2008 FIELD REPORT:

EVALUATION OF PINNIPED PREDATION ON ADULT SALMONIDS AND OTHER FISHES IN THE BONNEVILLE DAM TAILRACE

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INTRODUCTION

Since 2002, we have used surface observations to evaluate the seasonal presence, abundance, and predation activities of pinnipeds, including California sea lions (*Zalophus californianus*), Steller sea lions (*Eumetopias jubatus*), and Pacific harbor seals (*Phoca vitulina richardsi*) in the Bonneville Dam tailrace. This monitoring program is part of an ongoing effort to understand and appropriately manage pinniped predation on threatened and endangered salmonids, including spring Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) in the tailrace of the dam. The Corps and partnering agencies have utilized a variety of deterrents and barriers to prevent predation in or around fishways and to deter predation on salmonids and other fish in the tailrace. This report is intended as a summary of monitoring and deterrence efforts implemented by, or coordinated with, the U.S. Army Corps of Engineers (USACE). Agency partners included the Oregon Department of Fish and Wildlife (ODFW), the Washington Department of Fish and Wildlife (WDFW), the Columbia River Inter-Tribal Fish Commission (CRITFC), the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS), the U.S. Department of Agriculture (USDA) Wildlife Services, and Portland State University (PSU).

Objectives in 2008 were similar to those in previous years:

1. Estimate the number of adult salmonids and other fish consumed by pinnipeds in the Bonneville Dam tailrace and estimate the proportion of the adult salmonid run impacted.
2. Determine the seasonal timing and abundance of pinnipeds present at the Bonneville Dam tailrace, documenting individual California sea lion presence and predation activity when possible.
3. Evaluate the effectiveness of pinniped deterrents and barriers used at Bonneville Dam.

METHODS

SURFACE OBSERVATIONS

Methods used in surface observations are described in detail in Tackley et al. (2008). Observers stationed at each of the three major tailrace areas of the dam (Powerhouse One [PH1], Powerhouse Two [PH2], and the spillway) recorded pinniped presence, recorded and identified fish catches, and identified individual California and Steller sea lions when possible (see Appendix A for map). In 2008, observers were instructed to assign a confidence rating of 1 (least confident) to 5 (most confident) to each identified fish catch. The category of "unidentified salmonid" was eliminated from observation forms, and observers were instructed to identify all salmonid catches as either Chinook or steelhead. Individual pinnipeds were identified by cataloging unique physical characteristics and (for previously trapped and tagged animals) unique brand numbers. Individual identification was used to generate abundance estimates and to track individual predation and use patterns, both within and among years. Regular observations began roughly an hour before sunrise and ended an hour after sunset. Observations were occasionally conducted at night or at downstream locations, as time allowed.

In 2008, regular observations began on January 11, Mondays through Fridays, and increased to 7 days per week on February 4. Regular observations ceased on May 31 as the last of the California sea lions departed the area. This study period included the fish passage season from January 1 to May 31, with special attention paid to the spring Chinook salmon passage season at Bonneville Dam (about March 15 through June 15). Few pinniped sightings occurred outside this timeframe, although Steller sea lions were known to be catching and consuming white sturgeon (*Acipenser transmontanus*) in the Bonneville Dam tailrace and farther downstream as early as November.

In response to reported predation occurring downstream of the Bonneville Dam tailrace area, students from PSU conducted surface observations from Hamilton Island. Students observed the area from Tanner Creek downstream to the eastern tip of Ives Island, from January 13 through May 19. These student observers used the same methods and observation forms used by our observers. In addition, WDFW personnel used the same methods and forms to conduct surface observations in "blind spot" zones immediately downstream of our tailrace observation areas. Although observed catches recorded by PSU and WDFW observers are included in this report, they were not included in predation estimates for the Bonneville Dam tailrace.

PREDATION ESTIMATES

Expanded Catch Estimates

As in previous years, expanded adult salmonid, sturgeon, and lamprey catch estimates were calculated by taking the daily observed catch for each prey type, at each of the tailrace areas (PH1, PH2, and spillway), and expanding for the hours not observed based on hourly observed catch rates for the entire season (Appendix B, Equations 1-3). All three tailrace estimates were combined to calculate total daily estimated catch for the Bonneville Dam tailrace. For days on which no observations were made, we used linear interpolation to fill in the gaps. All daily estimated catch totals were added to get the total *expanded catch estimate* for the year. The *minimum estimated impact* on salmonids passing during the observation period (expressed as percent of run) was calculated by dividing the expanded salmonid catch estimate by the expanded salmonid catch estimate plus the total salmonid passage count from Bonneville Dam for the *January 1 through May 31* time period:

$$I_m = \frac{C_e}{(C_e + P)}$$

where

C_e is the expanded adult salmonid catch estimate,

P is the salmonid passage count at Bonneville from January 1 through May 31, and

I_m is the minimum estimated impact on adult salmonids passing Bonneville from January 1 through May 31.

Expanded Chinook Catch Estimates

We estimated Chinook salmon catch and the minimum estimated impact on the Columbia River spring Chinook salmon run at Bonneville Dam from 2002 to 2008. For 2002 through 2007 data, we multiplied daily expanded salmonid catch estimates by the percentage of identified salmonid catches recorded as Chinooks to estimate expanded Chinook catch. Daily estimates were combined to calculate the total expanded Chinook catch estimate for each year. In 2008, observers were instructed to identify all salmonid catches as either Chinook or steelhead and assign a confidence rating to their identification certainty. After reviewing the confidence rating distribution for 2008, we determined that for these simple estimates, it was acceptable to assume that all catches identified as Chinook were indeed Chinook, regardless of confidence ratings. Therefore, for 2008 data, we simply used the standard expanded estimate equation (Appendix B, Equation 3) to generate the expanded Chinook catch estimate. For all years, the estimated impact on Chinook passing during the observation period (expressed as percent of run) was calculated by dividing the expanded Chinook catch estimate by the expanded Chinook catch estimate plus the total salmonid passage count from Bonneville Dam for the *January 1 through June 15* time period (similar to salmonid impact estimates).

Adjusted Catch Estimates

For a variety of reasons, observers were sometimes unable to identify the fish caught during a predation event. To provide more comprehensive adult salmonid and sturgeon catch estimates, we used daily observed catch distributions to proportionally divide unidentified (or "unknown") catches (Appendix B, Equations 4-5). The daily observed catch distributions included adult salmonids, sturgeon, American shad (*Alosa sapidissima*), northern pikeminnow (*Ptychocheilus oregonensis*), and unidentified bass (Centrarchidae). Lamprey and smolt (juvenile salmonids) were excluded from this proportional allocation, as we determined that their unique sizes and shapes made them extremely unlikely to be recorded as unidentified fish.

Observed catch distributions and catch rates of California sea lions and Steller sea lions differ substantially, so we calculated the proportional distribution of the unidentified catch separately by pinniped species. As with the expanded catch estimate calculations, we expanded for missed observation hours or days. The proportionally split catch totals for California sea lions and Steller sea lions were added to the expanded catch estimates to calculate the adjusted catch estimate (Appendix B, Equation 5).

DETERRENTS AND MANAGEMENT ACTIVITIES

We used and evaluated a variety of sea lion deterrents, from physical barriers to non-lethal harassment (hazing) techniques in 2008. Sea lion exclusion devices (SLEDs) are large, barred, grate-like physical barriers that were installed at Bonneville Dam's twelve primary fishway entrances to prevent sea lions from entering the fishways. The SLEDs feature 15.38-in (39.05 cm) gaps that are designed to allow fish passage. In 2008, SLEDs were installed between January 28 and February 28 and removed between June 10 and June 30. Floating orifice gates (FOGs) were equipped with stab plates to prevent sea lions from entering the fishway collection channel running below deck of PH2. These stab plates were installed on December 3, 2007. In addition to these stab plates, SLED-like FOG barriers were installed at the two FOGs at the north and two FOGs at the south ends of the powerhouse on March 21 and 25. Airmar dB Plus II* acoustic deterrent devices (ADDs), which emit a 205 decibel sound in the 15 kHz range, were installed at fishway entrances by January 10 and removed on May 28.

Hazing involved a combination of acoustic, visual, and tactile non-lethal deterrents, including vessel chasing, above-water pyrotechnics (cracker shells, screamer shells or rockets), rubber bullets, rubber buckshot, and beanbags. Boat-based crews also used underwater percussive devices known as seal bombs. Dam-based and boat-based crews coordinated with USACE personnel, including our observers, to ensure safety and to increase the effectiveness of hazing efforts. Dam-based hazing by U.S. Department of Agriculture (USDA) Wildlife Services agents began on March 3 and was conducted 7 days per week through the end of May.

Boat-based hazing was conducted by personnel from ODFW, WDFW, and CRITFC from December 11 through May 15. Boats operated from the Bonneville Dam tailrace (river mile 146) downstream to Navigation Marker 85 (river mile 139). Boats could not operate within 30 m of dam structures or within 50 m of fishway entrances. The use of seal bombs was prohibited within 100 m of fishways, collection channels, or fish outfalls for the PH2 corner collector and smolt monitoring facility, and boat crews ceased using seal bombs after adult salmonid passage exceeded 1,000 fish per day.

Personnel from ODFW and WDFW operated four floating sea lion traps along the PH2 corner collector from March 14 through May 4. In accordance with their Marine Mammal Protecion Act (MMPA) Section 120 authority, captured animals were either selected for transfer to holding facilities or released. Captured California sea lions that were unbranded were either branded and released on-site or transported to Astoria for processing. Steller sea lions were released on-site.

DIDSON TEST DEPLOYMENTS

We conducted a test of the DIDSON underwater acoustic camera to assess its potential for observing the interaction of fish and sea lions near PH2 fishway entrances and to assess possible adverse effects of sea lion deterrents on fish behavior. The DIDSON (Dual frequency IDentification SONar) is manufactured by Sound Metrics Corp.* of Lake Forest Park, WA. It is a multi-beam sonar that uses a lens system to form the individual beams. It is used to produce video-like images through turbid water where conventional video cameras relying on ambient or

* Does not imply endorsement by the U.S. Army Corps of Engineers

artificial light cannot. The objective of this pilot study was to deploy the DIDSON at one or more of the major fishway entrances of the PH2 tailrace and evaluate its performance. We were able to successfully deploy a workable system at two of the fishway entrances a few days before the last sea lion left the project for the season, at the tail-end of the spring Chinook salmon run and the beginning of the American shad run.

RESULTS AND DISCUSSION

PREDATION ACTIVITY

In 2008 (January 1 through May 31), observers completed 5,131 hours of observations at the three tailrace observation areas. During this period, observers saw pinnipeds catch and consume at least 5,621 fish. Adult salmonids (*Oncorhynchus* spp.) were the primary prey item, comprising at least 75.5% (n=4,243) of observed catches. White sturgeon and Pacific lamprey were the second and third most commonly identified prey types, comprising 10.8% (n=606) and 2.0% (n=111) of total observed catch, respectively. Observers were unable to identify 12.4% (n=698) of the fish caught and consumed by pinnipeds during this period. As in previous years, all catch estimates should be treated as minimum estimates.

Predation on Adult Salmonids

In 2008, the expanded adult salmonid catch estimate for the Bonneville Dam tailrace observation area was 4,466 or 2.9% of the adult salmonid run at Bonneville Dam from January 1 through May 31. The adjusted estimated catch was 4,927 (or 3.2% of the run) (Table 1). California sea lions were the primary salmonid predator, accounting for 96.2% (n=4,081) of the 4,243 observed catches (Table 2). This percentage was lower than was seen in previous years, as observed salmonid catch by Steller sea lions increased from 0.3% (n=12) in 2007 to 3.8% (n=162) of total take in 2008.

Chinook salmon were the most commonly identified prey species, comprising about 93.2% (n=3,955) of observed adult salmonid catch in 2008. The expanded Chinook catch estimate for the Bonneville Dam tailrace observation area was 4,115 or 2.3% of the Chinook run at Bonneville Dam from January 1 through June 15 (Table 3). Note that this time period differs from the passage season used for total salmonid estimates. This period includes the accepted Columbia River spring Chinook passage season at Bonneville Dam, which extends beyond the period during which sea lions are present. Steelhead comprised about 6.8% (n=288) of observed adult salmonid catch during the same period. Steelhead, which are present in the Bonneville Dam tailrace throughout the winter and spring months, comprised the majority of salmonid catches prior to the onset of the spring Chinook salmon run (Figure 1).

Table 1. Salmonid catch summary (2002-2008). Total salmonid passage counts include all adult salmonids that passed Bonneville Dam from January 1 through May 31. Adjusted catch estimates include expanded catch estimates and likely additional catch.

Year	Bonneville Dam Salmonid Passage (Jan. 1-May 31)	Observed Salmonid Catch		Expanded Salmonid Catch Estimate		Adjusted Salmonid Catch Estimate	
		Observed Catch	*% of Run (1/1 to 5/31)*	Estimated Catch	*% of Run (1/1 to 5/31)*	Estimated Catch	*% of Run (1/1 to 5/31)*
2002	284,733	448	*0.2%*	1,010	*0.4%*	-	-
2003	217,185	1,538	*0.7%*	2,329	*1.1%*	-	-
2004	186,804	1,324	*0.7%*	3,533	*1.9%*	-	-
2005	82,006	2,659	*3.1%*	2,920	*3.4%*	-	-
2006	105,063	2,718	*2.5%*	3,023	*2.8%*	3,401	*3.1%*
2007	88,474	3,569	*3.9%*	3,859	*4.2%*	4,355	*4.7%*
2008	**147,543**	**4,243**	***2.8%***	**4,466**	***2.9%***	**4,927**	***3.2%***

Table 2. California sea lion and Steller sea lion predation on adult salmonids at Bonneville Dam, from January 1 through May 31, 2008. Adjusted catch estimates include expanded catch estimates and likely additional catch.

Predator	Observed Salmonid Catch		Expanded Salmonid Catch Estimate		Adjusted Salmonid Catch Estimate	
	Observed Catch	*% of Run (1/1 to 5/31)*	Estimated Catch	*% of Run (1/1 to 5/31)*	Estimated Catch	*% of Run (1/1 to 5/31)*
California Sea Lions	4,081	*2.7%*	4,290	*2.8%*	4,687	*3.1%*
Steller Sea Lions	162	*0.1%*	176	*0.1%*	240	*0.2%*

Table 3. Expanded Chinook salmon catch estimates (2002-2008). Regular observations were not made at the spillway in 2004.

Year	Chinook Passage (Jan. 1 – June 15)	Expanded Chinook Catch Estimate	% of Chinook Run (Jan. 1 – June 15)
2002	316,468*	880‡	0.3%
2003	247,059	2,313	0.9%
2004	210,569	3,307	1.5%
2005	102,741	2,742†	2.6%
2006	130,014	2,580	1.9%
2007	101,068	3,403	3.3%
2008	174,247	4,115	2.3%

* Fish counts did not start until March 15 in 2002. Chinook passage from January 1 through March 15 was minimal in all other years.

‡ From March 15 through April 25, used fish passage count split between Chinook salmon and steelhead to estimate Chinook catch proportion of unidentified salmonid catch. Thereafter, and in all other years, used observed catch distribution to divide unidentified salmonid catch.

† In 2005, regular observations did not start until March 18.

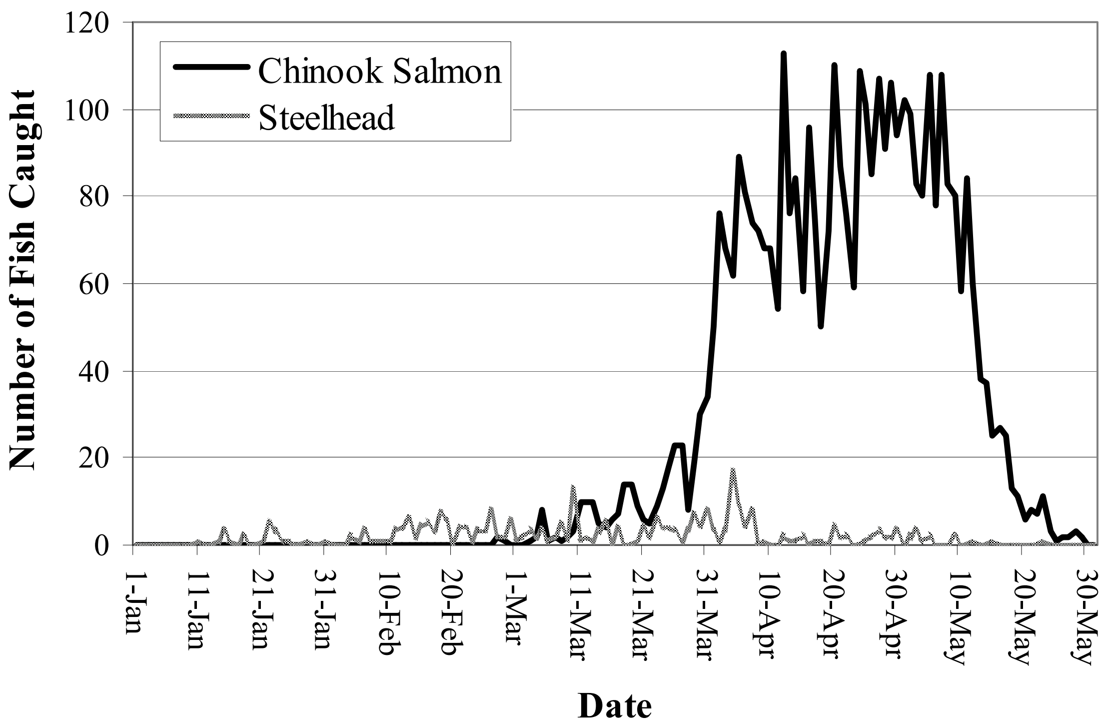


Figure 1. Daily observed Chinook salmon and steelhead catch in the Bonneville Dam tailrace in 2008.

Predation on White Sturgeon

In 2008, the expanded sturgeon catch estimate for our observation area was 792, continuing the upward trend in predation on sturgeon in the Bonneville Dam tailrace (Table 4). When unidentified catch was divided proportionally according to daily catch distributions and added to the expanded sturgeon catch estimate, the adjusted catch estimate was 1,139. White sturgeon was the most commonly observed prey item for Steller sea lions, which made 97.7% (n=592) of the 606 observed sturgeon catches in 2008. Steller sea lions were known to be catching sturgeon in the vicinity of Bonneville Dam as early as November 2007, so observed and expanded catches represent minimum catch.

When possible, observers estimated the total lengths of sturgeon caught by pinnipeds. The estimated total lengths of sturgeon caught in 2008 ranged from less than 2 ft (0.6 m) to 7 ft (2.7 m), but 85.9% of sturgeon lengths (n=561) were 4 ft (1.2 m) or shorter.

Table 4. White sturgeon catch summary. Hours observed, total observed number of white sturgeon caught, and expanded estimates of white sturgeon catch at Bonneville Dam (2005-2008). Adjusted estimates include expanded catch estimates and likely additional catch, which is based on the proportional distribution of unidentified catch.

Year	Total Hours Observed	Observed Sturgeon Catch	Expanded Sturgeon Catch Estimate	Adjusted Sturgeon Catch Estimate
2005	1,108	1	-	-
2006	3,647	265	315	413
2007	4,433	360	467	664
2008	5,131	606	792	1,139

Predation on Pacific Lamprey

In 2008, the expanded Pacific lamprey catch estimate was 145, which is comparable to the estimated 143 caught in 2007 (Table 5). Lamprey was once again the second most commonly observed prey item for California sea lions, which made 105 of the 111 observed lamprey catches in the Bonneville Dam observation area. However, lamprey catch comprised the lowest proportion of total observed catch (2.0%) since observations began in 2002. Most predation occurred in May, and catch rates were highest in the early morning and late evening crepuscular hours.

Table 5. Pacific lamprey catch summary. Hours observed, total observed number of Pacific lamprey caught, expanded estimates of lamprey catch, and the percentage (%) of total observed fish catch at Bonneville Dam (2002-2008).

Year	Total Hours Observed	Observed Lamprey Catch	Expanded Lamprey Catch Estimate	% of Total Observed Fish Catch
2002	662	34	47	5.6%
2003	1,356	283	317	11.3%
2004	553	120	816	12.8%
2005	1,108	613	810	25.1%
2006	3,647	374	424	9.8%
2007	4,433	119	143	2.6%
2008	5,131	111	145	2.0%

Night Observations

We conducted a total of 16 hours of additional observations one hour before and one to two hours after regular daylight observations in April and May to determine whether predation was occurring at night. Given the obvious difficulties of detection (we tried night vision binoculars, scopes, and high powered spot lights, all with less success than ambient light, binoculars, and listening), we were able to discern an average of 2.3 pinnipeds present and foraging per hour. At least 1 salmonid, 1 sturgeon, and 18 unidentified fish were caught during those hours. There were fewer pinnipeds and less predation in the early morning hours (average 1.5 pinnipeds and 0.4 catches per hour) than in the early night hours (average 3.5 pinnipeds and 2.3 catches per hour). However, most pinnipeds typically departed in the first or second hour of night observation. Few hours were sampled, but these observations are supported by the large numbers of sea lions seen hauled-out in the early morning hours, with more animals becoming active and hunting as the morning progressed. Therefore, while hazing activities or social factors may have encouraged additional foraging toward the crepuscular hours, we saw little evidence of large-scale nocturnal predation.

Additional Observations

Students from PSU observed the area approximately from Tanner Creek to the upstream tip of Ives Island on 76 days between January 13 and May 19 for a total of 303 observation hours. Observation effort was normally distributed, with peak effort between 1200 h and 1400 h (Appendix B). Students observed at least 1 unidentified salmonid, 46 Chinook, 28 steelhead, 1 lamprey, 11 shad, 8 sturgeon, and 9 unidentified fish catches. We did not calculate expanded estimates of catch in this location as observation effort was not sufficiently evenly distributed across daylight hours. Observers in this area saw an average of 1.0 California sea lions and 0.6 Steller sea lions per hour of observation, and observed an average of 0.25 salmonids (maximum of 6) and 0.3 sturgeon caught per hour. As they observed for 303 of the 2048 hours of daylight between January 1 and May 31 and observed 75 salmonid catches, simple arithmetic would suggest that up to 507 salmonids may have been caught in this area. Although we have noted times of notable predation activity at Tanner Creek, this figure may be far from realistic, as little is known about temporal predation patterns in this area, and observation effort was concentrated on mid-day hours (when observed predation rates in the Bonneville Dam tailrace are relatively low). PSU students also reported a higher number of shad catches, many of which were quite early in the season, than observers in our tailrace observation area noted. We suspect that some of these catches were misidentified.

WDFW personnel also conducted supplemental observations, in the area between our tailrace observation areas and Tanner Creek. They observed on 33 days for 180 hours during the season. After subtracting catches already documented in tailrace areas, we determined that WDFW observers recorded at least 35 Chinook, 2 sturgeon, and 1 unidentified fish catches. The number of salmonids caught per hour of observation (0.19) was comparable to that seen by the PSU observers downstream (0.25). However, both rates were considerably lower than the 0.87 salmonids caught per hour of observation in the tailrace observation areas upstream.

PINNIPED ACTIVITY

At 103 animals, the estimated number of individual pinnipeds observed at Bonneville Dam in 2008 was higher than estimates from the previous three years (Table 6). California sea lion and Steller sea lion numbers both increased in 2008. While the 17 Steller sea lions observed on one day was certainly more than we have seen previously, the increase in California sea lion identifications may have been due to the slight reduction in hazing effort, which allowed us several hours each morning to make positive individual sightings before hazing efforts began. As in previous years, hazing activity typically resulted in behavioral changes in the sea lions (more time below the water surface, less time with backs and unique markings exposed, etc) that made identification of individuals challenging. These estimates should be considered minimum estimates.

Table 6. Estimated total number of pinnipeds present at Bonneville Dam (2002-2008).

	2002	2003	2004	2005*	2006	2007	2008
California Sea Lions	30	106	101	80+	72	69	84
Steller Sea Lions	0	3	2	4+	10	9	17
Harbor Seals	1	2	2	1+	3	2	2
TOTAL	*31*	*111*	*105*	*85+*	*85*	*80*	*103*

* Regular observations did not begin until March 18 in 2005.

The highest number of pinnipeds counted on any one day was 63 (April 16), which was more than the peaks noted in previous years (Figure 2). This continues the trend of an increasing peak daily pinniped abundance since 2002. Mean daily number of pinnipeds present was 21.0, higher than in any previous year. The most number of days an individual California sea lion was observed at Bonneville was 80 days in 2008, also higher than in any previous year (Figure 3). California sea lions not previously identified continue to show up each year. Of the 63 highly identifiable animals (HIA) observed in 2008, 23 (36.5%) were "new" additions to that category, and three sea lions had been observed all seven observation years.

Steller sea lions were not only present in greater numbers in 2008, they also did not leave after dam and boat based hazing efforts began, as they had in 2006 and 2007 (Figure 4).

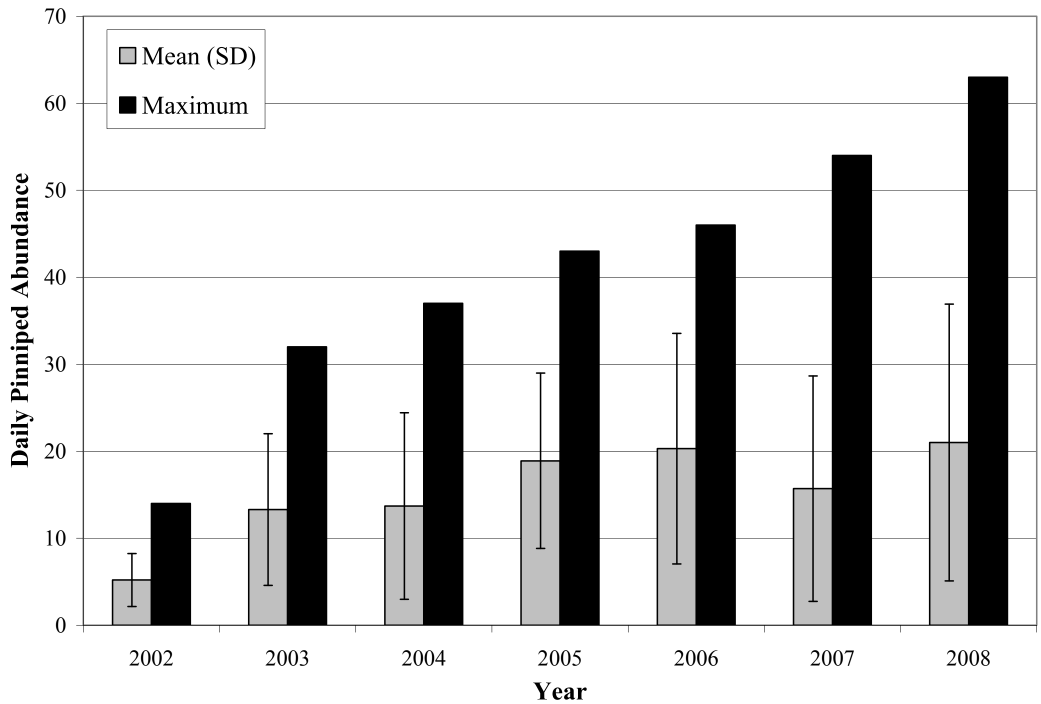


Figure 2. Mean (and standard deviation) and maximum daily estimated number of pinnipeds present at Bonneville Dam between January 1 and May 31, 2008.

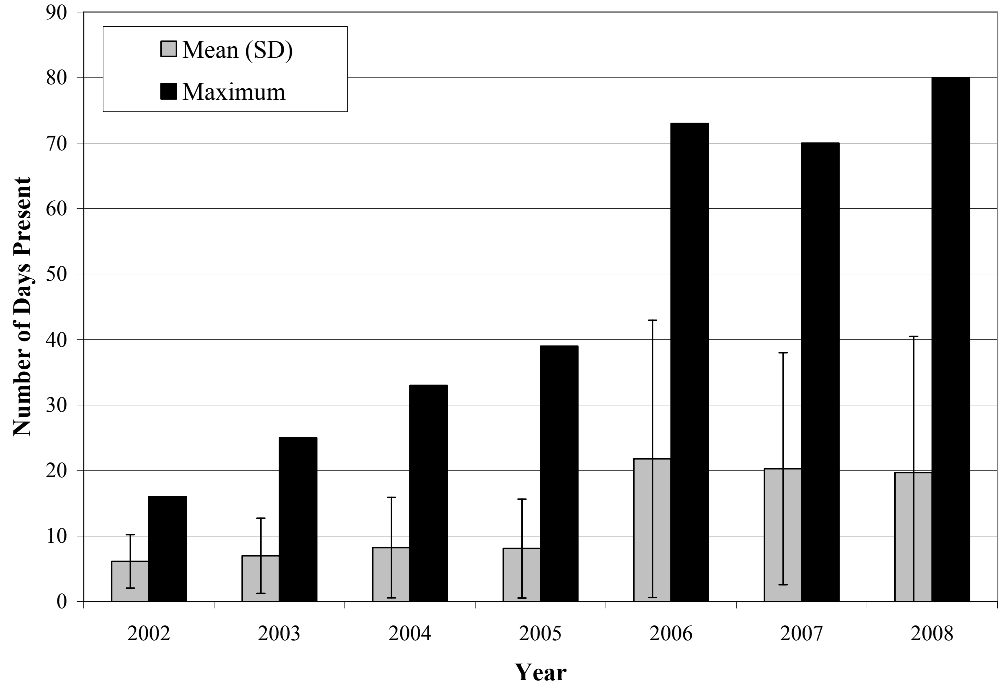


Figure 3. Mean (and standard deviation) and maximum number of days individual California sea lions observed at Bonneville Dam between January 1 and May 31, 2008.

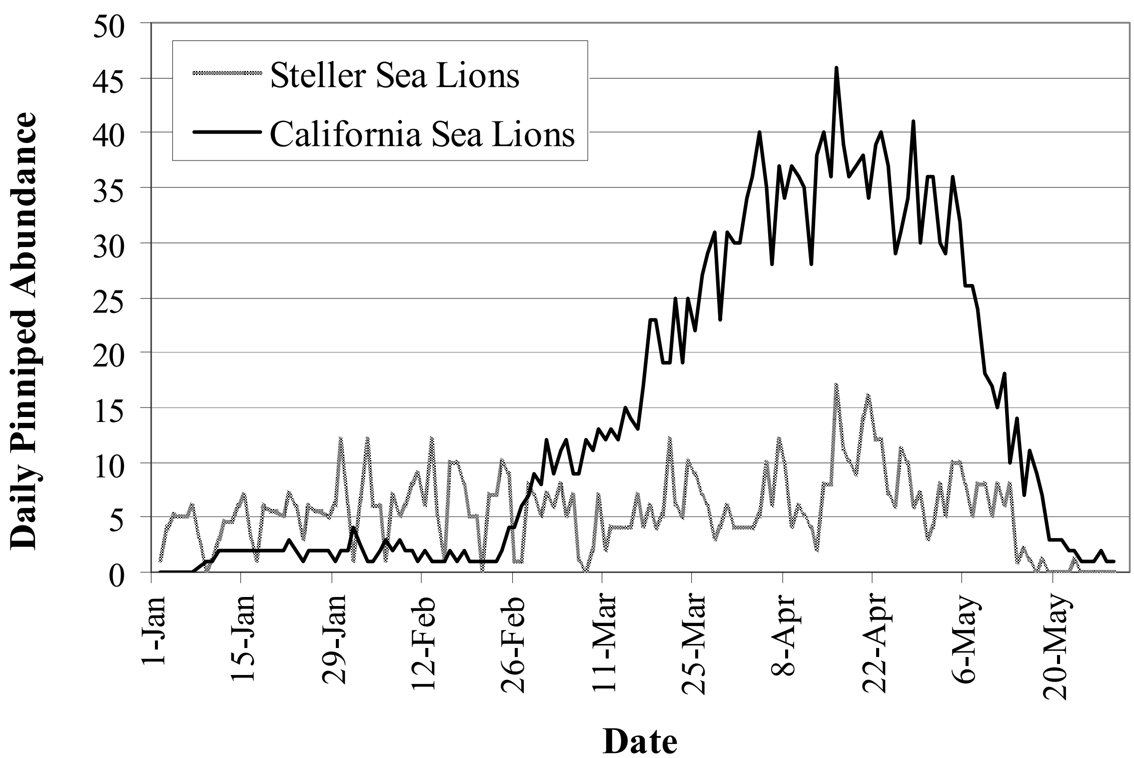


Figure 4. Daily abundance estimates for California sea lions and Steller sea lions at Bonneville Dam (2008).

DETERRENTS AND MANAGEMENT ACTIVITIES

Physical Barriers

No sea lions were observed inside any of the fishways this year, and observers did not note any sea lions attempting to get through the SLEDs or FOG barriers in 2008, despite significant predation activity near dam structures. C404, the only animal seen in the fishways after SLEDs were installed in previous years, was not observed at Bonneville Dam in 2008.

Acoustic Deterrent Devices

Acoustic deterrent devices (ADDs) were again installed at all main fishway entrances. As in previous years, pinnipeds were observed swimming and eating fish within 20 ft (6.1 m) to 50 ft (15.2 m) of some of the ADDs, with no obvious deterrent effect observed.

Non-Lethal Harassment

ODFW, WDFW, and CRITFC hazed from boats on 89 days between December 11 and May 15. USDA agents hazed from the dam on 87 days between March 3 and May 29. Hazing activity was not as frequent or intense as it was in previous years, as reflected in the number of hazing hours recorded. The number of observation hours during which boat-based or dam-based crews were present at least once was about half that of 2007, when hazing boats were seen at least once during 1,271 observation hours and USDA agents were present during 1,269 observation hours. Table 7 shows the number of hours boats or USDA agents were present at each tailrace, and the actual amount of time (minutes present converted to fractional hours) hazers were in the tailrace areas in 2008. Of course, boat crews also hazed sea lions in areas downstream of the tailraces, out of view of observers. We were unable to record this downstream activity.

As in previous years, hazing activity temporarily moved some sea lions out of tailrace areas, but the animals typically returned and resumed foraging shortly after hazers left the area. The high adult salmonid and sturgeon catch estimates seen in 2008 suggest that at best, hazing at the current level of intensity only blunts the ever-increasing predation trend.

To provide a more useful description of the level of hazing activity, we compared the observed number of actual hazing hours to the number of daylight hours during which hazing was possible. Between January 1 and May 31, there were approximately 2,048 hours of daylight, or 6,144 work hours required to cover all three tailrace areas. When the 52 days of spill (when boats can not enter the spillway tailrace and dam-based hazing is ineffective) were subtracted, this brings the potential hours of daylight hazing to 5,322. Our observers were present for 83.5% (5,131 hours) of these hours, while hazing boats were present at least once per hour for 12.9% of the hours and USDA agents were present at least once per hour for 14.7% of the hours. Actual hazing activity within the observation area (based on actual minutes of presence per hour) occurred during 3.2% of total hours for boat hazing and 6.4% for dam hazing. Pinnipeds were not present every single hour, therefore hazing personnel time was better spent roving the project and focusing on the location where the most pinnipeds were present.

Table 7. Total hours of hazing activity in the Bonneville Dam tailrace observation area in 2008.

Location	Number of Hours Hazers were Present at Least Once		Actual Observed Time (Hours) Hazers were Present	
	Boat hazing	*Dam hazing*	*Boat hazing*	*Dam hazing*
PH1	280	527	78.3	230.8
PH2	191	202	36.8	106.4
Spillway	200	53	50.5	4.1
Other	17	-	5.8	-
TOTAL	688	782	171.5	341.3

Trapping and Removal

Four traps were deployed along the PH2 corner collector in mid-March, and trapping events occurred on April 24, April 28, and May 1. On April 24, ODFW and WDFW trapped six California sea lions. Of those trapped, three California sea lions were on the list of identified animals that met criteria for removal. These animals were transferred to a holding facility. The three that were not branded and not on the list were transported to Astoria, where they were weighed, branded, and released. Two of these recently branded animals subsequently returned to Bonneville Dam. On April 28, five California sea lions were trapped, of which three were on the list and therefore removed. The fourth sea lion was branded on-site and released. On May 1, no animals were successfully trapped. On May 4, personnel discovered that the doors on two of the traps were closed, trapping two Steller sea lions and four California sea lions. By the time this was detected and personnel arrived to release them, all had expired from heat exhaustion. Trapping activities were immediately halted as a result of this incident and the resulting investigation.

DIDSON TEST DEPLOYMENTS

The first DIDSON deployment was at the upstream Washington shore north upstream fishway entrance (NUE) of PH2. We obtained 36 hours of DIDSON video between May 13 and 20 from this location. The DIDSON was lowered to about two feet below the tailrace surface. The camera provided a field of view that was approximately 30 degrees horizontal and 10 degrees vertical. The camera was tilted down slightly and panned to look out into the tailrace along the edge of the discharge from the fishway entrance. The maximum range was set at 18 m, and the resolution was set to low resolution. With this deployment, the camera provided a plan-view of the area in front of the fishway entrance. Air entrained in the discharge there produced a visible plume along one edge of the DIDSON image. Chinook and shad were readily detected and could usually be distinguished based on size. Most of the fish were seen crossing the beam heading towards the nearby entrances along the face of the powerhouse. No sea lions were detected at this location.

The second deployment was at the shoreward side of the north downstream entrance (NDE) at PH2. We obtained 15 hours of DIDSON video on May 21 and 22. The camera was aimed to look towards the north shore. Otherwise, the deployment was basically the same as the north upstream deployment. Shad were continuously milling in this area. Sturgeon were observed occasionally. One California sea lion was present in the area and was detected several times.

In these test deployments, the DIDSON had no difficulty producing useful video of objects 18 m into the tailrace. A conventional video camera would likely have been limited to one or two meters under these conditions. A disadvantage of the DIDSON compared to conventional video is its lower resolution, which makes identification and tracking of smaller objects challenging under certain physical conditions. At PH2 fishway entrances, the fish of interest range in size from a few inches (juvenile salmon) to several feet (adult sturgeon) in length. In the applications we envision for fish and sea lion observations, lower resolution should not present a serious challenge. Overall, DIDSON showed excellent potential as a tool for evaluating fish responses to physical barriers (SLEDs) and acoustic deterrents at fishway entrances. Obtaining useful video of pinniped behavior would be more challenging, but we suggest further evaluation of this technology to assess this and other potential applications.

RECOMMENDATIONS

1. In light of continuing increases in estimated adult salmonid and white sturgeon catch, the earlier and more protracted presence (if not total seasonal abundance) of California and Steller sea lions from January through May in the Bonneville Dam tailrace, and potential management actions by wildlife management agencies, we strongly suggest a continuation of this important monitoring program.
2. The Corps should continue to coordinate with agency partners performing observations in the area immediately downstream of our study area.
3. SLEDs and FOG barriers have proved effective and should continue to be used to prevent sea lions from entering the fishways of Bonneville Dam.
4. The Corps should consider discontinuing the use of acoustic deterrent devices (ADDs), as this device has demonstrated little or no usefulness as a sea lion deterrent at fishway entrances.
5. Test deployments of a DIDSON camera demonstrated the potential for using this tool to assess the reaction of fish to acoustic deterrents and SLEDs, and possibly to evaluate sea lion predation near fishway entrances. We recommend further investigation of this technology as a tool for understanding the less visible impacts of sea lion predation and deterrents.
6. The Corps should continue to assist in the pursuit and evaluation of potential non-lethal deterrent technologies as part of a long-term strategy to reduce pinniped predation on adult salmonids, sturgeon, and lamprey in the Bonneville Dam tailrace.

ACKNOWLEDGEMENTS

We would like to thank all who continue to help us provide the most accurate information on pinniped predation at Bonneville Lock and Dam. The Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, NOAA National Marine Fisheries Service, Pacific States Marine Fisheries Commission, and the Columbia River Inter-Tribal Fish Commission all contributed personnel and equipment to conduct the boat-based hazing program, while the USDA Wildlife Services continues to conduct the dam-based hazing program. Special thanks to Robin Brown (ODFW), Steve Jeffries (WDFW), Matt Tennis (PSMFC), and Bryan Wright (ODFW) for their advice, input, and cooperation. David Clugston, Robert Rose, and Bernard Klatte (USACE) helped with study objectives, funding, and program support. Ken Tolotti of the University of Idaho Cooperative Fish and Wildlife Research Unit (UICFWRU) helped with installation and maintenance of the acoustic deterrent array system. Just as in 2007, the Bonneville Lock and Dam rigging crew should be commended for successfully deploying and removing SLEDs, and for assisting with sea lion trapping efforts in 2008.

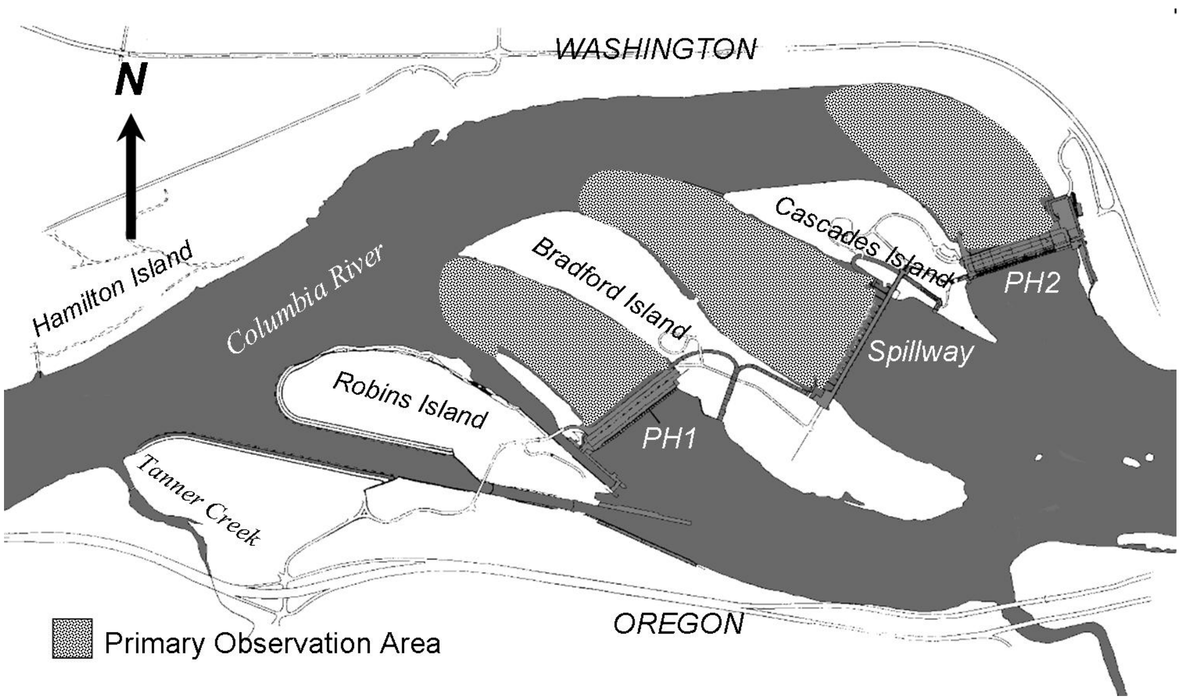
We thank John Dalen and Bill Nagy for taking the time and energy to manage the often challenging DIDSON test, including deployment, data management, and analysis.

A very big thank you goes to all the observers who collected valuable data for us this year. Observers from our own staff at the Fisheries Field Unit (Mike Jonas, Patricia Madson, and the authors) form the core of our observation team and this program would not be possible without them. Interns from the Student Conservation Association (SCA) did a great job of assisting with observations and data management. Lindsey Albright, Breena Apgar-Kurtz, Tabitha Finch, Tancy Moore, Leah Trombley, and Alice Dou Wang endured particularly harsh winter and spring weather and performed admirably. Dr. Debbie Duffield, Sharon Stuart Glaeser, Mandy Cook, and student observers from Portland State University's Bi 410 class contributed valuable information on predation downstream of our observation area and we appreciate their continuing interest in this issue.

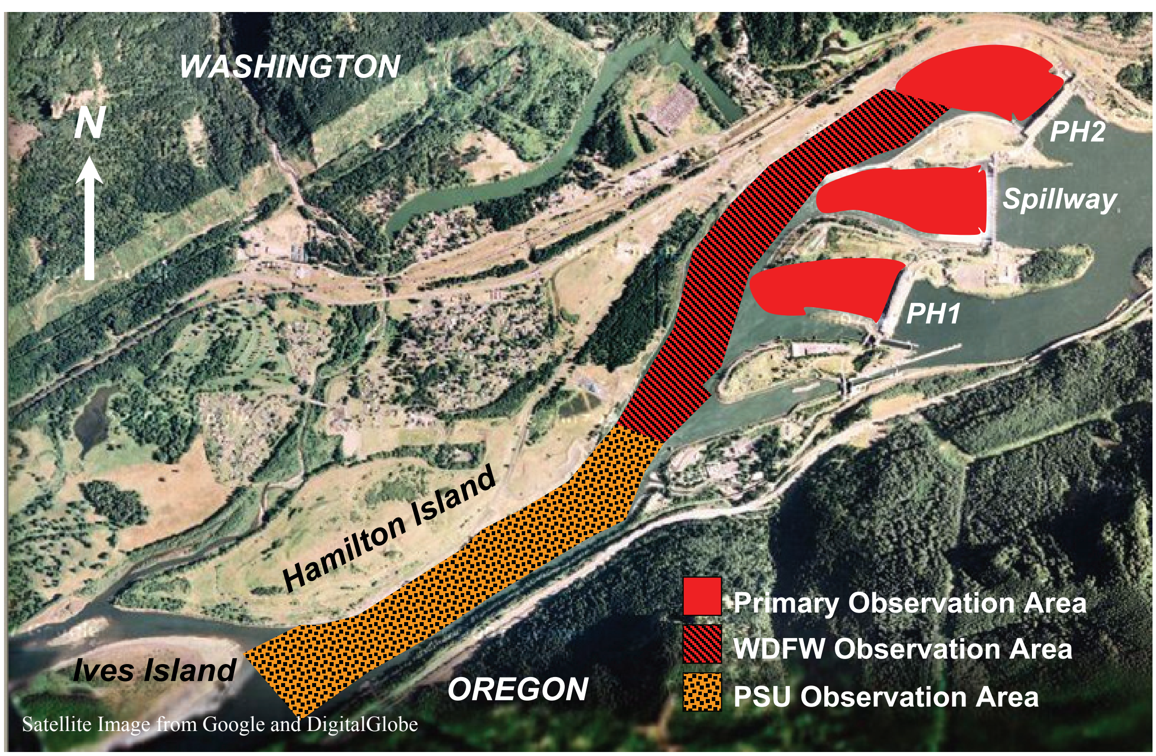
REFERENCE

Tackley, S., R. Stansell, and K. Gibbons. 2008. Pinniped predation on adult salmonids and other fish in the Bonneville Dam tailrace, 2005-2007. U.S. Army Corps of Engineers, CENWP-OP-SRF, Bonneville Lock and Dam, Cascade Locks, OR.

Appendix A. Map (A.1) and satellite image (A.2) of Bonneville Lock and Dam and vicinity, with observation areas highlighted.



A.1



A.2

Appendix B. Equations used to calculate predation estimates.

Equation 1. Hourly catch proportions (R_i)

Observers were not always present during all daylight hours, particularly early in the season, or during the earliest or latest regular observation hours. To estimate how many fish (in this example, adult salmonids) were caught during those missed hours, we expanded using known total season catch rates for each hour of the day. We used catch rates rather than raw observed catch to assess the relative hourly catch proportion to account for variation in the number of hours of observation logged for each hour of the day.

For example, observers logged only 112 hours for the 04:00-04:59 hour, but logged 197 during the 05:00-05:59 hour. In 2008, the adult salmonid catch rate (S_i divided by H_i) was highest during the 05:00-05:59 hour, at 1.43 adult salmonids caught per hour observed. This same catch rate calculation was made for each hour of the day. To calculate the hourly catch proportion (R_i) for each hour of the day, we added all the hourly catch rates together, then divided each catch rate by the sum. For example, the 05:00-05:59 hour accounted for 0.11 or 11% of the sum of all catch rates. In other words, 11% of all adult salmonid catches recorded in 2008 were made during the 05:00-05:59 hour, when catch was adjusted for observation effort. Thus:

$$R_i = \frac{\left(\frac{S_i}{H_i}\right)}{\sum_{i=1}^{m}\left(\frac{S_i}{H_i}\right)} \qquad (1)$$

where

R_i is the hourly catch proportion, calculated for each observed hour of the day, for all tailrace areas combined (Ex: 0.11 (or 11%) of total salmonid catch occurred during the 05:00-05:59 hour in 2008),

i is the hour of the day,

m is the latest hour of the day observed during regular observations (ex: 19:00-19:59 in 2008),

S_i is the total seasonal observed salmonid catch for the particular observed hour of the day (ex: 05:00-05:59) for all tailraces combined, and

H_i is the total seasonal number of hours observed for the particular observed hour of the day for all tailrace areas combined (ex: 197 hours of observation for the 05:00-05:59 hour in 2008).

Equation 2. Daily expansion factors (K_j)

Although observers were present during most daylight hours, some observation hours were missed. Observation effort and catch varied between tailraces, so expanded estimates were calculated separately at each tailrace, using the hourly catch proportions (R_i) calculated for the entire observation area and the entire season. For each day of the observation season, we calculated the tailrace's daily expansion factor (K_j) by adding all catch proportions for hours that were observed on that particular day.

For example, on April 7, observers were present at PH1 from 05:00 to 11:59 and 13:00 to 19:59. When all the hourly catch proportions for that day were added, the sum (the daily expansion factor, as used in expanded catch estimates) was 0.91, or 91%. Therefore, based on total season catch proportions, observers likely captured 91% of the daytime catch at PH1 on April 7. Thus:

$$K_{PH1\,j} = \sum_{i=1}^{m} A_{ij} R_i \tag{2}$$

where

m is the latest hour of the day observed during regular observations (ex: 19:00-20:00 in 2008),

A_{ij} = 1 if observations were made during hour i of day j,

= 0 if no observations were made during hour i of day j, and

R_i is the hourly catch proportion, calculated for each observed hour of the day, for all tailrace areas combined (ex: 0.11 (or 11%) of total adult salmonid catch occurred during the 05:00-05:59 hour in 2008).

Equation 3. Expanded catch estimates

We expanded observed catch to include catch estimates for hours and days missed by observers. Daily expanded catch estimates are combined to get the expanded catch estimate (C_e) for the season. The following example includes adult salmonids, but this equation was also used for other fish catch estimates, including Chinook salmon, sturgeon, lamprey, and unidentified fish.

For example, on April 7, the daily expansion factor for PH1 was 0.91 and observed adult salmonid catch at PH1 was 35 fish. When we divided 35 by 0.91, we got a daily expanded estimate of 38 fish. This same daily calculation is done for each tailrace (PH1, PH2, and spillway) to get the daily expanded catch estimate for the entire study area. On April 7, the daily estimate was 90 fish (8 more than observed catch that day). Occasionally, entire observation days were missed. We used linear interpolation to estimate catch on missed days. For example, if the daily estimated catch on April 1 was 10 fish and the estimate was 20 fish for April 3, then we estimated that 15 fish were caught on April 2. All of these missed-day estimates were added (Q) then combined with the sum of all daily catch estimates to get the total expanded catch estimate for the season (C_e), which was 4,466 in 2008. Thus:

$$C_e = Q + \sum_{j=1}^{N} \left(\frac{O_{PH1\,j}}{K_{PH1\,j}} + \frac{O_{PH2\,j}}{K_{PH2\,j}} + \frac{O_{SPL\,j}}{K_{SPL\,j}} \right) \tag{3}$$

where

Q is total estimated catch for unobserved days, calculated by linear interpolation of daily catch estimates for the day prior to and the day following the day(s) in question,

N is the last day of regular sea lion observations,

$O_{PH1\,j}$ is the observed adult salmonid daily catch at PH1,

$O_{PH2\,j}$ is the observed adult salmonid daily catch at PH2,

$O_{SPL\,j}$ is the observed adult salmonid daily catch at the spillway,

$K_{PH1\,j}$ is the daily expansion factor for PH1,

$K_{PH2\,j}$ is the daily expansion factor for PH2, and

$K_{SPL\,j}$ is the daily expansion factor for the spillway.

Equation 4. Likely additional catch by California (A_c) and Steller sea lions (A_s)

Observers were not always able to identify the species of fish being caught and consumed. Such catches were recorded as "unidentified" fish. The daily *identified* fish catch distribution was used to calculate daily proportional allocation of *unidentified* catch. These daily totals were then added together to get the likely additional catch for the season. The observed diets and catch rates of California and Steller sea lions differed substantially, with California sea lion diet dominated by adult salmonids and Steller sea lion diet dominated by sturgeon. To provide more accurate estimates, we estimated additional catch separately by predator species.

For example, on April 7, California sea lions caught and consumed an estimated 82 adult salmonids (X_j), 1 lamprey, and an estimated 3 unidentified fish. When the single lamprey catch was excluded, 100% of identified catches (X_j divided by Z_j) were adult salmonids. This proportion was multiplied by the daily expanded unidentified catch estimate for California sea lions (U_j), which was 3. So for April 7, we estimated that California sea lions likely caught at least 3 additional adult salmonids, given that 100% of identified catches were adult salmonids. This same calculation was made for all days of the season and for both sea lion species, producing an additional catch estimate of 397 adult salmonids for California sea lions (A_c) and 64 salmonids for Steller sea lions (A_s). Thus:

$$A_c = \sum_{j=1}^{N} \left(\frac{X_j}{Z_j} \right) \cdot U_j \tag{4}$$

where

N is the last day of regular sea lion observations,

X_j is the daily expanded (salmonid *or* sturgeon) catch, calculated by dividing observed daily (salmonid or sturgeon) catch (by California *or* Steller) by a predator species-specific (California *or* Steller) daily expansion factor (K_j) for each tailrace,

Z_j is total daily identified fish catch (excludes Pacific lamprey and smolts) by California sea lions *or* Steller sea lions, and

U_j is the daily expanded unidentified catch estimate for California sea lions *or* Steller sea lions.

Equation 5. Adjusted catch estimates (C_a)

Adjusted catch estimates include both the expanded (adult salmonid *or* sturgeon) catch estimate (C_e) and the likely additional (adult salmonid *or* sturgeon) catch by California sea lions (A_c) and Steller sea lions (A_s).

For example, in 2008 the expanded adult salmonid catch estimate (C_e) was 4,466 fish. California sea lions (A_c) likely caught an additional 397 salmonids, and Steller sea lions (A_s) likely caught an additional 64 fish. This brings the adjusted catch estimate (C_a) up to 4,927 fish. Thus:

$$C_a = C_e + A_c + A_s \tag{5}$$

where

C_e is the expanded salmonid *or* sturgeon catch estimate,

A_c is the likely additional salmonid *or* sturgeon catch by California sea lions, and

A_s is the likely additional salmonid *or* sturgeon catch by Steller sea lions.

Appendix C. Hours of observation, observed catch, and presence of pinnipeds observed by PSU students between Tanner Creek and Ives Island between 1 January and 31 May, 2008. Pinnipeds observed in this area included California sea lions (CSL), Steller sea lions (SSL), and harbor seals (HBR).

Hours	Hours Observed	Observed Salmonid Catch	Observed Sturgeon Catch	Observed Unidentified Catch	Number of Hours Present (CSL)	Number of Hours Present (SSL)	Number of Hours Present (HBR)	Salmonid Catch Per Hour Observed
0400-0459	0							
0500-0559	0							
0600-0659	6	0	0	0	2	1	0	0.00
0700-0759	14	8	0	3	9	5	0	0.57
0800-0859	19	4	1	0	12	8	2	0.21
0900-0959	28	5	0	0	14	10	0	0.18
1000-1059	29	6	0	1	20	9	0	0.21
1100-1159	32	0	1	1	14	12	0	0.00
1200-1259	41	6	1	0	21	9	0	0.15
1300-1359	41	10	2	2	19	15	0	0.24
1400-1459	37	13	2	0	18	15	1	0.35
1500-1559	27	12	0	1	15	12	0	0.44
1600-1659	19	2	0	0	14	5	0	0.11
1700-1759	8	8	0	1	6	3	0	1.00
1800-1859	2	1	1	0	2	1	0	0.50
1900-1959	0							
SUM	*303*	*75*	*8*	*9*	*166*	*105*	*3*	