

THE M/V SELENDANG AYU OIL SPILL SUBSISTENCE SEAFOOD SAMPLING PROGRAM AND PUBLIC HEALTH EVALUATION PROCESS

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ABSTRACT

On December 8, 2004, the M/V Selendang Ayu, a bulk freighter, ran aground on the western shoreline of Unalaska Island, Alaska, spilling an estimated 339,538 gallons of intermediate fuel oil and 14,680 gallons of marine diesel. A primary concern arising from this incident was the potential contamination of traditional subsistence seafood resources consumed by tribal members and others on Unalaska Island. The process of addressing this concern consisted of the following components: 1) formation of a subsistence seafood 'core' or management team that included representatives of the local tribe, native corporation, federal and state agencies, and the responsible party; 2) formation of an advisory team representing technical specialists from non-governmental organizations (NGOs), academia, and subsistence users; 3) identification of important subsistence seafood resources, including intertidal mussels, sea urchins, chitons, salmon, cod and sea lions; 4) a consumption survey of major subsistence seafood users from Unalaska Island; 5) the collection of 56 samples in 2005 and 9 in 2006 by teams that included representatives of the core and advisory teams; 6) polycyclic aromatic hydrocarbon (PAH) analysis and organoleptic and paralytic shellfish poison (PSP) testing of the collected samples; 7) a risk-based public health evaluation of the analytical results of collected samples by the State of Alaska Division of Public Health; and 8) communication of the results to the public.

In the core spill area (Skan and Makushin Bays), only one subsistence sample contained PAHs exceeding risk-based screening criteria. This was a mussel sample collected in April 2005 prior to clean-up actions. No samples collected in 2006 exceeded public health screening criteria. In the main subsistence area (Unalaska Bay), only one chiton sample collected in June 2005 exceeded risk-based public health screening criteria. However, it was determined that the elevated PAH concentrations were not derived from the Selendang Ayu. Subsequent samples collected from the same location could not confirm elevated PAHs. Overall, PAHs were not present at levels of health concern, but two samples contained

PSP toxin above regulatory guidelines. Due to PSP concerns, the State of Alaska has an on-going advisory against the consumption of locally harvested shellfish that pre-dates the spill.

INTRODUCTION

On December 8, 2004, the M/V Selendang Ayu ran aground and broke apart near Unalaska Island, Alaska, USA between Skan Bay and Spray Cape approximately 25 air miles southwest of Dutch Harbor (Figure 1). An estimated 339,538 gallons of intermediate fuel oil and 14,680 gallons of marine diesel/miscellaneous oils have been released to the environment (ADEC, 2005; Barry, 2005).

Approximately 474 miles (806 segments) of shoreline were evaluated for potential clean up activities. Of those, portions of 70 miles of shoreline (123 segments) were identified as needing additional treatment (ADEC, 2005). Clean up activities commenced during May of 2005 and all but 26 segments (15.54 miles of shoreline) met clean up criteria as of September 2005. The remaining 26 segments located in Skan and Makushin Bay, were evaluated for clean up in the spring of 2006. At the end of operations in June 2006, nineteen of these segments met end point criteria established for the response (M/V Selendang Ayu Unified Command (UC), 2006a). Two of the remaining seven shoreline segments were not cleaned to end point criteria due to safety concerns (inaccessible shoreline). Five additional segments were near end point criteria, and were designated by the Unified Command for no further treatment, as the remaining oil did not pose a threat to public health or the environment.

This report is a summary of the public health response by Alaska Native organizations, federal, state and local officials, and the responsible party (RP). Detailed information on the cleanup can be found on the Unified Command internet site (M/V Selendang Ayu Unified Command, 2006b). The public health evaluations of the results of the subsistence sampling in 2005 and

2006 provided by the Alaska Division of Public Health (ADPH, 2006; ATSDR, 2007) are summarized here.

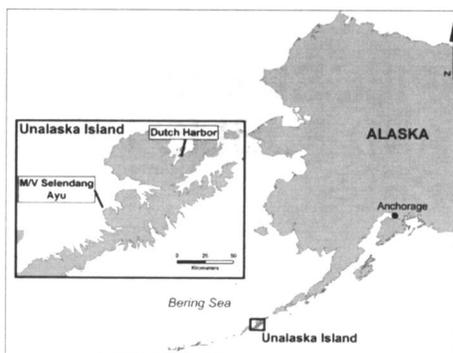


FIGURE 1. LOCATION OF M/V SELENDANG AYU GROUNDING; UNALASKA ISLAND, ALASKA.

METHODS

Subsistence Fishery Advisory Group

In March of 2005, the Unified Command of the M/V Selendang Ayu grounding and oil spill formed a Subsistence Fishery Advisory Group whose charge was to evaluate whether subsistence foods in the Unalaska area were impacted by the spill. A smaller 'core' group within the advisory group was responsible for writing draft sampling plans and other documents, which were then reviewed by the larger group before being made final. The groups held monthly or semimonthly conference calls over a period of approximately one year, and consisted of the following twenty-two members:

- 1) Six representatives of the Qawalangin Tribe, the Ounalashka Corporation (OC), the Aleutian Pribilof Islands Association (APIA), the Alaska Native Harbor Seal Commission (ANHSC), the Alaska Native Science Commission (ANSC), and the Bureau of Indian Affairs (BIA);
- 2) Five State representatives from various departments and divisions of the Alaska Department of Environmental Conservation (ADEC), the Alaska Department of Health and Social Services, Division of Public Health (ADPH), and the Alaska Department of Fish and Game (ADFG);
- 3) Five Federal representatives with the Alaska Maritime National Wildlife Refuge (AMNWR), the U.S. Fish and Wildlife Service (USFWS), and the National Oceanic and Atmospheric Administration (NOAA);
- 4) Three personnel representing the Responsible Party (RP), from Polaris Applied Sciences and Chumis Cultural Resources; and
- 5) One person representing the University of Alaska Marine Advisory Program (MAP).

Subsistence Food Consumption Questionnaire

The M/V Selendang Ayu Subsistence Fishery Core Group designed and administered a subsistence food consumption questionnaire (ADPH, 2006). The questionnaire was modeled after the Aleutian Pribilof Islands Association Alaska Traditional Diet Project Nutrition Questionnaire of August 2003 (APIA, 2003). The questionnaire was presented to the Alaska Area Institutional Review Board (IRB), and it was concluded IRB approval was not necessary.

SUBSISTENCE FOODS SAMPLING

Samples of marine invertebrates and fish used as subsistence food resources were collected using tissue sampling methods described in ADPH (2006). In 2005, 56 samples of subsistence fishery resources were collected in: 1) Unalaska Bay, 2) Makushin and Skan Bays in the core spill area near the grounding site of the M/V Selendang Ayu on Spray Cape, and 3) Kashega and Kismaliuk Bays to the southwest of the core spill area as per a sampling plan developed by the M/V Selendang Ayu Subsistence Core Group (ADPH, 2006). Sampling teams consisting of personnel from Polaris Applied Sciences, the Qawalangin Tribe, Ounalashka Corporation, NOAA, the Marine Advisory Program of the University of Alaska Fairbanks, and Chumis Cultural Resource Services collected samples of blue mussels, black chitons, green sea urchins, pink salmon, Pacific cod, and harbor seal from June to September of 2005 at 24 locations on Unalaska Island (ADPH, 2006). In addition to these samples, NOAA collected five samples of blue mussels at two oiled shoreline locations in Skan Bay in April 2005 prior to clean-up actions. Mussel samples were also collected at eight locations and submitted for organoleptic and Paralytic Shellfish Poisoning (PSP) testing at the ADEC laboratory in Palmer, Alaska.

The public health evaluation report on the 2005 samples recommended that additional mussel samples be collected near the spill site in 2006 (ADPH, 2006). Seven sampling sites for spring 2006 were chosen based on the following criteria: 1) sites previously sampled in 2005, located in or near segments that did not meet cleanup endpoint by the end of 2005 operations, and/or 2) subsistence areas not sampled in 2005, located on shorelines oiled during the initial incident. A sampling team consisting of a representative of Polaris Applied Sciences and the Qawalangin Tribe collected blue mussel samples from six of the seven locations in May 2006 using methods detailed in the spring 2006 sampling plan (Polaris Applied Sciences, 2006). A NOAA representative collected mussels from the seventh site.

Collected subsistence foods were analyzed for polycyclic aromatic hydrocarbons (PAHs). Health concerns of exposure to oil from spills are mainly focused on PAHs due to their chemical and toxicological properties (Bolger et al., 1996). Some PAHs are potentially carcinogenic, they are relatively (compared to other compounds in oil) resistant to environmental degradation, and can accumulate in the food chain.

ANALYTICAL METHODOLOGY

PAH concentrations in subsistence samples were determined by modified USEPA Method 8270c at the Woods Hole Group Analytical Laboratory in Raynham, Massachusetts. The raw analytical chemistry data are available upon request from Polaris Applied Sciences, Kirkland, WA. Organoleptic and paralytic shellfish poisoning toxin (PSP) testing was conducted at the Alaska Department of Environmental Conservation Laboratory in Palmer, AK.

Spring and Summer 2005 Sampling

In April 2005, prior to shoreline clean up activities in North and South Skan Bay, the most heavily oiled areas, two composite (10 to 20 individuals) blue mussel samples were collected for PAH analysis from North Skan Bay (SKN) and 3 composite blue mussel samples were collected from South Skan Bay (SKS; Figure 2).

During June and July of 2005, composite samples of (10 to 20 individuals) blue mussels, black chitons, and green sea urchins were collected from Unalaska Bay in areas frequented by residents of Unalaska in Captain's (CBW), Iliuliuk (DTE), and Summer (SMB) Bays (Figure 2 inset). During August and September of 2005, after oil spill clean up activities were essentially completed for the summer, composite samples of blue mussels, black chitons,

and green sea urchins were collected near the Selendang Ayu grounding and spill area in Anderson (AND), Cannery (CNB), Kashhega (KSB), Kismaliuk (KMK), Makushin (MKS), and North and South Skan (SKN and SKS) Bays.

Overall, 17 composite black chiton, 30 composite blue mussels, and 12 composite green sea urchin roe samples were collected and analyzed for PAH analysis. In addition, three pink salmon were collected from Summer Bay (SMB), three pink salmon were collected from Skan Bay (SKN), and one pacific cod was collected from Naginak Cove (NGE). Blubber from a harbor seal harvested in Wide Bay (EIDER) was also collected.

Ten blue mussel composite samples were collected in Anderson, Cannery, Makushin, Skan and Summer Bays for organoleptic (i.e., inspection of the sample for oil by smell and sight by a panel of certified laboratory technicians) and PSP toxin analyses.



FIGURE 2. LOCATIONS OF SUBSISTENCE SAMPLES COLLECTED IN 2005.

Spring 2006 Sampling

As recommended in the 2006 public health evaluation (ADPH, 2006), nine additional blue mussel samples were collected near the spill site in 2006. A sampling team consisting of a representative of Polaris Applied Sciences and the Qawalangin Tribe collected samples from six of the seven proposed locations on May 26, 2006, accessing the sampling sites by helicopter. A representative of NOAA collected two samples from the north and south ends of segment SKN-11 on May 24, 2006. Blue mussel samples were collected at the following seven locations in spring 2006 (Figure 3): 1) Wide Bay (UNK), 2) Volcano Bay (VLC), Makushin Bay (MKS), North Skan Bay (SKN), South Skan Bay (SKS), Kashhega Bay (KSB), and Kismaliuk Bay (KMK).



FIGURE 3. LOCATIONS OF SUBSISTENCE SAMPLES COLLECTED IN 2006.

DETERMINATION OF BENZO(A)PYRENE EQUIVALENTS

Each subsistence sample analyzed for PAHs was evaluated for its overall carcinogenic potency by calculating benzo(a)pyrene (BaP) equivalents as done previously for the *Exxon Valdez*, *Kuroshima* (Unalaska Island, AK), *North Cape* (Rhode Island), *Kure* (Humboldt Bay, CA), *New Carissa* (Coos Bay, Oregon) and other oil spills (Bolger et al., 1996, Agency for Toxic Substances and Diseases Registry (ATSDR; 1999); Gilroy, 2000; Mauseth and Challenger, 2001). For each sample, the carcinogenic potency of each PAH compound was expressed relative to BaP and then summed for an overall estimate of BaP-like activity. PAHs that were not detected were assigned a value of zero. The USEPA provides BaP equivalents for six PAHs (Table 1; USEPA, 1993; 2004).

TABLE 1. BENZO(A)PYRENE EQUIVALENTS (BAP) FOR POLYCYCLIC AROMATIC HYDROCARBONS^A.

Compound	BaP Equivalent
Benzo(a)pyrene	1.0
Benzo(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene ^b	0.01
Chrysene ^c	0.001
Dibenzo(a,h)anthracene	1.0
Indeno[1,2,3-cd]pyrene	0.1

^a BaP equivalent values used to evaluate 2005 subsistence samples from USEPA (1993; 2004)

^{b,c} 2006 subsistence samples were evaluated using California EPA (2002) carcinogenic potency equivalency factors (PEFs)(ATSDR, 2007), which were identical to the BaP Equivalents used in ADPH (2006) - with the exception of benzo(k)fluoranthene (0.1) and chrysene (0.01). These differing values had no effect on the conclusions of the evaluations.

RISK-BASED SCREENING CRITERIA

Risk-based screening criteria (i.e., the concentration that is reasonably considered safe) were calculated for each subsistence food to compare to the concentration of carcinogenic PAHs (i.e., BaP equivalents) detected in each sample. The risk-based screening criteria were calculated using the following formula and the standard assumptions in Table 2:

$$\text{Risk-based screening criteria } (\mu\text{g/kg}) = \frac{\text{RL} \times \text{BW} \times \text{AT} \times \text{CF}_1}{\text{CF}_2 \times (\text{SF} \times \text{ED} \times \text{CR})}$$

TABLE 2. INPUT VARIABLES FOR RISK-BASED SCREENING CRITERIA.

Input Variable	Symbol	Value	Units
Acceptable risk level	RL	1.0 x 10 ⁻⁶	
Body weight, adult	BW	70	kg
Averaging time	AT	70	years
Conversion factor	CF ₁	1000	µg/mg
Conversion factor	CF ₂	1000	g/kg
USEPA slope factor for BaP	SF	7.3	(1/mg/kg-day)
Exposure duration	ED	3	years
Consumption rate	CR	see Table 3	g/day

^a USEPA's risk management range for excess cancer risk above background is one-in-one-million (10⁻⁶) to one-in-ten thousand (10⁻⁴) (U.S. EPA, 1993; 2004; American Cancer Society, 2005).

^b Standard default for adult body weight (U.S. EPA, 1993; 2004).

^c Standard default for life expectancy (U.S. EPA, 1993; 2004).

^d Estimated maximum residence time for oil (Bolger et al., 1996; Gilroy, 2000).

RESULTS

Subsistence Food Questionnaire

Twenty-three known frequent subsistence food consumers were interviewed about their seafood consumption in late September and early October of 2005. The upper confidence limit of the mean ingestion rate (g/day) was calculated (the survey results are posted on the Unified Command web site). Table 3 presents the results of this survey and the results of a survey conducted by the Alaska Department of Fish and Game (ADFG), Division of Subsistence in 1994 for Unalaska (ADFG, 2001). For the ADFG survey, mean ingestion rates for subsistence resources were based on a random sample of 106 households in Unalaska and were determined as follows. Households were asked how much of a resource they harvested per year. The total yearly harvest for the 106 households was used to estimate the total annual harvest for the Unalaska/Dutch Harbor community.

TABLE 3. UPPER 95TH CONFIDENCE LIMIT OF THE MEAN INGESTION RATE (G/DAY) AND RISK-BASED SCREENING CRITERIA FOR THE SELENDANG AYU OIL SPILL NEAR UNALASKA, ALASKA.

Resource	Selendang Ayu consumption survey (2005) ingestion rate ^a (g/day)	Risk-based screening criteria (µg/kg)	ADFG (1994) ingestion rate ^b (g/day)	Risk-based screening criteria (µg/kg)
black chitons	3.7	60.1	16.3	13.7
sea urchin roe	2.2	99.9	8.3	27.0
blue mussels	1.5	145.3	11.9	18.8
all salmon	65.3	3.4	98.2	2.3
all harbor seal tissues	11.6	19.3	25.8	8.7
pacific cod	11.9	18.9	27.6	8.1

^a the ingestion rate for blue mussels represents all shellfish (i.e., razor, butter, steamer clams; blue mussels, and cockles). See ADPH (2006) for additional information.

^b See ADPH (2006) for detailed information on the derivation of the ingestion rate.

RISK-BASED SCREENING CRITERIA

Based on the ingestion rates for each subsistence food sampled, a risk-based screening value was calculated (Table 3). Since the ADFG ingestion rates were greater than the ingestion rates determined from the Selendang Ayu subsistence food questionnaire for all foods sampled, and the calculated risk-based screening criteria were lower, the risk-based screening criteria based on the ADFG ingestion rates were used to compare to the total BaP equivalents for each sample.

PAH ANALYTICAL RESULTS AND COMPARISON TO RISK-BASED SCREENING CRITERIA

Spring and Summer 2005 Sampling Results

The PAH analytical results (total PAHs and total BaP equivalents) and calculated risk-based screening criteria for samples collected in 2005 are shown in Table 4 for each sample. The samples with total BaP equivalents exceeding the risk-based screening criteria are shown in bold print.

Samples collected from Unalaska Bay

One composite black chiton sample (CH-SMB7-062305-01) collected in June 2005 from Humpy Cove had a total BaP equivalents of 41 µg/kg compared to the calculated risk-based screening criteria of 13.7 µg/kg (Table 4). This sample was reanalyzed by the laboratory on two additional occasions and the results were 83 and 158 µg/kg (Table 4). The source of PAHs in this sample was not Selendang Ayu oil (see discussion). Two other composite black

chiton samples (CH-SMB7-062305-02 and CH-SMB7-062305-03) were collected at the same time in the same area of Humpy Cove. The results of these samples were significantly lower (0.00016 µg/kg and 0.00013 µg/kg) and not above the risk-based screening criteria. An additional composite black chiton sample was collected in September (CH-SMB7-9-25-05) from the same area in Humpy Cove and this result (0.0053 µg/kg) was lower than the risk-based screening criteria of 13.7 µg/kg. No other samples from Unalaska Bay exceeded the risk-based screening concentration.

Samples collected near the spill site

The total BaP equivalents for one composite blue mussel sample (35 µg/kg) collected from North Skan Bay in April 2005 (prior to clean up operations) exceeded the calculated risk-based criteria of 18.8 µg/kg. The results of the only composite blue mussel sample collected from North Skan Bay in September (8.6 µg/kg total BaP equivalents) did not exceed the risk-based screening criteria (Table 4).

No other samples collected near the spill site exceeded the risk-based screening criteria.

Organoleptic analysis

Petroleum was not detected in the ten blue mussel samples collected in 2005 by organoleptic analysis (Table 5).

TABLE 5. PARALYTIC SHELLFISH POISONING (PSP) TOXIN AND ORGANOLEPTIC RESULTS.

Collection Date	Location ID	Sample ID	Species	PSP Toxin (µg/100 g)	Organoleptic? (1)
08/29/2005	Anderson Bay 1	MU-AND2-8-29-05-02	blue mussels	48	no
08/29/2005	Cannery Bay	MU-CNB17-8-29-05-02	blue mussels	59	no
06/26/2005	Humpy Cove 1	MU-OR-SMB07-06-26-05-01	blue mussels	34	no
06/26/2005	Humpy Cove 1	MU-OR-SMB07-06-26-05-02	blue mussels	33	no
06/26/2005	Humpy Cove 1	MU-OR-SMB07-06-26-05-03	blue mussels	34	no
08/28/2005	Makushin Bay	MU-MKS11-8-28-05-02	blue mussels	40	no
09/25/2005	Morris Cove	MU-SMB-10-9-25-05-02	blue mussels	≤33	no
08/27/2005	S. Skan Bay 1	MU-SKS06-8-27-05-02	blue mussels	137	no
08/28/2005	S. Skan Bay 3	MU-SKS17-8-28-05-02	blue mussels	110	no
09/25/2005	Summer Bay 2	MU-SMB-01-9-25-05-02	blue mussels	≤32	no

(1) Organoleptic results represent the presence of petroleum by inspection and smell.

PSP toxin testing

PSP toxin was detected in 8 of 10 composite blue mussel samples tested in 2005. Two samples (MU-SKS06-8-27-05-02 and MU-SKS17-8-28-05-02) collected from Skan Bay had PSP toxin detected above 80 µg/100g; greater than the level allowed for commercial sale (Table 5).

Spring 2006 Sampling Results

Analytical results for the nine blue mussel samples collected in spring 2006 are summarized in Table 6 (ATSDR, 2007). Total BaP equivalent concentrations for all samples were below the blue-mussel specific risk-based screening concentration of 18.8 µg/kg. Therefore, PAHs in blue mussels in the areas sampled do not pose a cancer risk to subsistence consumers.

TABLE 4. TOTAL POLYCYCLIC AROMATIC HYDROCARBONS (PAHS) AND TOTAL BENZO(A)PYRENE (BAP) EQUIVALENTS IN SUBSISTENCE SAMPLES COLLECTED IN 2005 FOR THE SELENDANG AYU OIL SPILL NEAR UNALASKA, ALASKA.

Collection Date	Species	Location ID	Sample ID	Total PAHs (µg/kg)	Total BaP Equivalents (µg/kg)	Risk-based Screening Concentration (µg/kg)
Samples collected from Unalaska Bay						
06/25/2005	black chitons	Captains Bay	CH-CBW01-06-25-05-01	36	0.019	13.7
06/23/2005	black chitons	Humpy Cove 1	CH-SMB7-062305-01-rep 1*	836	41	13.7
06/23/2005	black chitons	Humpy Cove 1	CH-SMB7-062305-01-rep 2*	791	83	13.7
06/23/2005	black chitons	Humpy Cove 1	CH-SMB7-062305-01-rep 3*	1882	158	13.7
06/23/2005	black chitons	Humpy Cove 1	CH-SMB7-062305-02	13.8	0.00016	13.7
06/23/2005	black chitons	Humpy Cove 1	CH-SMB7-062305-03	7.5	0.00013	13.7
09/25/2005	black chitons	Humpy Cove 1	CH-SMB-07-9-25-05	8.6	0.0053	13.7
07/20/2005	black chitons	Humpy Cove 2	CH-SMB6/7-7-20-05	48	0	13.7
07/21/2005	black chitons	Iliuliuk Bay 1	CH-SMB1-7-21-05	11	0.019	13.7
07/21/2005	black chitons	Iliuliuk Bay 2	CH-DTE37-7-21-05	16	0.00031	13.7
07/20/2005	black chitons	Morris Cove	CH-SMB10-7-20-05	17	0	13.7
07/21/2005	black chitons	Summer Bay 1	CH-SMB3-7-21-05	16	0.031	13.7
06/25/2005	blue mussels	Captains Bay	MU-CBW01-06-25-05-01	254	0.074	18.8
06/26/2005	blue mussels	Humpy Cove 1	MU-SMB07-06-26-05-01	34	0.054	18.8
09/25/2005	blue mussels	Humpy Cove 1	MU-SMB-07-9-25-05	12	0.04	18.8
07/20/2005	blue mussels	Humpy Cove 2	ML-SMB6/7-7-20-05	29	0.037	18.8
07/21/2005	blue mussels	Iliuliuk Bay 1	ML-SMB1-7-21-05	24	0.045	18.8
07/21/2005	blue mussels	Iliuliuk Bay 2	ML-DTE37-7-21-05	79	0.056	18.8
07/20/2005	blue mussels	Morris Cove	ML-SMB10-7-20-05	9	0.012	18.8
09/25/2005	blue mussels	Morris Cove	MU-SMB-10-9-25-05-01	15	0.029	18.8
07/21/2005	blue mussels	Summer Bay 1	ML-SMB3-7-21-05-rep 1*	108	0.047	18.8
07/21/2005	blue mussels	Summer Bay 1	ML-SMB3-7-21-05-rep 2*	180	0.0021	18.8
09/25/2005	blue mussels	Summer Bay 2	MU-SMB-01-9-25-05-01	13	0.018	18.8
06/25/2005	green sea urchin roe	Captains Bay	UR-CBW01-06-25-05-01	116	0	27
06/23/2005	green sea urchin roe	Humpy Cove 1	UR-SMB7-062305-01	120	0	27
07/20/2005	green sea urchin roe	Humpy Cove 2	UR-SMB6/7-7-20-05	14	0.021	27
07/21/2005	green sea urchin roe	Iliuliuk Bay 1	UR-SMB1-7-21-05-rep 1*	52	0	27
07/21/2005	green sea urchin roe	Iliuliuk Bay 1	UR-SMB1-7-21-05-rep 2*	9	0	27
07/21/2005	green sea urchin roe	Iliuliuk Bay 2	UR-DTE37-7-21-05	22	0.029	27
07/20/2005	green sea urchin roe	Morris Cove	UR-SMB10-7-20-05	6	0	27
07/21/2005	green sea urchin roe	Summer Bay 1	UR-SMB3-7-21-05-rep 1*	9	0.00024	27
07/21/2005	green sea urchin roe	Summer Bay 1	UR-SMB3-7-21-05-rep 2*	7	0.00033	27
08/05/2005	harbor seal blubber	Wide Bay	SL-EJDER-8-5-05	18	0	8.7
08/02/2005	pink salmon	Humpy Cove 3	SMB7-PNK-8-02-05-01	17	0.75	2.3
08/02/2005	pink salmon	Humpy Cove 3	SMB7-PNK-8-02-05-02	6.8	0.0021	2.3
08/02/2005	pink salmon	Humpy Cove 3	SMB7-PNK-8-02-05-03	13	0.43	2.3
Samples collected near the spill site						
08/29/2005	black chitons	Anderson Bay 2	CH-AND3-8-29-05	7.8	0.0035	13.7
08/31/2005	black chitons	Kismaliuk Bay 2	CH-KMK28-8-31-05	36	0.0062	13.7
08/31/2005	black chitons	Kismaliuk Bay 3	CH-KMK32-8-31-05	32	0.0045	13.7
08/28/2005	black chitons	Skan Bay S. 1	CH-SKS06-8-28-05	12	0.057	13.7
08/28/2005	black chitons	Skan Bay S. 3	CH-SKS17-8-28-05	7.1	0.006	13.7
08/29/2005	blue mussels	Anderson Bay 1	MU-AND2-8-29-05-01	7.1	0.0047	18.8
08/29/2005	blue mussels	Cannery Bay	MU-CNB17-8-29-05-01	8.4	0.83	18.8
09/23/2005	blue mussels	Cannery Bay	MU-CNB-19-9-23-05-01	86	0.54	18.8
09/23/2005	blue mussels	Cannery Bay	MU-CNB-19-9-23-05-02	9.4	0.0031	18.8
08/31/2005	blue mussels	Kashega Bay	MU-KSB7-8-31-05	19	0.0053	18.8
08/31/2005	blue mussels	Kismaliuk Bay 1	MU-KMK7-8-31-05	70	0.14	18.8
08/28/2005	blue mussels	Makushin Bay	MU-MKS11-8-28-05-01	18	0.073	18.8
09/23/2005	blue mussels	Makushin Bay	MU-MKS-11-9-23-05	91	0.037	18.8
04/25/2005	blue mussels	Skan Bay N.	SKN-11(North)-rep 1*	8706	35	18.8
04/25/2005	blue mussels	Skan Bay N.	SKN-11(North)-rep 2*	12411	17	18.8
04/25/2005	blue mussels	Skan Bay N.	SKN-11(South)	7759	9.3	18.8
09/23/2005	blue mussels	Skan Bay N. 2	MU-SKN-11-9-23-05	6079	8.6	18.8
04/25/2005	blue mussels	Skan Bay S.	SKS-4(North)	1009	0.59	18.8
04/28/2005	blue mussels	Skan Bay S.	SKS-4N	1692	1.1	18.8
04/25/2005	blue mussels	Skan Bay S.	SKS-4(South)	642	0.53	18.8
08/27/2005	blue mussels	Skan Bay S. 1	MU-SKS06-8-27-05-01	257	0.4	18.8
08/28/2005	blue mussels	Skan Bay S. 3	MU-SKS17-8-28-05-01	537	0.16	18.8
09/23/2005	blue mussels	Skan Bay S. 4	MU-SKS-04-9-23-05-01	479	0.76	18.8
09/23/2005	blue mussels	Skan Bay S. 4	MU-SKS-04-9-23-05-02	800	1.1	18.8
08/29/2005	green sea urchin roe	Cannery Bay	UR-CNB17-8-29-05-01	13	1.2	27
08/29/2005	green sea urchin roe	Cannery Bay	UR-CNB17-8-29-05-02	9.9	0.73	27
08/28/2005	green sea urchin roe	Skan Bay S. 2	UR-SKS10-8-28-05	92	0.15	27
08/28/2005	Pacific cod	Naginak Cove	CD-NGE7-8-28-05	4.9	0.0042	8.1
08/28/2005	pink salmon	Skan Bay N. 1	PNK-SKN4-8-28-05-01	7.3	0.0035	2.3
08/28/2005	pink salmon	Skan Bay N. 1	PNK-SKN4-8-28-05-02	7.1	0.0054	2.3
08/28/2005	pink salmon	Skan Bay N. 1	PNK-SKN4-8-28-05-03	4.8	0.0029	2.3

*"rep" represents a laboratory replicate

TABLE 6. TOTAL POLYCYCLIC AROMATIC HYDROCARBONS (PAHS) AND TOTAL BENZO(A)PYRENE (BAP) EQUIVALENTS FOR SELENDANG AYU OIL SPILL SUBSISTENCE SAMPLES COLLECTED ON UNALASKA ISLAND IN SPRING 2006 (ATSDR, 2007).

Collection Date	Species	Location ID	Sample ID	Total PAHs (µg/kg)	Total BaP equivalents (µg/kg)	Risk-based screening concentration (µg/kg)
24 May 2006	Blue mussels	Skan Bay	SKN-11 North 5-24-06	613	0.19	18.8
24 May 2006	Blue mussels	Skan Bay	SKN-11 South 5-24-06	467	0.17	18.8
26 May 2006	Blue mussels	Wide Bay	MU-UNK05-26May06	2.3	0.027	18.8
26 May 2006	Blue mussels	Wide Bay	MU-UNK05-26May06 (duplicate sample)	2.4	0.032	18.8
26 May 2006	Blue mussels	Volcano Bay	MU-VLC05-26May06	2.9	0.037	18.8
26 May 2006	Blue mussels	Makushin Bay	MU-MKS11-26May06	51	0.088	18.8
26 May 2006	Blue mussels	Skan Bay	MU-SKS04-26May06	159	0.076	18.8
26 May 2006	Blue mussels	Kashega Bay	MU-KSB08-26May06	3.1	0.037	18.8
26 May 2006	Blue mussels	Kismaliuk Bay	MU-KMK28-26May06	14	0.050	18.8

COMMUNICATION OF RESULTS TO THE PUBLIC

In mid-April 2006, the ADPH released the public health evaluation of the results of the 2005 subsistence seafood sampling program (ADPH, 2006). This document was posted on the M/V Selendang Ayu UC internet site (2006b) along with a press release (dated April 18, 2006) announcing the results and a fact sheet explaining the significance of the results (M/V Selendang Ayu UC, 2006c; 2006d). The results were presented to subsistence consumers in a video conference call in the spring of 2006.

Following the release of the final ATSDR health evaluation of the 2006 samples, a health educator from ADPH will conduct an informal needs assessment at the site (ATSDR, 2007). This will entail contacting community leaders, including representatives of the Qawalangin tribe, to identify any ongoing health concerns related to the spill, and need for education regarding PSP.

DISCUSSION

The following is a summary of the conclusions and recommendations of the public health evaluations of the impact of the M/V Selendang Ayu oil spill on subsistence seafood resources (ADPH, 2006; M/V Selendang Ayu UC internet site, 2006b; ATSDR, 2007).

The risk-based screening criteria used in this evaluation are designed to be conservative for the protection of public health and do not represent thresholds of toxicity. For example, the risk-based screening criteria developed here used a conservative excess cancer risk estimate of 1×10^{-6} . This excess cancer risk equates to one excess cancer in a population of one million people. This is a theoretical estimate that is based on very conservative mathematical calculations. The true risk could be much lower, even zero. To put this in perspective, for the United States it is estimated that men have a 1 in 2 lifetime risk of developing cancer and females have a 1 in 3 lifetime risk (American Cancer Society, 2005). Additionally, it is the policy of the State of Alaska to utilize an excess cancer risk estimate of 1×10^{-5} in risk assessments. Using an acceptable risk level of 1×10^{-5} would increase the calculated risk-based screening criteria by a factor of 10. The risk-based screening criteria calculated from the ADFG survey ingestion rates were 2 to 7 times lower (except salmon) than screening criteria calculated from the Spill Task Force survey ingestion rates (Table 3). Also, the upper 95th confidence interval of the mean was used.

Only two samples collected in 2005 had concentrations of BaP equivalents that exceeded the risk-based screening criteria, and no samples collected in 2006 exceeded criteria. In regard to the two 2005 samples that exceeded criteria:

- 1) The source of PAHs in the black chiton sample collected from Humpy Cove in June 2005 is unknown. However, a chemical fingerprint analysis of the oil signature indicated that the source of PAHs detected in the sample was

pyrogenic (i.e., sources derived from the combustion of fossil fuels such as wood ash, diesel and bunker fuel soot, and creosote/coal tar treated timbers) in origin and not from the Selendang Ayu oil (Douglas, 2006; ADPH, 2006). Additionally, PAHs detected in the 3 other black chiton composite samples collected from the same area were very low and not above the risk-based screening criteria.

- 2) One composite blue mussel sample collected in April of 2005 (prior to clean up) from North Skan Bay contained BaP equivalents exceeding risk-based screening criteria. The other samples of blue mussels collected in Skan Bay in April (prior to clean up) and September (post clean up) did not exceed the risk-based criteria, but were elevated compared to all other areas (Table 4). These results are not unexpected since this was the main area impacted by the spill. Additionally, Skan and Makushin Bay had 26 segments of beach that did not meet clean up criteria in 2005.

Eight of 10 composite blue mussel samples collected in 2005 were positive for PSP toxins and two samples from Skan Bay had PSP toxin concentrations greater than the level allowed for commercial sale. Due to PSP concerns, the State of Alaska has an ongoing advisory in the state against the gathering and consumption of shellfish except at approved beaches (ADEC Division of Environmental Health, 2007). Since there are no approved beaches in the Unalaska/Dutch Harbor area, it was recommended that areas frequented by shellfish harvesters be re-posted to warn the public about the dangers of PSP. The ADPH considers the health hazard from PSP to be much more serious than any health hazards associated with PAH exposure at the levels currently found in mussels in the area (ADPH, 2006).

CONCLUSIONS

PAHs in subsistence resources from Unalaska Bay are not present at levels of health concern, based on sampling in 2005 and 2006. As expected, in 2005 PAHs were highest near the spill site, although, for the samples evaluated, the concentrations were not a health concern.

- One chitin sample collected from Summer Bay in 2005 contained PAHs above risk-based screening criteria; however, PAHs were below risk-based screening criteria in three other composite samples collected from the same area. The source of PAHs was not Selendang Ayu oil.
- In the core spill area (Skan and Makushin Bays), only one subsistence sample contained PAHs exceeding risk-based screening criteria. This was a mussel sample collected in April 2005 prior to clean-up actions.
- No samples collected in 2006 exceeded public health screening criteria.

- The levels of PAHs in subsistence food resources were lower in 2006 than in 2005, and are expected to further decline in the future, therefore; any small risk associated with exposure to PAHs through consumption of subsistence resources near the spill zone should either remain constant or decline over time. For example, BaP equivalents in blue mussels collected from North Skan Bay (SKN-11) declined nearly 200-fold from 35 µg/kg in April 2005 to 0.19 µg/kg in May 2006, due likely to both remediation activities and natural attenuation of residual contamination.
- The health hazards from PSP are much more serious than any health hazards associated with PAH exposure at the levels currently found. Two samples collected from Skan Bay in 2005 contained PSP toxin at concentrations above the allowable level for commercial sale.

RECOMMENDATIONS

- To err on the side of safety, subsistence gatherers should avoid consumption of foods on which oil can be seen, smelled or tasted (ATSDR, 2007).
- No additional sampling of subsistence foods for PAH contamination related to the M/V Selendang Ayu oil spill is warranted or recommended.
- Villagers should adhere to the statewide advisory for paralytic shellfish poisoning, and they should not collect shellfish from beaches that have not been approved. There are no approved beaches in the Unalaska / Dutch Harbor area.

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REFERENCES

- Agency for Toxic Substances and Disease Registry (ATSDR). (1995). *Toxicological profile for Polycyclic Aromatic Hydrocarbons (PAHs)*. ATSDR. U.S. Dept. of Health and Human Services; Public Health Service. Atlanta, Georgia.
- Agency for Toxic Substances and Disease Registry (ATSDR). (1999). *Health Consultation. M/V Kuroshima Oil Spill. Unalaska, Alaska*. Prepared by: Alaska Department of Health and Social Services, Division of Public Health, Epidemiology Section. May 17, 1999.
- Agency for Toxic Substances and Disease Registry (ATSDR). (2007). Health consultation (Draft): M/V Selendang Ayu oil spill, Unalaska, Alaska; Evaluation of blue mussel samples collected in May 2006. Atlanta: U.S. Department of Health and Human Services.
- Alaska Department of Environmental Conservation (ADEC). (2005). *Situation Report 103*. Dated September 15, 2005. Posted on M/V Selendang Ayu Unified Command Internet site. Retrieved from: http://www.dec.state.ak.us/spar/perp/response/sum_fy05/041207201/041207201_index.htm
- Alaska Department of Environmental Conservation (ADEC); Division of Environmental Health. (2007). DEC says don't let PSP put sickness in your summer plans. Posted on Food Safety and Sanitation Program Internet site. Retrieved from: <http://www.dec.state.ak.us/eh/fss/seafood/psp/general2.htm>
- Alaska Department of Fish and Game (ADFG). (2001). *Community Profile Database*. ADFG Division of Subsistence. Retrieved from: <http://www.subsistence.adfg.state.ak.us/geninfo/publctns/cpdb.cfm>
- Alaska Division of Public Health (ADPH). (2006). *M/V Selendang Ayu oil spill; Unalaska, Alaska; Public health evaluation of subsistence resources collected during 2005*. Final Report. Division of Public Health. State of Alaska Department of Health and Social Services. April 18, 2006. Retrieved from: http://www.dec.state.ak.us/spar/perp/response/sum_fy05/041207201/subsistence/Selendang%20Ayu%20subsistence%20report.pdf
- Aleutian Pribilof Islands Association (APIA). (2003). *Alaska Traditional Diet Project Nutrition Questionnaire*. APIA. August 2003.
- American Cancer Society. (2005). *Cancer Facts and Figures 2005*. Retrieved from: <http://www.cancer.org/downloads/STT/CAFF2005f4PWSecured.pdf>
- Barry, D.C. 2005. Selendang Ayu – Disposal of lightered liquids. Report to Doug Davis; Keesal, Young & Logan. Gallagher Marine Services, Inc. December 2, 2005.
- Bolger, M., S.H. Henry, and C.D. Carrington. (1996). Hazard and risk assessment of crude oil contaminants in subsistence seafood samples from Prince William Sound. *American Fisheries Society Symposium*, 18, 837-843.
- California Environmental Protection Agency (EPA). 2002. Part II; Technical support document for describing available cancer potency factors. Air Toxics Hot Spots Program risk assessment guidelines. Office of Environmental Health Hazard Assessment.
- Douglas, G. (2006). Letter from Gregory Douglas, PhD, NewFields Environmental Forensics to Gary Mauseth, Polaris Applied Sciences. Dated January 25, 2006. Appendix B in ADPH (2006). Retrieved from: http://www.dec.state.ak.us/spar/perp/response/sum_fy05/041207201/subsistence/Appendix%20B%20-%20Newfields%20letter%20-%20Jan%2025%202006.pdf
- Gilroy, D.J. (2000). Derivation of Shellfish Harvest Reopening Criteria Following the New Carissa Oil Spill in Coos Bay, Oregon. *Journal of Toxicology and Environmental Health; Part A* 60, 317-329.
- Hardenstine, J. (2006). Email message from Jeff Hardenstine, NewFields Environmental Forensics to Jerry Erickson, Polaris Applied Sciences, dated January 25, 2006.
- Mauseth, G.S. and G.E. Challenger. (2001). Trends in rescinding seafood harvest closures following oil spills. Pages 679-684 in: American Petroleum Institute. 2001. Proceedings of the 2001 International Oil Spill Conference. Held March 26-29, 2001 in Tampa, Florida.
- M/V Selendang Ayu Unified Command (UC). (2006a). *Unified Command Decision Memorandum; Subject: Final status of non-end point shoreline segments*. Dated June 23, 2006. Posted on UC Internet site. Retrieved from: http://www.dec.state.ak.us/spar/perp/response/sum_fy05/041207201/041207201_index.htm
- M/V Selendang Ayu Unified Command (UC). (2006b). *Unified Command: M/V Selendang Ayu grounding*. Internet site available at URL: http://www.dec.state.ak.us/spar/perp/response/sum_fy05/041207201/041207201_index.htm
- M/V Selendang Ayu Unified Command (UC). (2006c). Subsistence foods near Selendang Ayu wreck sampled for contaminants. Press release dated April 18, 2006. Posted on UC Internet site. Retrieved from: http://www.dec.state.ak.us/spar/perp/response/sum_fy05/041207201/subsistence/041207201_pr_subst_01.pdf
- M/V Selendang Ayu Unified Command (UC). (2006d). M/V Selendang Ayu oil spill; Subsistence foods consumption safety. Fact Sheet. Posted on UC Internet site. Retrieved from: http://www.dec.state.ak.us/spar/perp/response/sum_fy05/041207201/subsistence/factsheetApril2006.pdf
- Polaris Applied Sciences. (2006). *M/V Selendang Ayu oil spill Unalaska Island, Alaska; Subsistence fishery resources spring*

2006 sampling plan. Draft. Polaris Applied Sciences, Inc. Kirkland, Washington. May 4, 2006.

United States Environmental Protection Agency (U.S. EPA). (1993). *Provisional guidance for quantitative risk assessment of polycyclic aromatic hydrocarbons*. Report No. EPA/600/R-93/089. Office of Research and Development. U.S. EPA. Washington, D.C. July 1993.

U. S. Environmental Protection Agency (U.S. EPA). (2004). *Preliminary Remediation Goals*. U.S. EPA Region 9. October 2004. Retrieved from: <http://www.epa.gov/region09/waste/sfund/prg/index.html>