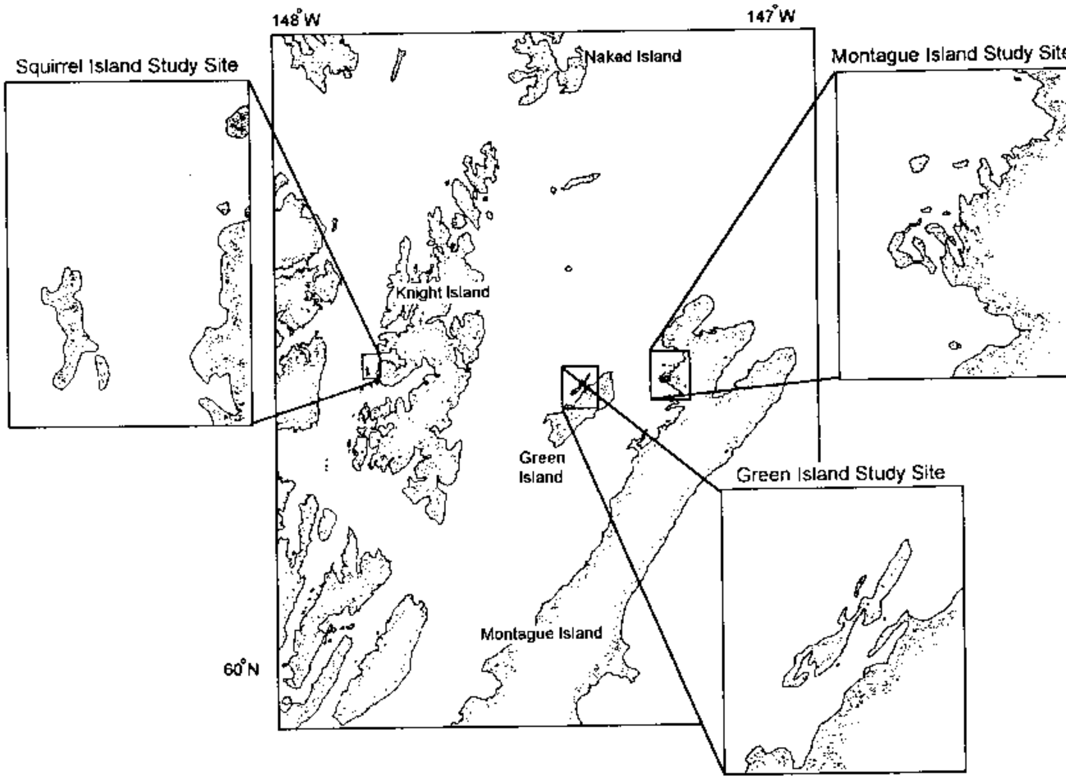

Figure 11-1. Sea otter forage study site locations in western Prince William Sound, 1991.

analysis. When more than three clams of the same species were retrieved from a single plot, three were randomly selected for hydrocarbon analyses. Clams were thawed in the laboratory and soft tissue was removed (using instruments cleaned with acetone and hexane) from the shell and placed in chemically clean jars, weighed, and refrozen. Samples were shipped to the Geochemical and Environmental Research Group (GERG), Texas A&M University, College Station, Texas, for analysis of the hydrocarbon content. The tissue extraction method used in the analysis was developed by McLeod et al. (1985) and modified by Wade et al. (1988, 1993) and Jackson et al. (in press). Laboratory methodology for the hydrocarbon analysis for this study was standardized with all Natural Resources Damage Assessment Studies by GERG (GERG standard operating procedures 8901-8905).

Data Analysis

The foraging record is defined in this chapter as the foraging data specific to a focal animal and was used as the sample unit in the analyses of foraging behavior. The sample unit in the analysis of dive and surface intervals was individual dives.

The percentage of successful dives was determined for all foraging records of adult and juvenile sea otters having ≥10 dives. Dives of unknown result were not included in this analysis. The proportion of successful dives was normalized by an arcsine square-root transformation. An analysis of variance (ANOVA) was used to test for differences in foraging success among sites and between adults and juveniles.

The number of prey items captured per dive was averaged for each foraging record by site. Dives resulting in the capture of mussels were excluded from this analysis due to the difficulty in obtaining accurate counts on a per-dive basis. Dives of unknown result were not used in this analysis. An ANOVA was used to test for differences in the number of prey retrieved per dive among sites.

Mean dive and surface intervals were tested among study sites and prey types (clams, crabs, and mussels) by a two-way ANOVA for an unbalanced sample.

Foraging records for each focal animal having ≥10 foraging dives were summarized into the proportion of dives resulting in the capture of clams, crabs, or mussels within each study site. The Kruskal-Wallace nonparametric procedure was used to test for differences in the proportion of clams, crabs, and mussels captured among sites for adult sea otters and between adults and juveniles (sample sizes were sufficient to test age differences only for the Green Island study site).

Hydrocarbon concentrations were reported by GERG in ng/g wet weight for alkanes and aromatics, and in µg/g wet weight for the unresolved complex mixture (UCM). Mean concentrations of total alkanes, total aromatics, and UCM were tested among study sites by ANOVA procedures. Prior to analysis, data were transformed by a $\log_{10}(x_i + 1)$ to normalize the distribution.

RESULTS

Foraging Behavior

At Squirrel Island, 69 foraging records were observed (68 adults and 1 juvenile). Thirty-eight foraging records (29 adults and 9 juveniles) were observed at Green Island and 72 foraging records (69 adults and 3 juveniles) were observed at Montague Island.

Sea otters recovered prey items on 87–92% of their foraging dives and foraging success did not differ among sites (F=1.23, P=0.29) (Table 11-1). Mean foraging success rates were 90% (*n*=82) for adult and 92% (*n*=10) for juvenile sea otters in all study sites combined and did not differ significantly (F=0.50, P=0.48).

Mean number of prey retrieved per dive were 1.2, 1.0, and 1.3 for Squirrel, Green, and Montague Islands, respectively; differences were not detected among sites (F=2.19, P=0.11). Size class was estimated for 1867 prey items; the majority of prey items, 96% or greater, were <9 cm in all sites (Table 11-1).

Mean dive intervals varied from 43 to 88 seconds, and surface intervals varied from 37 to 48 seconds for all prey types within the study sites. Dive intervals differed significantly for dives retrieving clams (80–119 seconds), mussels (20–35 seconds), and crabs (63-82 seconds) among study sites (F=19.83, P<0.001) and among prey types (F=135.92, P<0.001), and the interaction between site and prey type also differed (F=24.16, P<0.001).

Prey Composition

Adults differed in the proportion of dives resulting in the capture of clams (χ^2=9.73, P=0.01), crabs (χ^2=7.03, P=0.03), and mussels (χ^2=7.21, P=0.03) among sites (Table 11- 2). The median proportion of dives resulting in the capture of clams was higher than that for mussels or crabs in all study sites for adults and was less (0.29) for Squirrel Island than for Green (0.75) or Montague (0.62) Islands. Sample sizes were insufficient to allow testing for differences in prey composition related to sex or reproductive status. Juvenile sea otters at the Green Island site captured mussels on a significantly higher proportion of dives than did adults (χ^2=5.73, P=0.02) (Table 11-2). Differences in the proportion of dives in which clam or crab were captured (in the Green Island area) were not detected between adult and juvenile sea otters. There again, sample sizes were insufficient to allow for testing of age group differences in the proportion of dives resulting in the capture of prey at Squirrel and Montague Island study sites.

Clams were retrieved on 34%, 61%, and 44% of the successful sea otter foraging dives at Squirrel (*n*=833), Green (*n*=759), and Montague (*n*=752) Islands, respectively (Table 11-3). *Saxidomus giganteus* was the most commonly identified clam in the sea otter diet for all study sites. Other clam species identified were *Mya* spp.,

Table 11-1. Prey type, size class, proportion of successful dives, and mean number of prey retrieved per dive estimated for sea otters (*Enhydra lutris*) at three sites in western Prince William Sound, Alaska, during April-July 1991.

Prey type	Size class (cm)	Squirrel Island	Green Island	Montague Island
Clam	< 5	63%	79%	49%
	≥ 5 < 7	28%	20%	46%
	≥ 7 < 9	8%	1%	5%
	≥ 9 <12	1%	0%	0%
	≥ 12	<1%	0%	0%
		(n = 296)	(n = 479)	(n = 351)
Mussel	< 5	100%	100%	100%
		(n = 142)	(n = 159)	(n = 53)
Crab	< 5	18%	21%	43%
	≥ 5 <7	43%	71%	52%
	≥ 7 <9	30%	7%	5%
	≥ 9 <12	7%	0%	0%
	≥ 12	2%	0%	0%
		(n = 90)	(n = 14)	(n = 112)
All Prey[a]	< 5	63%	79%	49%
	≥ 5 <7	23%	17%	42%
	≥ 7 < 9	10%	4%	8%
	≥ 9 <12	3%	<1%	<1%
	≥ 12	1%	0%	1%
		(n = 598)	(n = 690)	(n = 579)
Mean number of prey per dive[b]		1.2	1.0	1.3
Percentage of successful dives		87%	92%	90%

[a] Includes clams, mussels, crab, and all other prey identified as to size class.
[b] Dives resulting in capture of mussels were excluded for this analysis due to the difficulty in obtaining accurate counts on a per dive basis.

Table 11-2. Median proportion of dives resulting in the capture of clams, crabs, and mussels for adult and juvenile sea otters (*Enhydra lutris*) in Prince William Sound, Alaska, 1991. (--- = no data)

	Green Island				Squirrel Island				Montague Island			
Age class	Clam[a]	Crab[b]	Mussel[b]	N[c]	Clam[a]	Crab[b]	Mussel[b]	N[c]	Clam[a]	Crab[b]	Mussel[b]	N[c]
Adults	0.75	0.0	0.0[d]	15 (356)	0.29	0.03	0.06	34 (754)	0.62	0.07	0.0	28 (531)
Juveniles	0.16	0.0	0.44[d]	8 (365)	---	---	---	---	0.17	0.41	0.0	2 (59)

[a] Significant differences among areas in the proportion of dives resulting in the capture of clam (P = 0.01) by adults determined by a Kruskal-Wallace test.
[b] Significant differences among areas in the proportion of dives resulting in the capture of crab (P = 0.03) and mussel (P = 0.03) by adults determined by Kruskal-Wallace tests.
[c] Number of foraging records (total number of foraging dives).
[d] Significant differences among age classes in the proportion of dives capturing mussels at Green Island (P = 0.02) determined by a Kruskal-Wallace test.

Table 11-3. Composition of sea otter (*Enhydra lutris*) prey determined by visual observation at three sites in western Prince William Sound Alaska, during April-July 1991. (— = no data)

	Squirrel Island (%)	Green Island (%)	Montague Island (%)
Clam[a]	34	61	44
Mya spp.	2	—	3
Protothaca staminea	3	5	<1
Saxidomus giganteus	21	20	9
Tresus capax	<1	<1	<1
Unknown clams	73	75	87
Mussel[a]	17	20	7
Mytilus edulis	100	100	100
Crab[a]	11	2	14
Telmessus spp.	46	27	72
Unknown crabs	54	73	28
Other	5	4	4
Balanus spp.	3	12	—
Chlamys spp.	—	—	6
Clinocardium spp.	21	3	33
Cucumaria spp.	5	—	—
Echiurus echiurus	3	67	12
Notoacmea spp.	3	—	—
Octopus spp.	3	—	3
Pisaster ochraceus	47	12	39
Pododesmus macrochisma	—	3	—
Pycnopodia helianthoides	3	—	—
Strongylocentrotus spp.	10	—	3
Chiton (class Polyplacophora)	3	—	—
Tunicate (class Ascidiacea)	—	3	3
Unknown prey	33	12	30

[a] Adults differed in the proportion of dives retrieving clam ($P = 0.01$), crab ($P = 0.03$), and mussel ($P = 0.03$) among study areas.

Protothaca staminea, and *Tresus capax*. Mussels (*Mytilus edulis*), and crabs (primarily *Telmessus* spp.) each contributed 20% or less to the identified species for each study site. Other prey included: limpets (*Notoacmea* spp.), barnacles (*Balanus* spp.), cockles (*Clinocardium* spp.), scallops (*Chlamys* spp.), sea cucumbers (*Cucumaria* spp.), fat innkeepers (*Echiurus echiurus alaskensis*), octopus (*Octopus* spp.), sea stars (*Pisaster* spp.), jingles (*Pododesmus* spp.), sunflower sea stars (*Pycnopodia helianthoides*), sea urchins (*Strongylocentrotus* spp.), chitons (Class Polyplacophora), and tunicates (Class Ascidiacea). These species contributed 5% or less to otter diets at each study site (Table 11-3).

Table 11-4. Estimated percentage of prey type (mussel, clam, crab, and other small invertebrates) found in 253 scat samples examined during 20 April to 2 May 1991 in western Prince William Sound, Alaska.

	Estimated percentage								
Prey type	100%	90%	75%	50%	25%	10%	5%	Occurrence in sample (percentage)	
Mussel[a]	76	24	10	13	14	6	10	153	(60%)
Clam[b]	23	22	8	15	21	10	17	116	(46%)
Crab[c]	0	2	2	5	21	10	7	47	(19%)
Other[d]	13	4	5	8	4	6	10	50	(20%)

[a] Mytilus edulis

[b] *Protothaca staminea, Saxidomas giganteus, Humilaria kennerleyi, Gari california:* includes unidentified shell fragments.

[c] Species not identified.

[d] Other is equivalent to one or more of the following species: scallop (*Chlamys* spp.), snail (*Natica* sp.), cockle (*Clinocardium* spp.), limpet (*Notoacmea scutum*), and other unidentified shell fragments.

Fifty-six percent of the 253 scat samples examined in the Green Island study site contained more than one prey species (Table 11-4). Mussels were observed in 153 of 253 (60%) sea otter scat and clams were observed in 116 of 253 (46%) scat examined. Clam species were primarily *Protothaca staminea* and *Saxidomus giganteus* with trace amounts of *Humilaria kennerleyi* and *Gari californica*. Crab and other small invertebrates were found in 19% and 20%, respectively, of scat sampled. Of scats containing a single prey type, 76 contained only mussels, 23 contained only clams, and 13 contained either scallops (*Chlamys* spp.), snails (*Natica* sp.), cockles (*Clinocardium* spp.), or limpets (*Notoacmea scutum*).

Prey Hydrocarbon Analysis

A total of 79 prey samples were collected for hydrocarbon analyses. Twenty-five prey were collected in seven plots at Squirrel Island; 33 prey in seven plots at Green Island, and 21 prey in six plots at Montague Island. *Protothaca staminea* (n=24), *Mya* spp. (n=23), and *S. giganteus* (n=20) were most frequently collected. Species composition and size class samples within sites are presented in Table 11-5.

Tissue samples of subtidal bivalves obtained from sites which had received heavy to moderate shoreline oiling in 1989 had no detectable differences in mean total alkane (F=2.35, P=0.10), aromatic (F=0.16, P=0.85), and UCM (F=0.56, P=0.57) concentrations from the site where no shoreline oiling occurred (Table 11-5). Mean concentrations of total alkanes and aromatics were slightly higher, however, for tissue samples collected at Green Island than those from Squirrel and Montague Islands. At all sites, *Mya arenaria* contained the highest concentration of total alkanes of all species sampled.

DISCUSSION

Although foraging success was high (90% for all observations), the majority of clams (95% of 1126) observed were small (estimated to be <7cm). Garshelis et al. (1986) reported clams captured by sea otters rarely exceeded 6 cm in the Green Island site during 1980–1981. During 1991, 79% (n=479) of the clams captured at Green Island were estimated to be <5 cm, 20% ranged between 5 and 7 cm, and none were estimated to be larger than 9 cm. Mean shell length for clams recovered in the dredge samples in the Green Island area ranged from 3.3 to 4.7 cm.

Dive duration and surface intervals between dives were variable for individuals but significantly different depending on the type of prey captured. Individual animals, water depth, geographic location, and food item all contribute to variation in duration of foraging dives (Estes et al. 1981; Garshelis 1983). Sea otters at Squirrel, Green, and Montague Islands foraged on the same principal species in

Table 11-5. Hydrocarbon and size class means for bivalves collected subtidally near Squirrel (oiled), Green (oiled), and Montague (non-oiled) Islands in western Prince William Sound, Alaska, summer 1991.

Sample location and species sampled	Total alkanes (ng/g)	Total aromatics (ng/g)	Unresolved complex mixture (μg/g)	Mean shell length (mm)	Mean wet meat mass (g)	N
Squirrel Island						
Humilaria kennerleyi	788.5	48.4	14.8	46	7.8	3
Mya arenaria	1752.6	79.4	0.0	41	4.4	4
Protothaca staminea	629.0	55.6	3.9	44	10.0	6
Saxidomas giganteus	900.3	51.7	6.3	51	14.6	11
Serripes groenlandicus	1225.1	57.0	6.3	56	16.2	1
Site mean ± SD	971.2 ± 712.0	56.9 ± 18.7	5.7 ± 8.3	47 ± 17.4	11.2 ± 6.1	25
Green Island						
Gari california	1278.2	39.7	3.7	47	0.4	4
Humilaria kennerleyi	1034.2	74.7	56.1	33	2.7	1
Mya arenaria	1494.4	68.8	4.0	40	4.1	15
Protothaca staminea	790.2	54.8	0.5	41	8.0	9
Saxidomas giganteus	897.8	45.9	0.5	41	8.2	4
Site mean ± SD	1189.9 ± 1033.0	58.9 ± 18.7	4.1 ± 10.9	41 ± 6.1	6.3 ± 3.5	33
Montague Island						
Gari california	823.3	49.2	3.8	49	5.5	1
Humilaria kennerleyi	569.1	59.7	11.6	52	13.7	2
Mya arenaria	996.4	72.5	1.2	48	7.1	4
Protothaca staminea	806.2	52.2	4.7	41	8.3	9
Saxidomas giganteus	843.0	49.0	0.3	33	4.0	5
Site mean ± SD	829.4 ± 163.9	55.9 ± 12.0	3.6 ± 6.4	42 ± 7.9	7.4 ± 4.0	21

1991, as were observed in previous years (Calkins 1978; Garshelis et al. 1986; Johnson 1987), suggesting there has been no detectable shift in prey composition over time or as a result of shoreline oiling at these study sites. Clams, mussels, and crabs were the primary prey of sea otters at all sites; however, there were differences in the proportion with which these prey were captured among sites. The difference in the proportions of prey type captured by sea otters among sites may have been influenced by the proportion of unidentified prey within each site (Table 11-3) or by variation in prey availability within each site. There was no replication of treatment types (heavy oil, moderate oil, and no oil); therefore, we have no measure of natural variation within each treatment.

Prey composition determined from scat contents also indicated mussels, clams, and crabs were important prey of sea otters. Sea otters haul out most frequently during the winter in PWS; therefore, these data primarily represent the overwinter diet near Green Island (Johnson 1987; VanBlaricom 1988). Johnson (1987) examined 3275 scat in the Green Island site during 1974–1984 and found 58%, 34%, 36%, and 16% of the scat contained clams, mussels, crabs, and other species, respectively. In our sample from the same region, we observed mussels most frequently (60%). Whether the observed differences reflect changes in prey use over time, changes in the ratio of adults and juveniles using the haulout site through time, or variation in scat content between observation periods is unknown.

Determination of sea otter prey composition through visual observation or scat analysis can yield different results; both methods have inherent biases. Prey composition based on visual observations is biased toward: (1) prey captured from nearshore areas; (2) larger prey items (greater than the paw size of the animal); and (3) prey captured during daylight hours. Prey composition based on scat analysis is biased against larger prey when no hard parts are ingested. Scat analysis also cannot reveal any potential variation in diet between adult and juvenile or male and female otters.

Adult sea otters foraged primarily on species found in the subtidal zone, whereas juveniles had a higher proportion of an intertidal species, the mussel, in their diet based on visual observation. Johnson (1987) also reported dietary differences between adult (19% mussel and 59% clam) and juvenile (63% mussel and 16% clam) sea otters at Green Island during 1974–1984. In California, Estes et al. (1981) found that juveniles commonly foraged in water ranging from 1 to 2 fathoms while adults nearly always foraged in deeper water. Mussels can easily be obtained by foraging sea otters because they occur in the intertidal zone and require little effort to capture (Estes et al. 1981; VanBlaricom 1988). Mean dive intervals for mussels were shorter than those recorded for other prey. However, mussels are less valuable calorically than other sea otter prey (Garshelis 1983).

Mean total aromatic and UCM concentrations in intertidal mussel tissue collected at our study site on Green Island during 1989 were 2566 ng/g (± 853) and

171.4 μg/g (± 58.6), respectively (Andres and Cody 1993). These values are as much as 40 times greater than the mean levels that we observed in the subtidal clam tissue samples at Green Island in 1991. Unfortunately, no intertidal mussels were collected in 1991 to assess the persistence of hydrocarbons in the mussel tissues at the Green Island site. Andres and Cody (1993) also reported hydrocarbon levels in mussel tissue of 82 ng/g (± 21) and 7.4 μg/g (± 1.7) for total aromatic and UCM concentrations, respectively, from our Montague Island study site; aromatic and UCM levels were slightly lower in the subtidal bivalve tissue collected 1991. Other sites in PWS were sampled annually (1989–1992) and, at some sites, mussel tissue and the underlying sediments consistently contained high concentrations (up to 50 parts per million) of total aromatic hydrocarbons (Babcock et al. 1993; Rounds et al. 1993).

Juvenile sea otters foraged on mussels to a greater extent than adults. However, individual adults and juveniles may specialize on only a few species, some of which occur in the intertidal region (Ralls et al. 1988; Riedman and Estes 1990). Therefore, juveniles and individual adults specializing in intertidal species could have a higher probability of encountering hydrocarbon contamination in their prey than individuals foraging in the subtidal regions.

CONCLUSIONS

Sea otter foraging success, in terms of the percentage of successful dives or mean number of prey items captured per dive, was not affected in the oiled area 2 years after the EVOS. Prey composition (primarily clam, mussel, and crab) was similar among oiled and nonoiled study sites and to prespill data from the western PWS region. Adult sea otters foraged primarily in the subtidal region, while juveniles foraged more frequently intertidally. Tissues of subtidal bivalve prey tested for hydrocarbon content did not differ regardless of the degree of shoreline oiling. Mussel tissue sampled in 1989–1992 in the intertidal regions exhibited, in site-specific areas, hydrocarbon concentrations similar to crude oil (Babcock et al. 1993). Contamination of mussels and other intertidal prey species may be of concern for juvenile sea otters and for adults specializing in the use of intertidal prey.

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