HNF-55606
Revision 1

Calendar Year 2012 Assessment of Larval Pacific Lamprey on the Hanford Reach of the Columbia River

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-09RL14728

P.O. Box 650
Richland, Washington 99352

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Mission Support Alliance

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1.0 Introduction

The U.S. Department of Energy, Richland Operations Office (DOE/RL) conducts ecological monitoring on the Hanford Site to collect and track data needed to ensure compliance with an array of environmental laws, regulations, and policies governing DOE activities. Ecological monitoring data provides baseline information about the plants, animals, and habitat under DOE stewardship at Hanford required for decision-making under the National Environmental Policy Act (NEPA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). In addition, ecological monitoring helps ensure that DOE, its contractors, and other entities that conduct activities on the Hanford Site are in compliance with the *Hanford Site Comprehensive Land Use Plan* (CLUP, DOE/RL 1999). DOE places priority on monitoring those plant and animal species or habitats with specific regulatory protections or requirements; that are rare and/or declining (federal or state listed endangered, threatened, or sensitive species); or of significant interest to federal, state, or tribal governments or the public.

Pacific lamprey (*Entosphenus tridentatus*) were selected for monitoring by the Mission Support Alliance (MSA) Public Safety and Resource Protection (PSRP) program due to their listing status, documented regional declines, cultural importance, lack of available information for the Hanford Reach of the Columbia River, and potential utility as an indicator species for contaminant uptake. Pacific lampreys are listed by the U.S. Fish and Wildlife Service (USFWS) as a Federal Species of Concern (USFWS 2011) and as a State Monitor species by the Washington Department of Fish and Wildlife (WDFW). On January 27, 2003, USFWS received a petition to list the Pacific lamprey in Oregon, Washington, Idaho, and California as federally threatened or endangered under the Endangered Species Act. In 2004, the USFWS found that the petition did not provide the required information to indicate that listing the species was warranted; therefore, a status review was not initiated. Pacific lamprey counts in Northwest streams have decreased dramatically since the mid-1960s. According to unpublished data collected by the U.S. Army Corps of Engineers, nearly 48,000 lampreys were counted at Winchester Dam on Oregon's Umpqua River in 1966; by 2001, the count was only 34. At Ice Harbor Dam on the lower Snake River, almost 50,000 were tallied in 1963; in 2001, the count dropped to 203. Some factors that may have contributed to the decline of lamprey include impeded passage at dams, over-harvesting, degraded habitat, and chemicals used to control non-native fish (BPA 2005). Historically, Pacific lampreys were important for food and medicinal purposes to Native American tribes in the mid-Columbia River Plateau, and they remain important for traditional tribal cultural practices (BPA 2005). Prior to this project, no studies of larval Pacific lamprey had been conducted on the Hanford Reach of the Columbia River.

Lampreys are a primitive group of fishes that are eel-like in form but lack jaws and paired fins. These species have a round sucker-like mouth (oral disc); lack scales, true bones, and jaws; and possess breathing holes instead of gills. Pacific lamprey, river lamprey (*Lampetra ayresi*), and western brook lamprey (*L. richardsoni*) are or have been known to inhabit the Columbia Basin. Both Pacific and river lampreys are anadromous, while western brook lampreys remain in the freshwater environment throughout their life cycle. Only Pacific and river lampreys are reported to inhabit the Hanford Reach (Gray and Dauble 1977). However, river lampreys have not been documented in the Columbia Basin since 1980 and may have been extirpated from the drainage (Meeuwig et al. 2004; Bond et al. 1983). Adult Pacific lampreys are characterized by the presence of three large teeth and posterior teeth on the

oral disc. Larval Pacific lampreys are nearly indistinguishable from other lampreys (USFWS 2011). Adult Pacific lampreys are parasitic and feed on a variety of fish, including Pacific salmon, flatfish, rockfish, and pollock, and are preyed upon by sharks, sea lions, and other marine animals. After spending from 1 to 3 years in the marine environment, Pacific lampreys cease feeding and migrate to freshwater between February and June. They are thought to overwinter and remain in freshwater habitat for approximately 1 year before spawning. Most upstream migration takes place at night (USFWS 2011).

Pacific lampreys have been found in streams from Hokkaido Island, Japan, and along the Pacific Rim, including Alaska, Canada, Washington, Oregon, Idaho, and California to Baja California, Mexico. The Pacific lamprey is the most widely distributed lamprey species on the west coast of the United States. Historically, Pacific lampreys are thought to have been distributed wherever salmon and steelhead occurred. The current distribution of the Pacific lamprey in western Washington includes most large rivers and streams along the coast and the Strait of Juan de Fuca. However, no population status or trend data are available, other than that collected in association with salmonid monitoring. The species' range extends long distances inland in the Columbia, Snake, and Yakima river systems. Recent data indicate that Pacific lamprey distribution has been reduced in many river drainages. They are extirpated above dams and other impassable barriers in larger rivers throughout coastal Washington and above dams in the upper Columbia and Snake rivers (USFWS 2011).

Pacific lampreys spawn in similar habitats to salmon in gravel bottomed streams at the upstream end of riffle habitat, typically above suitable young larvae (ammocoete) habitat. Spawning occurs between March and July, depending on location within their range. The degree of homing is unknown, but it is thought that adult migration and location of suitable spawning habitat may be aided by the detection of pheromones released by ammocoetes. Both sexes construct the nests, often moving stones with their mouths (USFWS 2011). Individual adult female Pacific lamprey lay tens of thousands of extremely small eggs in a nest built in a gravel or sandy streambed (BPA 2005). After depositing and fertilizing the eggs, the adults typically die within 3 to 36 days.

Embryos hatch in approximately 20 days. Ammocoetes drift downstream to areas of low velocity and fine substrates where they burrow, grow, and live as filter feeders for 2 to 7 years while feeding primarily on algae. Lamprey ammocoetes have been documented in the substrate in water up to 16 m deep (Jolley et al. 2012). Several generations and age classes of ammocoetes congregate in high densities, forming colonies. Ammocoetes are relatively immobile but will move during high flow events. Larger ammocoetes drift downstream, primarily during higher flows, in spring, and smaller ammocoetes drift downstream in the summer. Anecdotal information suggests that ammocoetes may reside within the hyporheic zone and may move laterally through stream substrates. Metamorphosis to macropthalmia (juvenile phase) occurs gradually over several months as they develop eyes, teeth, and become free swimming. Transformation from ammocoetes to macropthalmia typically begins in July to October. Between late fall and spring, juveniles migrate to the ocean, where they mature into adults (USFWS 2011).

Based on these life history patterns, there are several aspects of the larval biology of lampreys that make them particularly valuable for population censusing. Larval lampreys are easily collected from riverine systems where they burrow in soft substrates and are relatively inactive (Richards et al. 1982). The protracted duration of the larval stage of lamprey compared to the duration of larval life of other

fishes results in a major component of lamprey populations existing as larvae. Consequently, larval abundance may provide information about recruitment and survival rates, as multiple year classes are represented within the larval population (Meeuwig et al. 2004). These features also make juvenile Pacific lamprey an ideal indicator/sentinel species due to their extended larval period and relative immobility, potentially resulting in extended periods of exposure to contaminated sediments or water within areas of potentially contaminated groundwater upwelling.

As described above, because of their importance to tribal cultures, declining abundance, long residence time with limited mobility in the freshwater environment, and high susceptibility to water-borne contaminants, Pacific lampreys were selected as a species to be monitored under this program.

2.0 Methods

Aside from the general life history patterns as described in the Introduction, little is known about the ecology of lampreys in the Columbia River Basin. Additional information is needed to define more adequately the basic biology of these species for guidance in determining the suitability of available habitat or developing water quality criteria (Meeuwig et al. 2004).

The project area was the entire length (~50 miles) of the Columbia River as it flows through the Hanford Site on the Benton County side (right bank as one travels downstream; Figure 1). The project area was surveyed for potentially suitable ammocoete habitat using coarse scale metrics. Suitable habitat areas are characterized by fine-grained substrates, which are relatively rare on the Hanford Reach. Existing substrate maps were used to define survey areas. The upstream and downstream extent of each of these habitat transects was logged with a Global Position System (GPS). Areas containing suitable habitat were distinguished as either adjacent or not adjacent to known contamination plumes based on contamination plumes illustrated in Figure 1 (DOE/RL 2012a). Suitable habitat zones were then sampled with an ABP-2 backpack electrofisher (ETS Electrofishing) specifically designed for collection of juvenile lamprey. All electrofishing was conducted in accordance with a National Marine Fisheries Service Scientific Research Permit (#14283), a USFWS Endangered Species Act consultation (#13260-2011-1-0080), and only when water temperature and conductivity were suitable based on guidelines in the WDFW Washington State Scientific Collection Permit (#12-304a) used for this project. Sampling was conducted in September and October to minimize the potential interactions with anadromous salmonids. This time also coincides with seasonally low river flows that result in the highest likelihood of exposure to upwelling contaminated groundwater because groundwater infiltration rates into the Hanford Reach of the Columbia River increase as river discharge rates decrease (WCH 2010). This process was intended to capture the highest annual contaminant tissue burdens that the lamprey would have during a given year. Collected lamprey were measured to the nearest millimeter and released in close proximity to their capture location. Individuals selected for analysis were euthanized according to American Veterinary Medical Association protocols (AVMA 2007). Sampled individuals were transferred to a commercial analytical laboratory for trace metals analysis.

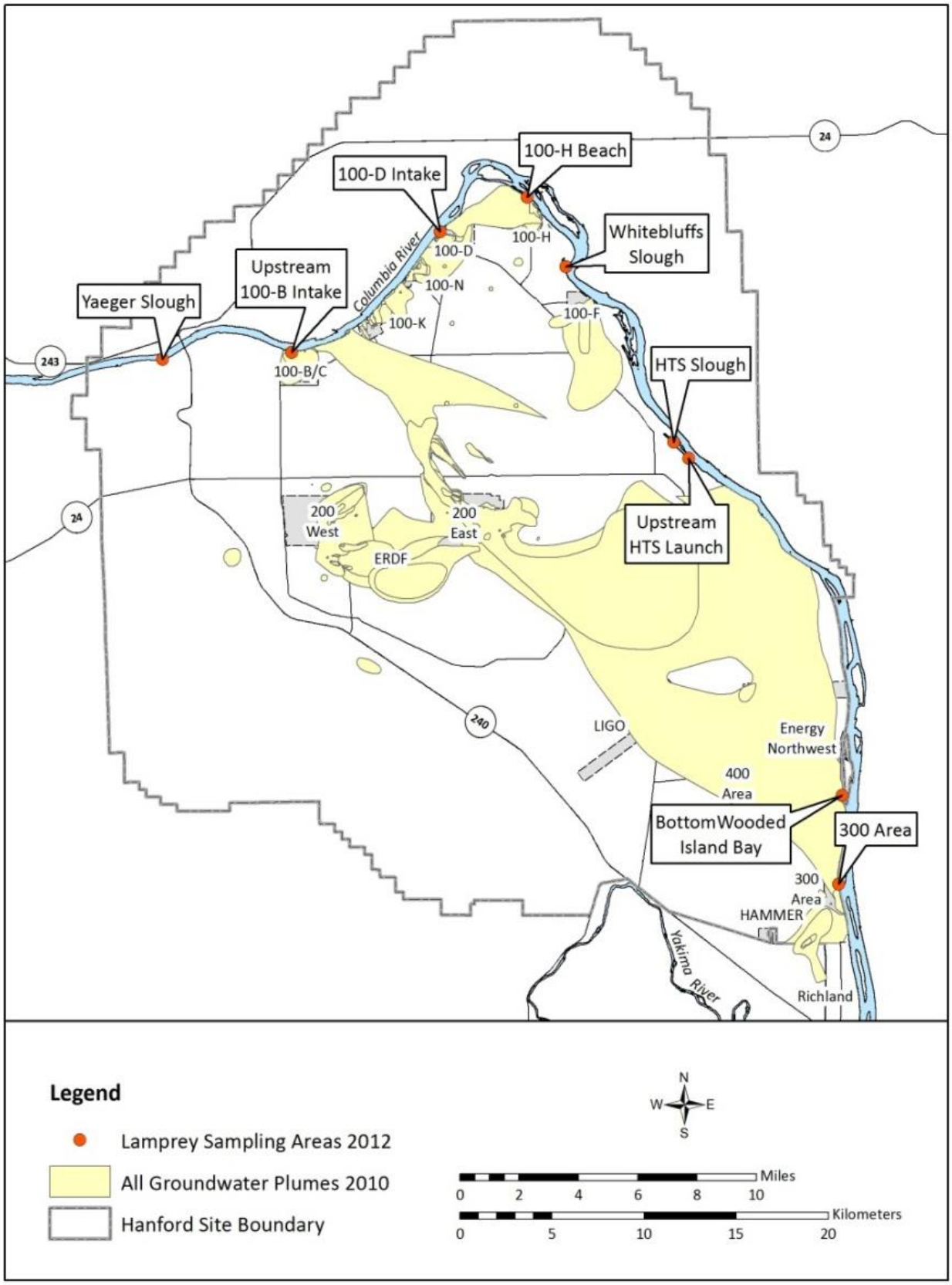

Figure 1. Lamprey Survey Areas for 2012 with Groundwater Contaminant Plumes from 2010

It was not possible to identify all lampreys collected to the species level, as difficulties associated with morphological descriptions for taxonomic classification to this level have been well documented for lampreys (Hubbs and Potter 1971; Richards et al. 1982; Meeuwig et al. 2004). Although dentition patterns and overall animal size have been used to discriminate among juvenile and adult lampreys, larval lampreys (ammocoetes) do not possess characteristic dentition patterns, and the protracted duration of the larval stage results in substantial or complete body size overlap among species. Color patterns have most widely been used for discrimination of larval lampreys found within the Columbia River Basin, but incomplete development of pigmentation and potential geographic variability in color patterns make this technique less useful for very young larvae (Richards et al. 1982; Meeuwig et al. 2004).

Because of the inherent difficulties described above, distinguishing lamprey ammocoetes to the species level was not possible in the field. However, Pacific and river lamprey are the only two species known to exist in the Hanford Reach, and river lamprey have not been reported in the Columbia Basin since 1980. As partly noted above, Pacific and river lamprey are both listed as Federal Species of Concern, and river lamprey are also designated as a Washington State candidate species. In 1977, Gray and Dauble reported that both species were present on the Hanford Reach; however, Meeuwig et al. 2004 conducted a Columbia basin-wide search for documentation of river lamprey but found nothing after 1980 (Bond et al. 1983). It is further worth noting that a juvenile salmonid collection system exists at McNary Dam (the first mainstem Columbia River Dam located immediately downstream from the Hanford Reach) where juvenile fish are sampled and identified prior to being passed downstream. Thousands of juvenile lampreys (macropthalmia) are also collected and identified at this site, at least some of which likely originate from the Hanford Reach. To date, only juvenile Pacific lampreys have been identified passing McNary Dam (Mensik, pers. comm. 2011). Lamprey ammocoetes have been sampled on the Hanford Reach as recently as 1998 (Wagner et al. 1999; Hoffarth et al. 2001), which confirms that lampreys are present in this section of the Columbia River. However, the lack of river lampreys sampled at downstream locations or elsewhere in the Columbia Basin strongly suggested that only Pacific lamprey would be encountered during this monitoring effort. Collected specimens were classified as Pacific lamprey based on these factors.

3.0 Results

Surveyors conducted an assessment for suitable ammocoete habitat along the length of the study area on the central Hanford Site (Benton County) shoreline in early September 2012. The survey included 17 locations, with 13 locations determined to be potentially suitable for ammocoete occupation due to the presence of fine-grained substrate extending below the ordinary low water mark. Of the 13 potentially suitable sites, nine were surveyed during 2012. Electrofishing surveys began on September 17 and concluded on October 2, 2012.

A total of 16 surveys were conducted, with some sites being surveyed twice due to a change in the settings recommended by the manufacturer of the backpack electrofisher (O'Neil, pers. comm.). The original and revised recommended settings for lamprey electrofishing are shown in Table 1.

Table 1. Originally Recommended and Updated Settings for Lamprey Electrofishing on the Hanford Reach

Measurement	Initial Recommended Settings	Updated Settings from ETS Electrofishing

	Bursted Slow-phase Primary Wave Form	Standard Fast-pulse Secondary Wave Form	Bursted Slow-phase Primary Wave Form	Standard Fast-pulse Secondary Wave Form
Voltage	125 V	125 V	Increased to achieve ~2 amps (range 250–400 V)	
Pulse frequency	3 Hz	30 Hz	3 Hz	30 Hz
Duty cycle	25%	25%	25%	25%
Burst pulse train	3:1	continuous	3:1	continuous

Of the nine locations surveyed, lamprey ammocoetes were detected at two locations: near the 300 Area and near the 100-H Area (Table 2). Both sites were in or immediately adjacent to known contaminated groundwater plumes (DOE/RL 2012a). Several size classes of lamprey were observed and collected at both locations that ranged from 30 mm to 125 mm (1.2 in to 4.9 in; Figure 2). Six ammocoetes from the 300 Area and four from the 100-H Area Beach were euthanized for analysis (one of the 300 Area specimens was archived but not analyzed). The remainder of the captured ammocoetes were measured and released at the sampling location.

Table 2. Number of Collected Lamprey by Location

Location	Lamprey Detected	Total Lamprey	Lamprey Euthanized for Analysis
Yaeger Slough	No	--	--
100-B Intake	No	--	--
100-D Intake	No	--	--
100-H Beach	Yes	27	4
White Bluffs Slough	No	--	--
HTS Slough	No	--	--
HTS Boat Launch	No	--	--
Bottom Wooded Island Bay	No	--	--
300 Area	Yes	26	6

Figure 2. Lamprey Sizes Ranging from ~ 30 mm (left) to 100 mm (right) Representing Different Age Classes

Due to the limited whole organism mass of the ammocoetes (0.61 g to 2.56 g [0.02 oz to 0.09 oz]), only trace metals analysis was performed on specimens collected. Detected analytes were aluminum,

chromium, copper, manganese, lead, antimony, selenium, thorium, uranium, zinc, and nickel (Table 3). Undetected analytes were silver, arsenic, beryllium, cadmium, and thallium. The largest ammocoetes were selected for analysis at each location to maximize the mass available for analysis. Table 4 provides a summary of the length, weight, and disposition of each ammocoete. The results of the metals analysis are provided in Attachment A.

Table 3. Percent of Individual Lamprey Samples with Detectable Levels of Analytes by Sample Location

Analyte	300 Area % Detection (n=5)	100-H % Detection (n=4)
Aluminum	100	25
Chromium	40	0
Copper	100	100
Manganese	100	100
Nickel	40	0
Lead	40	25
Antimony	0	25
Selenium	80	75
Thorium	20	75
Uranium	100	0
Zinc	100	100

Table 4. Length, Weight, and Disposition of Lamprey Ammocoete Collected During 2012

Lamprey Number*	Length (mm)	Weight (g)	Disposition	Lamprey Number*	Length (mm)	Weight (g)	Disposition
300 Area 1	99	1.73	sampled	100-H Area 7	32	N/A	released
300 Area 2	102	1.69	sampled	100-H Area 8	35	N/A	released
300 Area 3	85	1.11	sampled	100-H Area 9	30	N/A	released
301 Area 4	94	1.27	sampled	100-H Area 10	34	N/A	released
301 Area 5	88	1.19	sampled	100-H Area 11	30	N/A	released
301 Area 6	79	N/A	archived	100-H Area 12	36	N/A	released
302 Area 7	47	N/A	released	100-H Area 13	33	N/A	released
302 Area 8	40	N/A	released	100-H Area 14	33	N/A	released
302 Area 9	41	N/A	released	100-H Area 15	34	N/A	released
303 Area 10	32	N/A	released	100-H Area 16	30	N/A	released
303 Area 11	32	N/A	released	100-H Area 17	32	N/A	released
100-H Area 1	75	0.61	sampled	100-H Area 18	33	N/A	released
100-H Area 2	125	2.56	sampled	100-H Area 19	31	N/A	released
100-H Area 3	88	0.81	sampled	100-H Area 20	35	N/A	released
100-H Area 4	110	1.63	sampled	100-H Area 21	30	N/A	released
100-H Area 5	38	N/A	released	100-H Area 22	32	N/A	released
100-H Area 6	32	N/A	released				

* Approximately 20 additional small ammocoetes (≤30 mm) were observed but were not captured between the two locations.

Results for uranium in the 300 Area were significantly higher than the dataset from the 100-H Area (p value = 0.037; Figure 3). Although manganese levels in two of the specimens collected from the 300 Area appeared much higher than the remaining samples, and ANOVA performed between the 300 Area and 100-H datasets showed no significant difference (p = > 0.05). Similarly, ANOVA results showed that the datasets were not significantly different (p = > 0.05) between the two locations for the remainder of the trace metals detected (aluminum, chromium, copper, nickel, lead, antimony, selenium, thorium, and zinc).

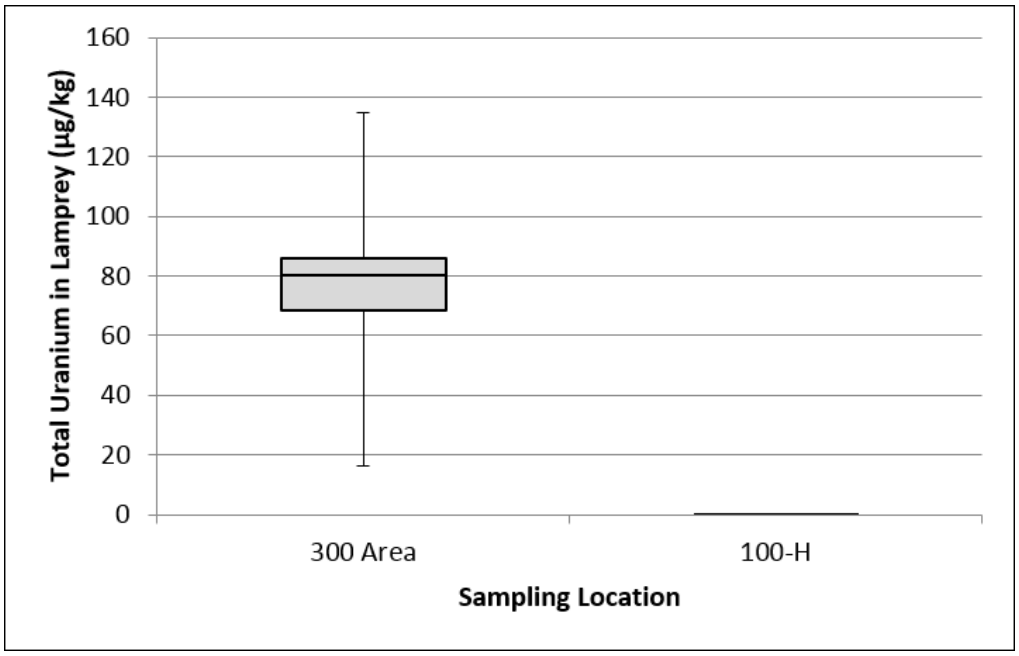

Figure 3. 300 Area and 100-H Area Lamprey Tissue Samples for Uranium

4.0 Discussion

Based on records in the MSA PSRP Database, juvenile lampreys have been encountered in the Hanford Reach using conventional electrofishing methods, but detections were extremely infrequent (≤5 individuals during hundreds of electrofishing hours). Comparatively, this study encountered 53 individual lampreys in approximately 4 hours of electrofishing. Therefore, the use of the ABP-2 backpack electrofisher with the updated settings (Table 1) represents an improvement in surveying efficiency and detectability of larval Pacific lamprey along the Hanford Reach. This study also shows that spawning has occurred and continues to occur along the Hanford Reach, based on the presence of multiple ammocoete age classes (Figure 4).

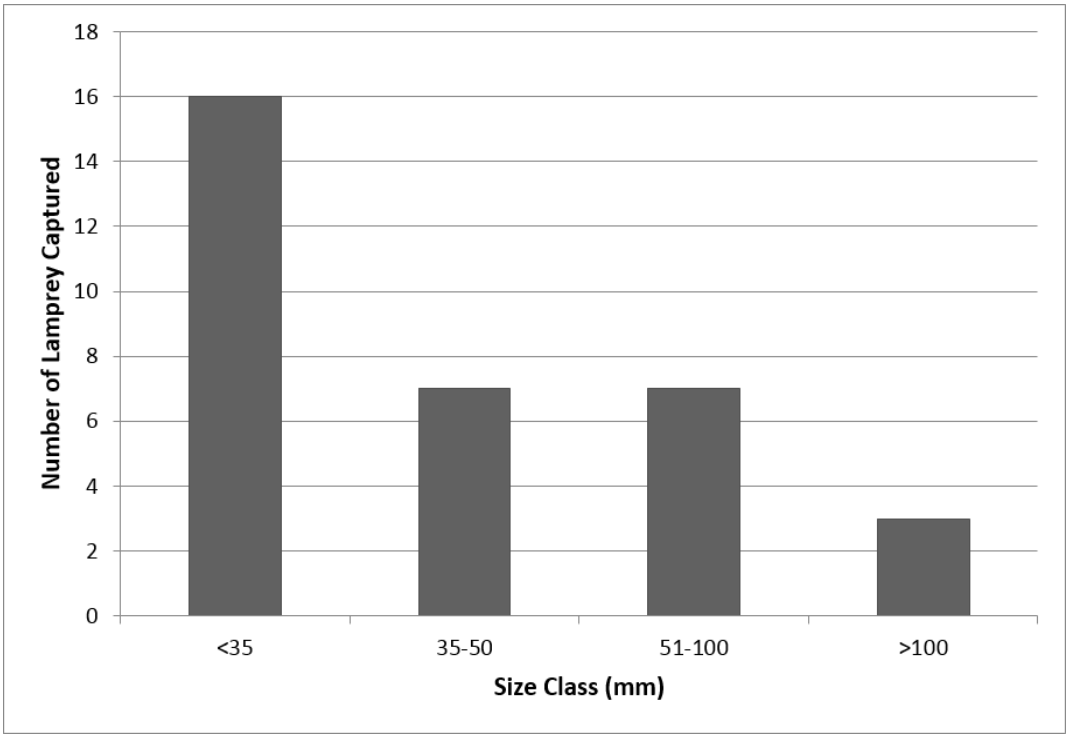

Figure 4. Size Class Distribution of Lamprey Captured During 2012

The updated ABP-2 backpack electrofisher settings were confirmed to be more effective, as demonstrated when a survey at the 100-H Area using the original settings produced no ammocoetes while a follow-up survey using the revised settings produced 27 ammocoetes. The original setting needed to be changed due to the relatively low electrical conductance of the water along the Hanford Reach (130–170 µS/cm). Freshwater streams in the U.S. range from 50–1500 µS/cm (). This lower percentage of dissolved ions makes the water more resistive to the movement of electricity, requiring more voltage to achieve the amperage (~ 2 amps) necessary to disturb ammocoetes from the substrate. These settings could vary due to conditions present at the time of future electrofishing efforts, so regular evaluation and adjustment of settings is necessary.

River discharge rates were higher than the 10-year average for the sampling period (Figure 5) and for most of 2012 (Figure 6; Columbia Basin Research 2013). Above average snowpack during winter of 2011–2012 caused the high flows, with Snoqualmie Pass at 150 percent of average in May 2012 (NOHRSC 2013). Although higher than average, the flows during the sampling period were the lowest observed during 2012. Thus, the tissue concentrations observed in the lamprey collected during 2012 should represent the highest contaminant tissue burdens present during 2012, but samples collected during a lower flow year would be necessary to depict the highest contaminant tissue burden that exists in lamprey ammocoetes on the Hanford Reach.

Figure 5. Outflow of the Columbia River During the 2012 Sampling Period and the 10-Year Average Outflow for the Columbia River at the Hanford Reach

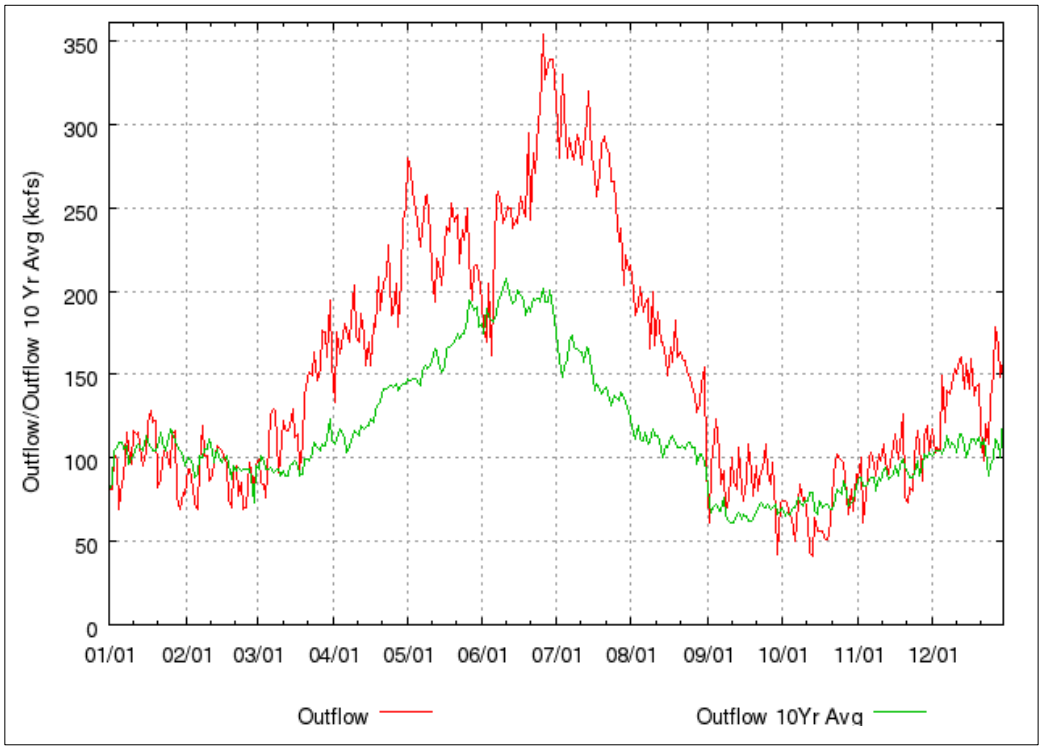

Figure 6. 2012 Outflow Rates Compared to the 10-Year Average Outflow for the Columbia River at the Hanford Reach

A fish tissue effect level for uranium was not provided in the *River Corridor Baseline Risk Assessment* (RCBRA; DOE/RL 2012b and 2012c), but whole organism tissue analysis was performed on sculpin (*Cottus* spp.) from the 300 Area as part of that project. The results of the RCBRA efforts were compared with the whole organism lamprey results collected during this study (Figure 7). Although both datasets are based on limited sample numbers (five each of lamprey and sculpin), a one-way ANOVA comparison between the sculpin from the 300 Area and the lamprey shows that the sculpin appear to have significantly higher tissue concentrations than the lamprey for uranium, F (1, 8), p value = 0.002.

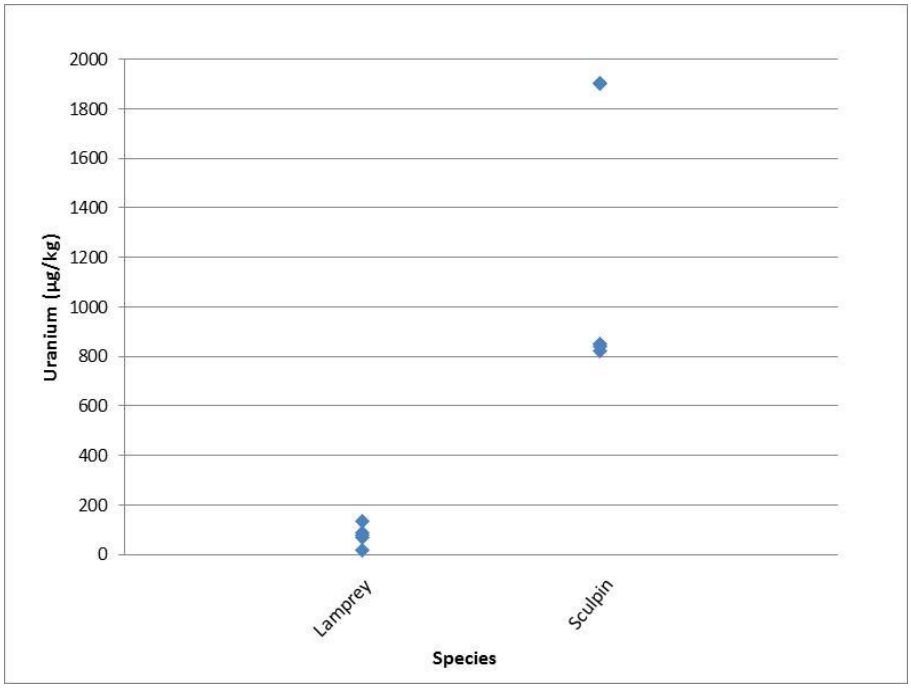

Figure 7. Comparison of Whole Organism Analysis for Uranium from Sculpin Collected During the RCBRA and Lamprey Collected During 2012

The Environmental Surveillance function within PSRP collected seep water samples in close proximity to both of the lamprey collection locations. The 100-H Spring 145-1 is located 260m (853 ft) upstream of the lamprey collection location at 100-H Area, while the 300 Area Spring 42-2 is located just 20 m (66 ft) from the lamprey collection location near the 300 Area. The contaminant levels in the seep water were compared to the levels in the lamprey tissue. The ecological risk screening value for uranium used by the RCBRA was 0.5 µg/L for water. This value is lower than those observed at the 100-H Spring 145-1 (0.84 µg/L) and much less than the values observed at the 300 Area Spring 42-2 (36.2 µg/L), but both locations are below the benchmark level for uranium (910 µg/L) used for fish exposure. The tissue and co-located seep water uranium concentrations are shown in Figure 8. Based on these results, there appears to be a correlation between the seep water and lamprey tissue levels for uranium. Additional co-located seep/pore-water and tissue samples may better define these relationships. However, it is unclear how robust the lamprey population is on the Hanford Reach and how resilient the two sub-populations identified during this study would be to repeated sampling efforts. If further sampling is conducted, preserving some samples from each location for histopathology may help identify any potential injuries from uranium exposure to target organs such as gills and kidneys (Barillet et al. 2007).

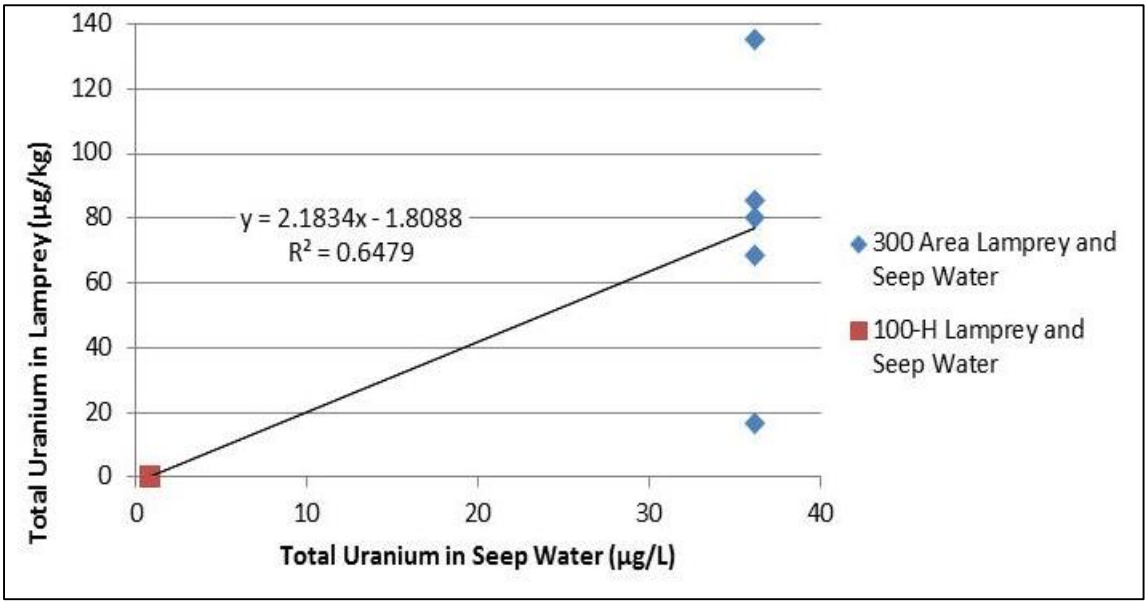

Figure 8. Regression of Uranium Levels Measured in Lamprey and Seep Water Samples from the 300 Area and 100-H Area

In addition to the potential for impacts from Hanford Site contaminants, flow fluctuations from upstream dam activities could also affect Pacific lamprey populations along the Hanford Reach. Lamprey are known to be susceptible to stranding (Luzier et al. 2011), and the rapid flow fluctuations that occur regularly on the Hanford Reach could result in the dewatering of lamprey nests, termed redds, or stranding of juveniles burrowed in the substrate. Pacific lamprey select spawning habitat similar to steelhead; therefore, the concerns for steelhead spawning being impacted by flow fluctuations (Wagner et al. 2012) also apply to lamprey. Flow fluctuations may affect redd site selection and suitability, especially when high flows cause suitable sites to become too deep for spawning. Further research into these issues could better define the cumulative effects on lamprey within the Hanford Reach.

Some of the variability observed in the analytical results may be due to incidental ingestion of sediment by individual ammocoetes. Removal of the gastrointestinal tract from future samples may alleviate this potential source of sample variability. The dataset also lacks data from a reference location. Although sampling was attempted at an upstream reference location (Yaeger Slough), no ammocoetes were located. Additional surveys for lamprey in upstream locations with suitable habitat characteristics could provide these data.

It is possible that additional lamprey ammocoetes are present along the Hanford Site shorelines and islands and in deeper water areas that were inaccessible to the backpack electrofishing method used during this study. Methods developed for surveying and sampling lampreys in deep water habitats may be used to define the range and extent of ammocoetes in deeper waters (Jolley et al. 2012). Potentially suitable habitat also exists on the islands and left bank of the Columbia River along the Hanford Reach, which were outside the scope of this study. Surveys in these areas using similar methods to this study, along with investigations into suitability and usage of spawning habitat, may help better define distribution, abundance, and habitat selection of Pacific lamprey ammocoetes on the Hanford Reach.

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Attachment A Calendar Year 2012 Assessment of Larval Lamprey Analytical Sample Results

Note: Results that were recorded as non-detects were plotted as zero to make sample results easier to view. When applicable, the method detection limit (MDL) was also plotted on the graphs.

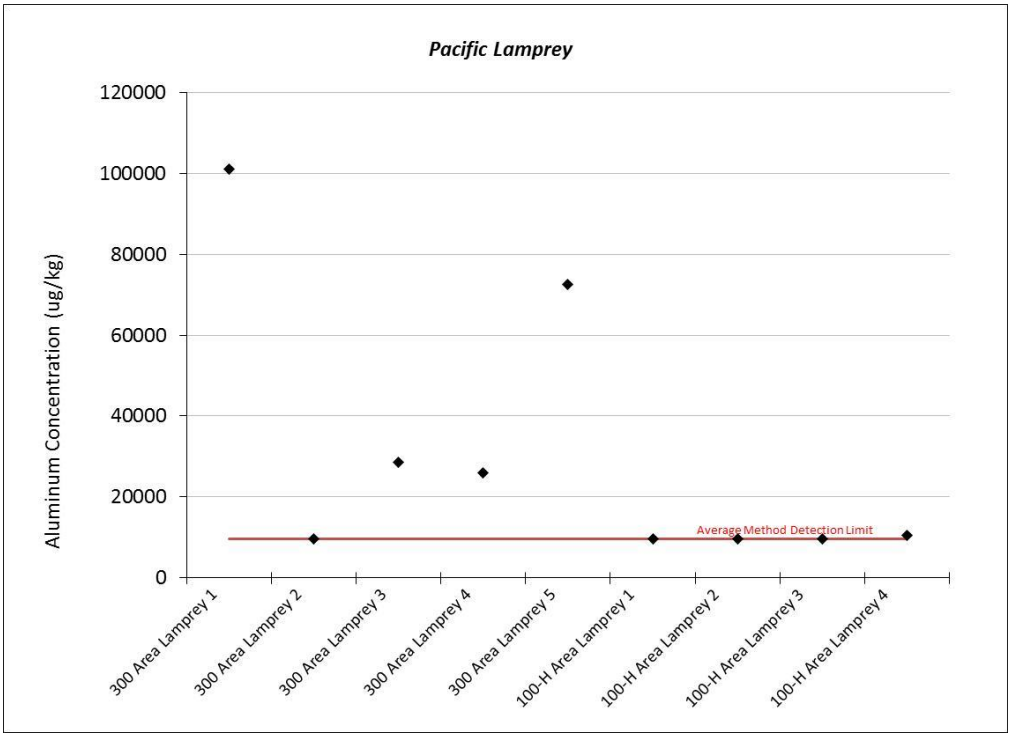

Figure A.1. Aluminum Concentrations Measured in Lamprey Tissue Samples Collected During 2012

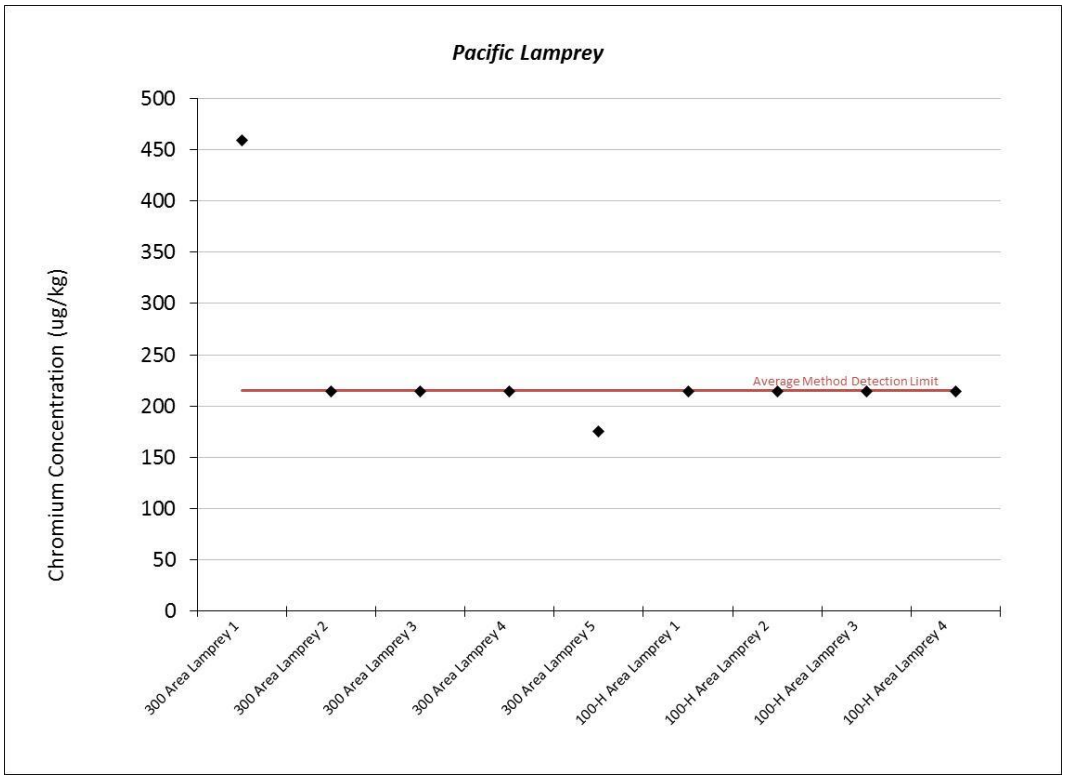

Figure A.2. Chromium Concentrations Measured in Lamprey Tissue Samples Collected During 2012

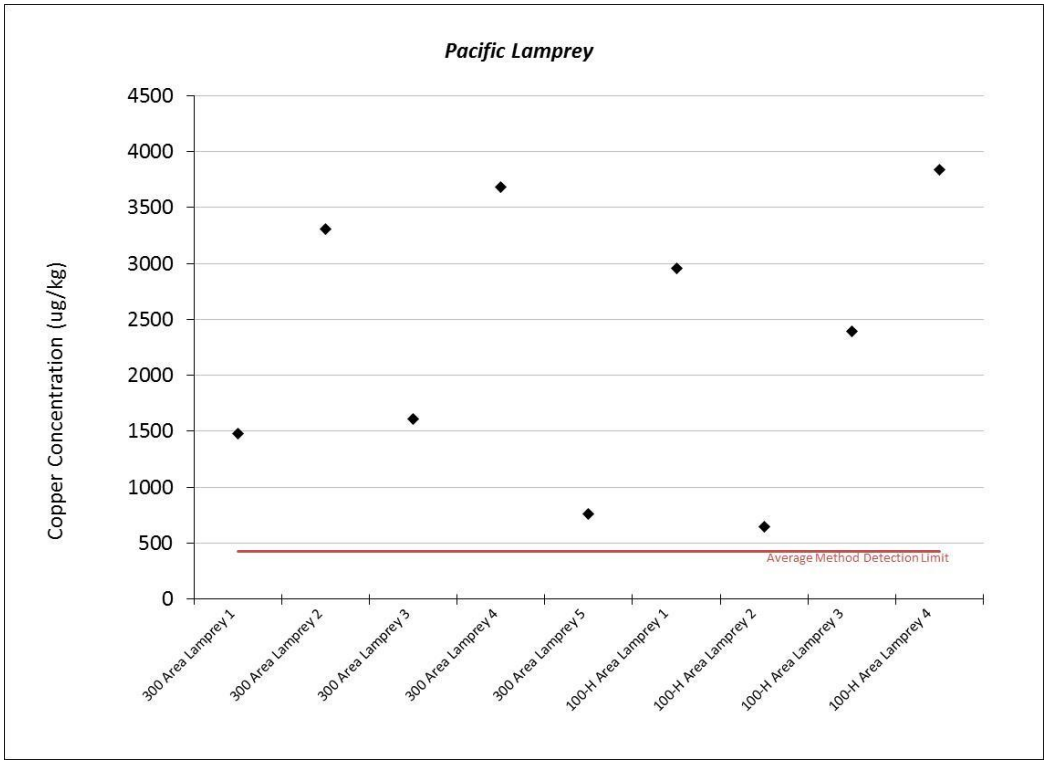

Figure A.3. Copper Concentrations Measured in Lamprey Tissue Samples Collected During 2012

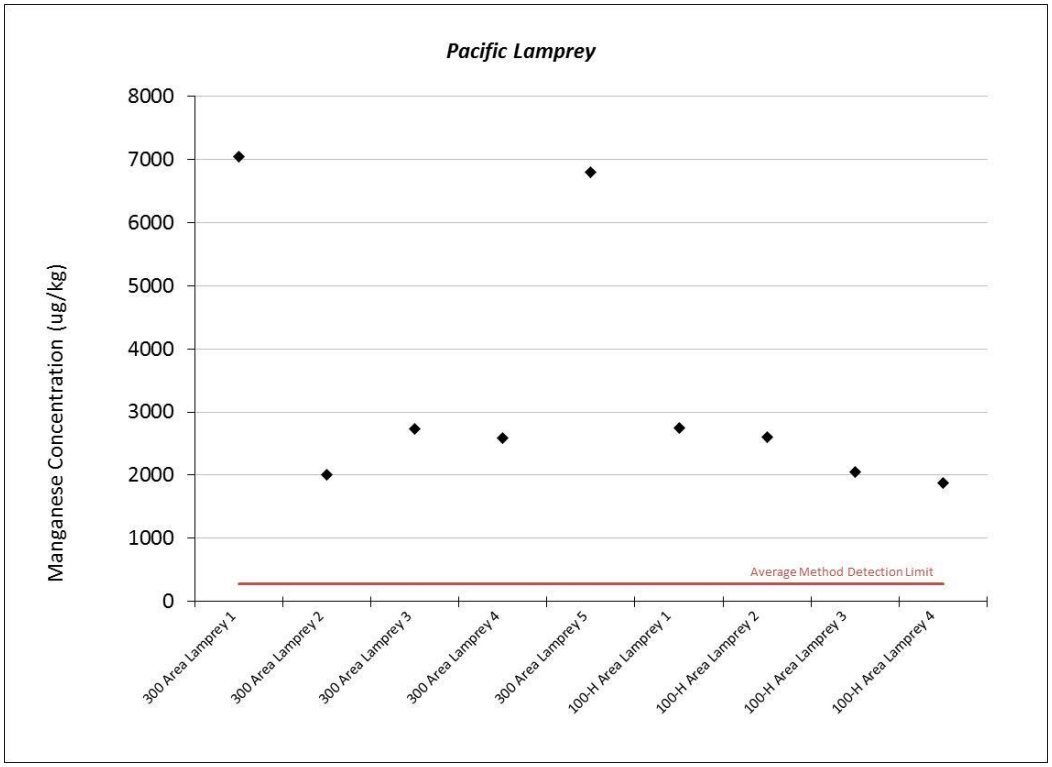

Figure A.4. Manganese Concentrations Measured in Lamprey Tissue Samples Collected During 2012

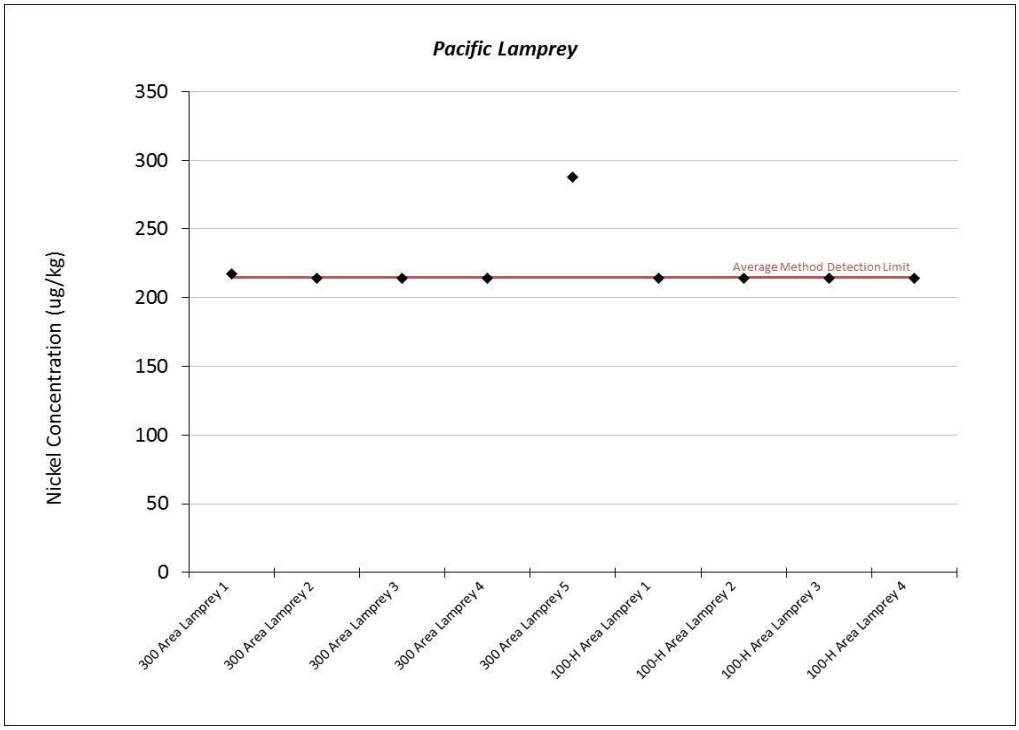

Figure A.5. Nickel Concentrations Measured in Lamprey Tissue Samples Collected During 2012

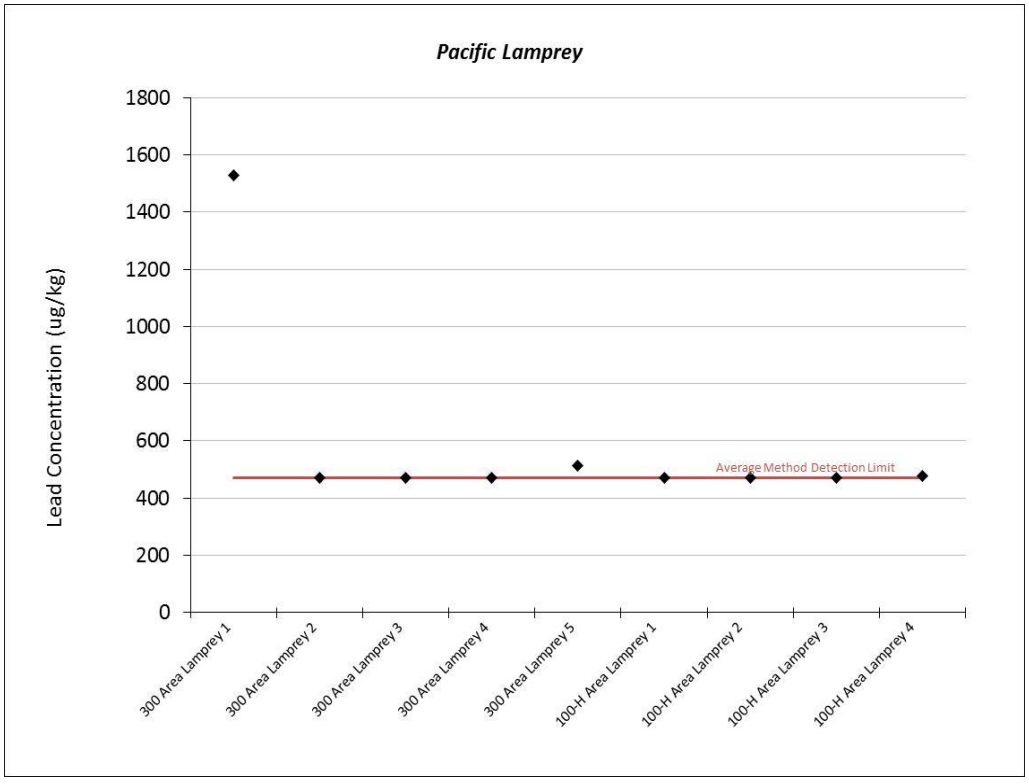

Figure A.6. Lead Concentrations Measured in Lamprey Tissue Samples Collected During 2012

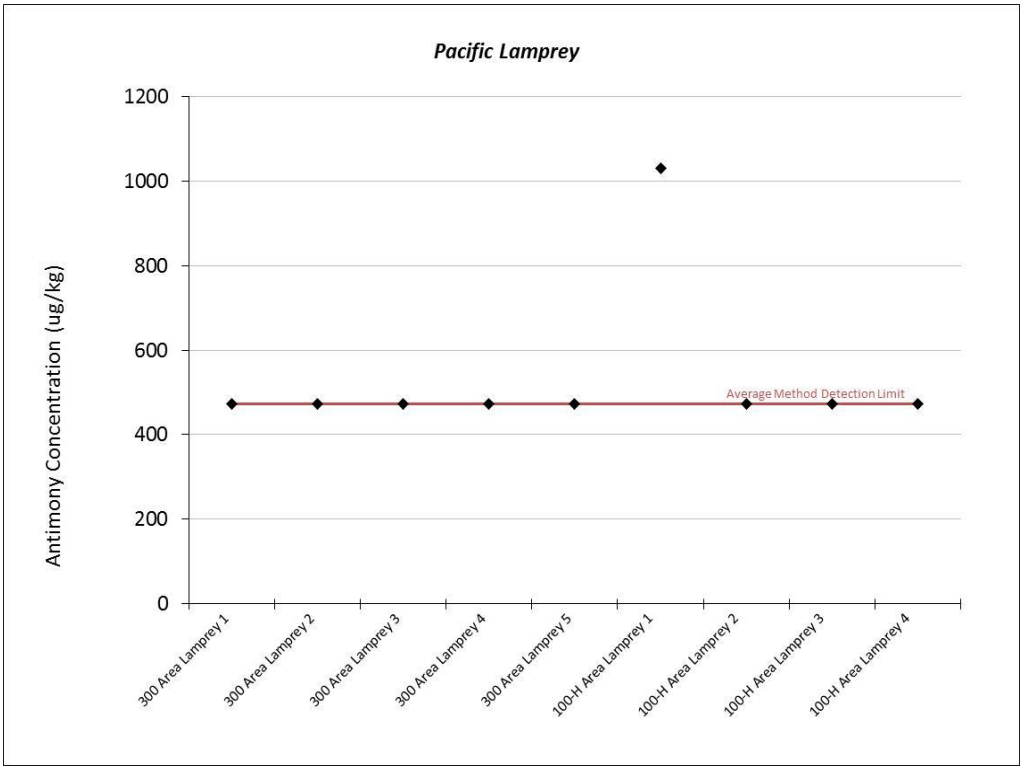

Figure A.7. Antimony Concentrations Measured in Lamprey Tissue Samples Collected During 2012

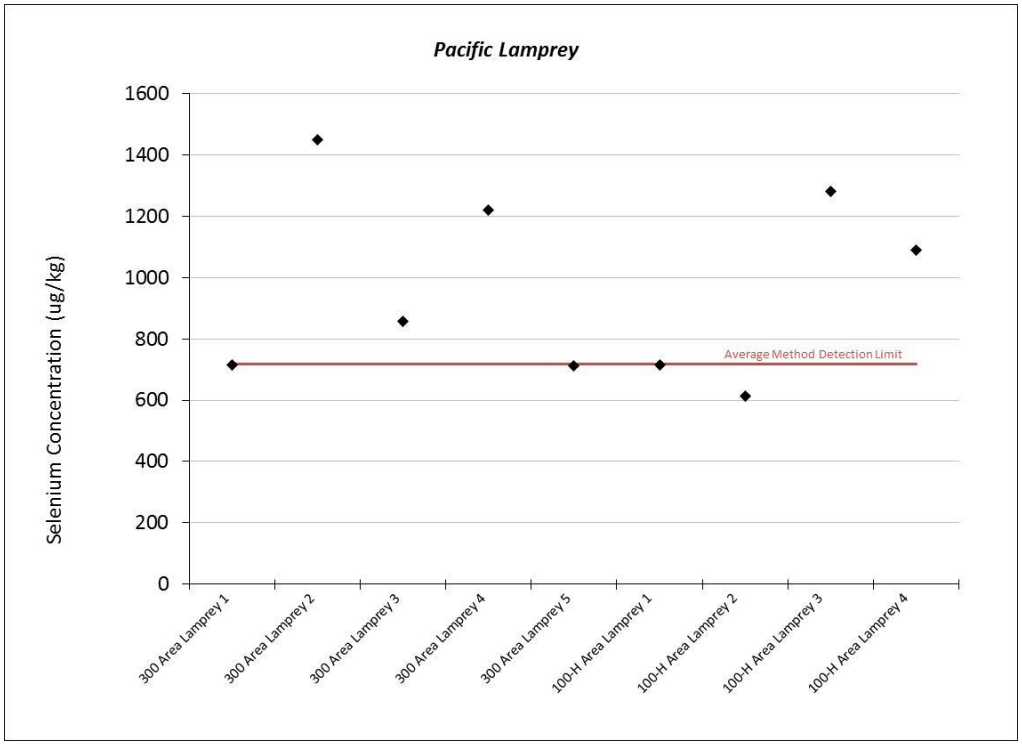

Figure A.8. Selenium Concentrations Measured in Lamprey Tissue Samples Collected During 2012

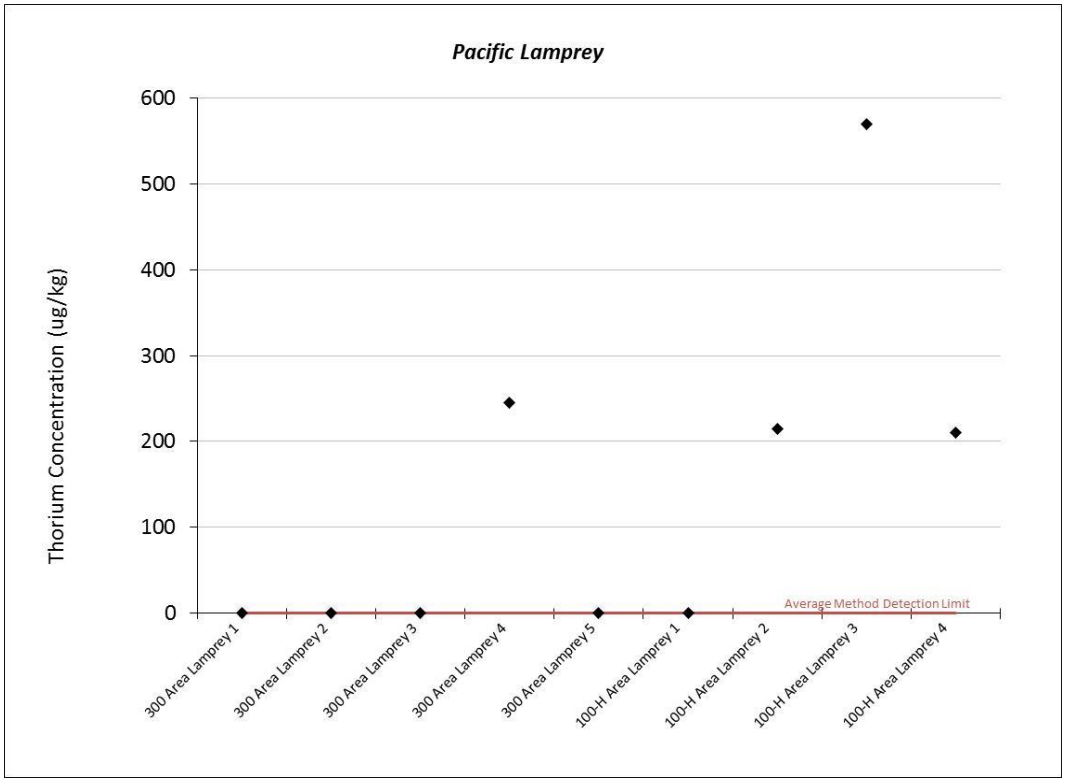

Figure A.9. Thorium Concentrations Measured in Lamprey Tissue Samples Collected During 2012

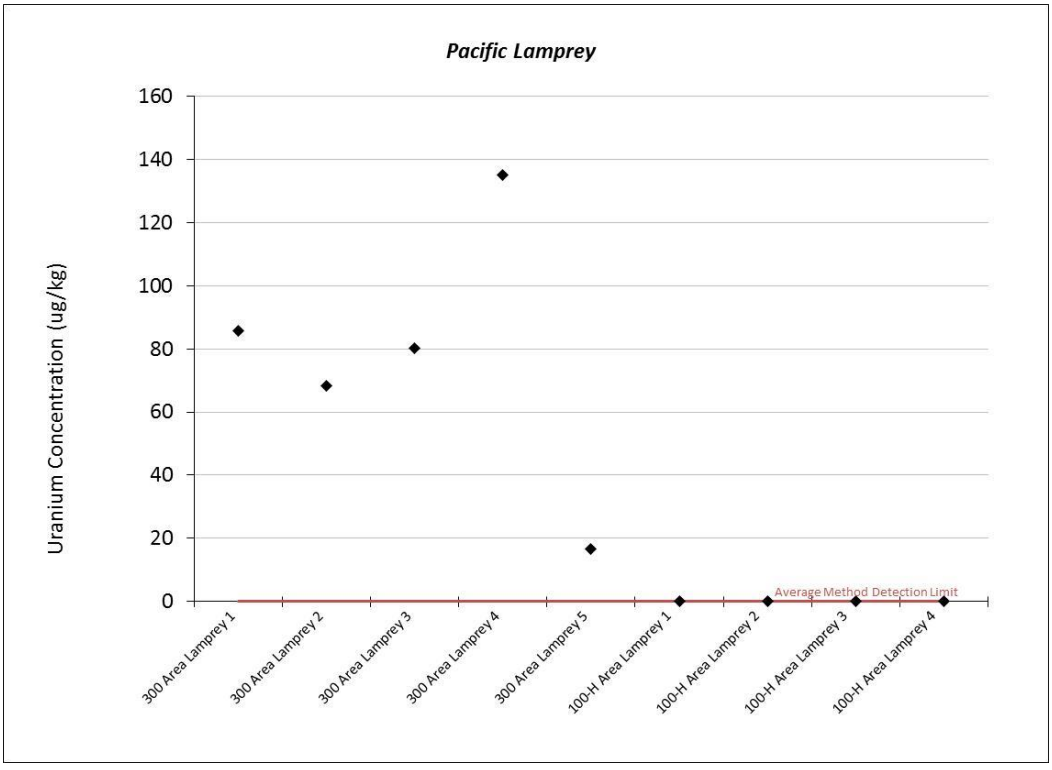

Figure A.10. Uranium Concentrations Measured in Lamprey Tissue Samples Collected During 2012

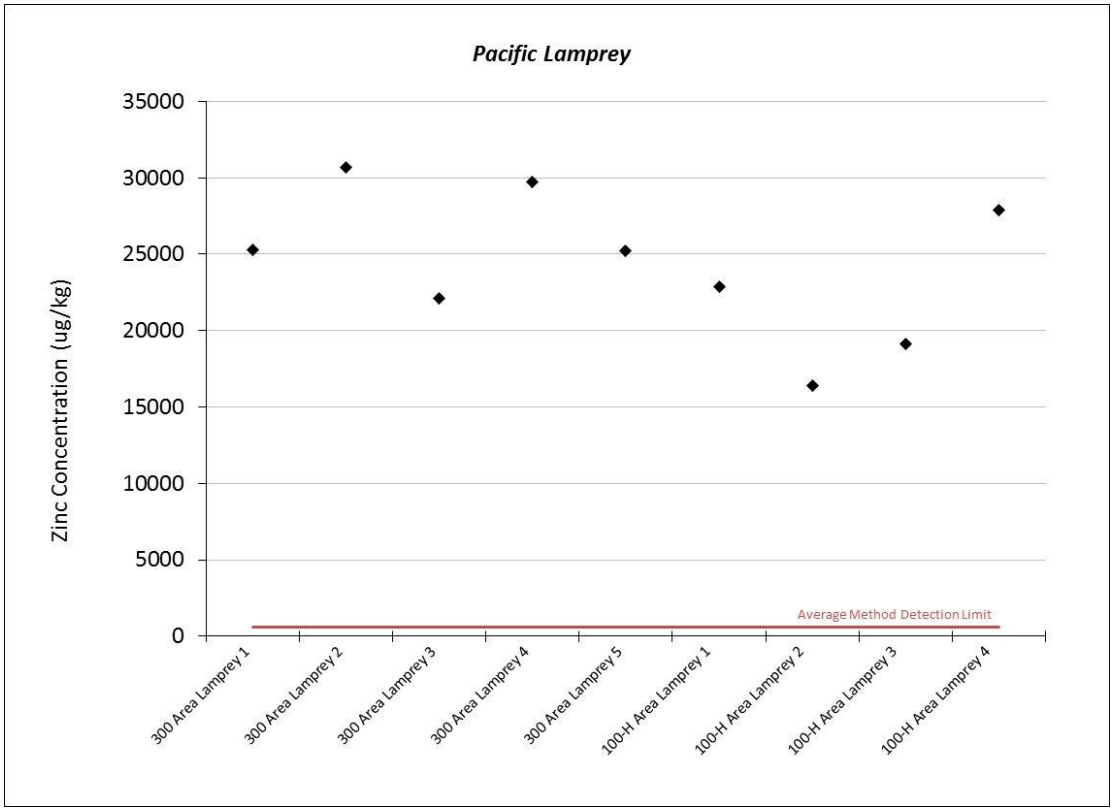

Figure A.11. Zinc Concentrations Measured in Lamprey Tissue Samples Collected During 2012

Attachment B 2012 Inorganics Analysis Data Organized By Individual Sample Number & Location

Table B.1. 2012 Inorganics Analysis Data

Sample ID	No.	Thorium	Uranium	Aluminum	Antimony	Arsenic	Chromium	Copper	Lead	Manganese	Nickel	Selenium	Thallium	Zinc
		mg/kg		µg/kg										
300 AREA														
B2M938	1	0.0593	0.0857	101000	312	0	459	1480	1530	7040	217	0	473	25300
B2M939	2	0.0665	0.0684	9650	357	0	162	3310	357	2000	162	0	541	30700
B2M940	3	0.11	0.0801	28600	364	0	166	1610	364	2730	166	858	0	22100
B2M941	4	0.245	0.135	25900	383	0	174	3680	383	2580	174	1220	0	29700
B2M942	5	0.0734	0.0165	72600	385	0	175	762	512	6790	288	713	0	25200
100H														
B2M943	1	0.158	0.0327	20600	1030	0	455	2960	1000	2750	455	1520	0	22900
B2M944	2	0.215	0.0122	7070	343	520	0	649	343	2600	156	613	0	16400
B2M945	3	0.57	0.0246	14400	699	0	318	2390	699	2050	318	1280	0	19100
B2M946	4	0.21	0.0139	10500	407	0	185	3840	476	1870	185	1090	0	27900