FIELD REPORT:
2011 PINNIPED RESEARCH AND MANAGEMENT ACTIVITIES AT AND BELOW BONNEVILLE DAM

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October 4, 2011

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INTRODUCTION

Bonneville Dam, located approximately 146 miles upriver from the Pacific Ocean, is the lowermost hydroelectric project on the Columbia River. Bonneville Dam became operational in 1938 and today consists of two powerhouses on either side of a spillway, a navigation lock, adult fish ladders, juvenile fish by-pass facilities, and other operations and support buildings. From shore to shore, the Bonneville Dam spans over one mile of the Columbia between Washington and Oregon.

During the 1980s and 1990s, one to two California sea lions (*Zalophus californianus*) were reported annually at the dam during fishway inspections (Stansell 2004). However, in 2001, there were reports of up to six California sea lions observed at one time, and by 2002 the U.S. Army Corps of Engineers (USACE) estimated that 30 California sea lions were foraging at the dam for salmonids (*Onchorynchus* spp.), many of which are listed under the Endangered Species Act (ESA). Since then the minimum number of California sea lions has ranged from approximately 50 to 100 animals, with animals generally arriving earlier and occurring over a longer period each year. Salmonid predation at the dam by California sea lions increased from approximately zero before 2001, to over 5000 fish by 2010 (Stansell et al. 2010).

Steller sea lion (*Eumetopias jubatus*) abundance at the dam has also increased over the last decade, going from zero before 2003 to at least 75 by 2010 (Stansell et al. 2010). While Steller sea lions initially appeared to forage primarily on white sturgeon (*Acipenser transmontanus*), in recent years they have consumed increasing numbers of salmonids. In 2010 the number of sturgeon and salmonids consumed by Steller sea lions was estimated to be at least 2172 and 1025, respectively (Stansell et al. 2010).

In response to increasing pinniped predation at the dam, state, federal, and tribal partners have attempted to deter pinnipeds using a variety of non-lethal deterrents. Starting in 2005, these methods have included aerial and underwater pyrotechnics, acoustic harassment devices, vessel chase, rubber projectiles, and capture-relocation. In 2010 alone, for example, boat-based hazing crews used approximately 5000 rounds of cracker shells, 750 seal bombs, and 100 rounds of rubber buckshot in attempts to deter sea lions from the Bonneville Dam tailraces (Brown et al. 2010). While thought to be potentially effective at deterring predation by new animals arriving at the dam for the first time, they have been ineffective at deterring predation by habituated animals.

Increasing predation by California sea lions on ESA-listed salmonids and unsuccessful non-lethal deterrence efforts led the States of Washington, Oregon, and Idaho in November 2006 to apply under Section 120 of the Marine Mammal Protection Act (MMPA) for the authority to permanently remove California sea lions that were observed preying on salmonids near Bonneville Dam on the Columbia River (ESA-listed Steller sea lions are not subject to management under Section 120 of the MMPA). In March 2008, the National Marine Fisheries Service (NMFS) partially approved the States' application and issued a Letter of Authority (LOA) for the lethal removal of certain California sea lions under specific conditions (NMFS 2008). Despite intermittent suspensions due to litigation, a total of 37 qualifying California sea lions were permanently removed from the Columbia River during the first three years of

authorization (2008-2010). An additional three California sea lions died accidentally during trapping operations bringing the three-year total to 40 removals.

This report summarizes the seventh year of research on, and management of, pinnipeds at Bonneville Dam, led by the Oregon Department of Fish (ODFW) and Wildlife and Washington Department of Fish and Wildlife (WDFW), in association with the Columbia River Inter-Tribal Fish Commission (CRITFC). This work has been conducted in close coordination and cooperation with USACE and NMFS, as well as numerous other agencies.

METHODS

Boat-based deterrent activities

Boat-based hazers from CRITFC used a combination of acoustic and tactile deterrents (seal bombs, cracker shells, rubber buckshot, and vessel chase) in an attempt to deter pinnipeds from consuming threatened and endangered Columbia River salmon and steelhead (*Onchorynchus* spp.) as well as white sturgeon (*Acipenser transmontanus*). Hazers primarily patrolled the Boat Restricted Zone (BRZ) at the dam in pursuit of foraging sea lions. The following was recorded for each discrete hazing event: species and number of pinnipeds encountered; starting location, time and direction of travel of pinniped(s); type and number of deterrent devices used; and ending location, time and direction of travel of pinniped(s). Predation observations and identifying marks of pinnipeds were also noted.

For human and fish safety, boat access within the BRZ was limited to approximately 30 m from all Bonneville project structures and 50 m from main fishway entrances. No seal bombs were used within 100 m of fishways, floating orifices, the Powerhouse-2 corner collector flume or the smolt monitoring facility outfall. In addition, no seal bombs were used once salmon passage exceeded 1000 fish per day. Hazing activities were coordinated daily with the USACE Control Room and Fisheries Field Unit (FFU) personnel, as well as with USDA Wildlife Services staff, who were conducting additional sea lion hazing activities from project ground facilities. VHF-radio contact was maintained with Control Room staff while boat hazing crews were active in the BRZ.

Trapping

Sea lions were captured by ODFW and WDFW using haul-out traps placed along the Powerhouse-2 corner collector and below Powerhouse-1 near the old navigation lock. An additional sea lion trap was also operated year-round in Astoria at the East Mooring Basin. Sea lions use these traps as haulout sites, entering and exiting traps via a vertically-sliding door which was pad-locked open whenever a capture event was scheduled to be greater than 48 hours in the future. Traps were monitored daily when locked open. During active capture operations, traps were unlocked and were routinely monitored day and night to be sure the doors remained open until staff chose to close them. Trap doors were closed using a remote-controlled magnetic release mechanism. Monitoring the traps used a combination of physical visits to the trapping site, monitoring from the Washington shoreline, and by video cameras. Monitoring was

accomplished in coordination with ACOE Bonneville FFU, predation observers, USDA Wildlife Services staff, and Bonneville Project staff including park rangers, security and control room personnel. For interagency coordination, a telephone contact list was provided to all staff involved with monitoring the traps to insure a quick response by trained staff should any trap door close unexpectedly.

Once sea lions were captured they were herded into holding cages on a barge built specifically to handle and process sea lions. If an animal was an approved candidate for permanent removal it was transferred to an on-site holding facility for further evaluation. If a NMFS-approved zoo or aquarium facility was available to receive candidate sea lions for permanent holding, then captured animals would be given a health screening by field staff and veterinarians, including members of the States' Institutional Animal Care and Use Committee (IACUC). If an animal passed the health screening it would be transferred to Point Defiance Zoo and Aquarium in Tacoma, WA for temporary housing prior to shipment to a permanent holding facility. If an animal failed the health exam, or if there were no approved facilities prepared to accept an animal, then it was chemically euthanized. Euthanized animals were necropsied and tissues were collected for a variety of biological analyses.

GPS-phone telemetry

GPS-phone tags were attached to California sea lions and Steller sea lions in order to track movements and study foraging behavior around Bonneville Dam and in the lower Columbia River. Transmitters (Sea Mammal Research Institute, St. Andrews, Scotland) were approximately 10 x 7 x 4 cm and weighed 370 g. Tags included a Fastloc GPS receiver, along with wet/dry, pressure, and temperature sensors which were used to construct a continuous three-state behavioral model of time spent diving, at the surface, and hauled out. Transmitters were secured to light-weight nylon mesh netting and then glued to the sea lion's pelage mid-dorsum, or on the head or neck, using 5-minute epoxy.

Acoustic telemetry

In addition to GPS-phone tags, acoustic pingers (ultrasonic transmitters) were also attached to California sea lions and Steller sea lions in order to track movements and study foraging behavior around Bonneville Dam and in the lower Columbia River. Vemco V16-5H coded pingers (Vemco Ltd., Halifax, Nova Scotia, Canada) were used, which were 1.6-cm in diameter, 9.5-cm in length, weighed 16-g in water and operated at a frequency of 69-kHz with a power of 165 dB re 1 μPa at 1 m. Each pinger emitted a uniquely identifiable pulse train at random intervals every 30-90 s. Pingers were attached to the pelage mid-dorsum of a sea lion using 5-minute epoxy. A subset of tags contained a pressure sensor that allowed the depth of the tag to be determined each time it was detected. Sea lions were passively tracked using fixed arrays of Vemco VR2W acoustic receivers. Receivers were located from Bonneville Dam to the mouth of the river and the data they collected were regularly downloaded every 1-2 weeks. Receivers recorded a pinger’s identification number, date and time whenever a marked sea lion traveled within a receiver’s detection range.

Pinniped abundance surveys

Tandem vessel surveys of the lower Columbia River, Multnomah Channel, and the Willamette River were conducted in an attempt to document in-river distribution and to estimate river-wide pinniped abundance. Each survey consisted of two research vessels traveling approximately 15 minutes apart while three or more observers in each vessel watched for pinnipeds forward of the vessel. For each detection, the location of the vessel and approximate location of the animal were charted using a combination of GPS, GIS, and/or chart plotter. Attribute data such as weather, visibility, species, and group size were also recorded. Data were analyzed in a two-sample capture-recapture estimation framework where the animal locations constituted marks. A Huggins closed population model with time (i.e., boat) varying capture probability was fit to the data using the R package RMark (Laake 2011). Direction and speed of travel of animals were taken into account when attempting to determine whether a sighting constituted a 'capture' or 'recapture'. Vessel survey data was combined with concurrent aerial photographic counts of regional pinniped haul-outs and observer counts from Bonneville Dam and Willamette Falls to arrive at river-wide estimates of pinniped abundance. Trends in abundance and use of selected haul-outs were also monitored using automated trail cameras (typically used in sport hunting and remote wildlife photo-documentation applications).

Shore-based predation observations

Shore-based predation observations were conducted in the vicinity of the Interstate 5 Bridge between Columbia River miles 105 to 110. Observers recorded pinniped occurrence, foraging behavior, and sport fishery information for each observation period in order to assess the occurrence and magnitude of pinniped predation at a mid-river location.

Effect of removals

The number of salmonids that were not consumed (i.e., "saved") due to removal of California sea lions known to forage near Bonneville Dam from 2008-2011 was estimated using methodology described in Brown et al. (2010). The only change to the approach, besides incrementing by one year, was an update in the parameter defining the proportion of time spent in water based on new information provided by the GPS-phone tags.

RESULTS

Boat-based deterrent activities

Boat-based pinniped hazing crews from CRITFC hazed sea lions on 38 days from 2/28/2011-5/16/2011 (Table 1). Hazing resulted in a total of 173 and 359 "takes" (i.e., pinniped harassment events) of California sea lions and Steller sea lions, respectively. A total of 7839 cracker shells and 2439 seal bombs were used during deterrent activities.

Trapping

Four traps were placed below Powerhouse-2 along the Corner Collector on 1/27/11 (one trap was later moved below Powerhouse-1) but sea lions did not start hauling out on them until the last week of March. Due to a federal appeals court ruling on 11/23/2010 that revoked the States' original LOA, no lethal removal was authorized until a new LOA was issued on 05/13/2011. Use of this new LOA was voluntarily suspended shortly thereafter, however, in anticipation of further litigation; the LOA was ultimately revoked by NMFS (in concurrence with the States) on 7/27/11. During the brief period when the LOA was active, a single qualifying California sea lion was captured and euthanized on 5/18/11. Non-lethal trapping activities included the capture, marking and/or instrumentation of 13 California sea lions (Table 2) and 10 Steller sea lions (Table 3).

Telemetry

A total of seven California sea lions received telemetry devices: two received GPS phone tags and five received acoustic tags (Table 2). A total of ten Steller sea lions received telemetry devices: two received GPS phone tags only, five received acoustic tags only, and three received both GPS and acoustic tags (Table 3).

GPS-phone telemetry

GPS-phone tags transmitted data from deployment on 3/30/11 and 3/31/11, through as late as 7/27/11 (Figure 1). Tagged animals travelled from Bonneville Dam and Willamette Falls in the lower Columbia River basin, to between northern California and the Olympic Peninsula of Washington. A total of 13,762 location fixes were obtained as well as information from 163,755 dives. Average number of daily location fixes per tag (excluding first and last days of transmission) ranged from 29 to 48 (n=5 tags); minimum and maximum fixes per day per tag ranged from 0-8 and 56-87, respectively (theoretical maximum was 96 fixes per day). Tag retention ranged from 1 to 118 days (Tables 2-3).

Minimum number of round-trips between the estuary and Bonneville Dam ranged from one to four (Figures 2-4); one animal made two trips to Willamette Falls in addition to at least four trips to Bonneville Dam (Figure 3). Travel speeds did not appear to vary by sea lion species and, as expected, downriver travel speeds were greater than upriver speeds (Figure 5). Median downriver and upriver speeds were 1.86 m s^{-1} (4.17 mph) and 1.02 m s^{-1} (2.28 mph), respectively.

GPS data from the Bonneville tailraces revealed distinctive foraging behaviors of specific individual sea lions (Figure 6). For example, C287 foraged almost exclusively in the Powerhouse-1 tailrace whereas O12 foraged almost exclusively in the spillway. With some exceptions, GPS data showed that animals generally traveled directly between haul outs near the mouth of the Columbia River (South Jetty, East Mooring Basin (EMB)) and upriver foraging areas (Bonneville Dam, Willamette Falls). GPS-tagged Steller sea lions hauled out exclusively at the South Jetty haul-out whereas California sea lions hauled out exclusively at the EMB (Figure 7). C930 was the only animal that appeared to make dedicated foraging trips within the estuary itself, rather than simply transiting through it. Steller sea lions commonly foraged in the

river between Phoca Rock (and sometimes below it) and Bonneville Dam (e.g., see O11 in Figure 2).

The behavioral budget of sea lions was quantified by a three-state model of time spent diving, at the surface, and hauled-out. While roughly a third of each day was spent in each activity, there was much individual, daily, and site-specific variation in the observed ratios of these behaviors (Figure 8). For example, sea lions often hauled out continuously for one or more days while in the estuary, and did not haul out at all while transiting between the estuary and upriver foraging areas. Examples of more detailed daily behavioral profiles, and associated dive depth and location information, are depicted in Figures 9-14. At this level of resolution, it can be seen that sea lions often (though not always) followed a diurnal behavior pattern, with daylight hours predominantly spent diving and nighttime hours spent hauled out or rafting. Dive data are further summarized in Figures 15 and 16, the former for all dives occurring within the BRZ (approximately above Tanner Creek) and the latter for all dives occurring in transit between foraging areas (Bonneville Dam, Willamette Falls) and estuary haul-outs (EMB, South Jetty).

Acoustic telemetry

Acoustic tags were detected approximately 44,473 times, from 4/5/11 to 6/3/11. Tagged animals were detected throughout the Columbia River, including one animal (C930) at Willamette Falls. Tag retention and/or time within range of receivers ranged from 1 to 46 days (Tables 2-3). Movement profiles based on acoustic telemetry was similar to those based on GPS data (Figures 2-4), though one animal (C012) exhibited a less common pattern of making upriver foraging trips that did not reach terminal foraging areas.

Pinniped surveys

Tandem boat surveys were attempted on three occasions in 2011. The first survey was a pilot test of the methodology and occurred on 3/8/2011, running from Bonneville Dam (below the BRZ) to the confluence of the Columbia and Willamette Rivers. The second survey was scheduled for 3/22-3/23/2011, running from Bonneville Dam to the mouth of the river on the first day, and then Multnomah Channel and the Willamette River on the second. However, the first leg of the survey only covered as far as Jim Crow Point when engine trouble in one of the vessels ended the survey prematurely. This forced a cancellation of the tandem survey on the second day, though a single vessel surveyed the Multnomah Channel on the return trip. The third and final survey was scheduled for 4/27-4/28/2011, again travelling from Bonneville Dam to the mouth of the river on the first day, and then Multnomah Channel and the Willamette River on the second. The downriver leg of the survey was again cut short, this time near Puget Island due to inclement weather and hazardous boating conditions. The second leg of the survey occurred as scheduled from the confluence of the Multnomah Channel and Columbia River, up to Willamette Falls.

Pinniped detections are depicted in Figure 17. Sighting distances from boat to pinniped(s) ranged from an estimated 63 m to 1099 m, with an average of 413 m (possibly indicating that animals were less likely to surface near vessels or moved away from vessels prior to surfacing). The estimated probability of a single vessel detecting a pinniped on a given survey ranged from

0.20 to 0.75 (Table 4). The probability of at least one vessel on a given survey detecting a pinniped ranged from 0.42 to 0.87. Complete, river-wide estimates of pinniped abundance were generally not possible due to logistical issues. Table 5, however, summarizes the various counts that were obtained and provides minimum estimates of pinniped abundance for the dates and locations covered. For example, on 3/22/2011, there were at least approximately 150 sea lions river-wide and close to 1000 harbor seals in the estuary.

Shore-based predation observations

Shore-based predation observations totaled 217.5 hours over 34 days from 3/7/11 to 5/17/11. Six predation events were observed, one of which involved a fish being taken off a line in the sport fishery. Five of the predation events involved Steller sea lions. Additionally, two Steller sea lions and one California sea lion were observed transiting upriver through the observation area.

Effect of removals

The median estimated daily individual salmonid biomass requirement based on a bioenergetics model was 14.2 kg (95% confidence interval was 7.8 to 27.1 kg/day), which translated into a median of 3 Chinook/day (95% confidence interval was 2 to 6 Chinook/day). The median estimated seasonal salmonid requirement for each sea lion was 57 salmonids (95% confidence interval was 6 to 216 salmonids/season). The predicted number of salmonids that would have been required from 2008 to 2011 by the 39 eligible California sea lions that were removed from the Columbia River was between 2283 and 8738 fish (Table 6).

DISCUSSION

Overall, the 2011 field season was successful from a research standpoint but unsuccessful from a management standpoint. New research efforts in 2011 (e.g., GPS-phone tags, river-wide pinniped surveys) provided an unprecedented level of information on pinniped abundance, distribution, and foraging behavior in the Columbia River. Management, however, was hampered by continued litigation and a lack of removal authority for the majority of the season, and a continued lack of effective non-lethal deterrent methods.

Boat-based deterrent activities

As in previous years, the purpose of non-lethal, boat-based deterrent activities was two-fold. First, it attempts to disrupt sea lion foraging behavior and reduce sea lion abundance immediately below Bonneville Dam, thereby increasing salmonid survival. Second, it fulfills the LOA requirement that predatory California sea lions be exposed to hazing prior to subjecting them to permanent removal efforts. Observations and GPS tag data suggest that these activities only cause a short-term disruption in foraging behavior and fail to deter the majority of sea lions from the dam. The continued lack of effective non-lethal deterrents that can be used in this situation without having potentially negative impacts on fish passage remains a problem.

Trapping

Haul-out traps were used repeatedly and safely to mark and tag sea lions, but lack of removal authority for most of the season required the release of numerous (10-15) California sea lions eligible for removal. Following the important progress made during 2008-2010, the lack of removal authority for most of 2011 represented a major setback to the states' effort at managing the impact of California sea lion predation on threatened and endangered salmonids at Bonneville Dam by not being able to continue efforts to remove the core population of repeat offenders.

Telemetry

Continued instrumentation of sea lions with telemetry instruments allowed us to increase and refine our understanding of sea lion foraging behavior in the Columbia River. The use of GPS tags in particular provided us with nearly continuous, high-quality location, dive, and haul-out data. It, along with the tandem boat survey data, suggests that sea lions generally travel directly between haul-outs in the estuary (South Jetty, EMB) and upriver foraging locations (Bonneville Dam, Willamette Falls, mouths of tributary rivers), without making prolonged stops to forage or haul-out mid-river (Figures 2-4). One exception to this general picture may be when an individual sea lion encounters an area where sport fishing effort is concentrated and attempts to take hooked fish from anglers. While this is known to occur, the telemetry data suggest that most sea lions may focus on quickly transiting the river rather than spending time foraging between lower river haul-outs and upriver foraging areas.

The GPS data showed a close correspondence between what the USACE recorded and where the animal spent most of its time. For example, based on the GPS data (Figure 6), C287 appeared to forage almost exclusively in Powerhouse-1. An examination of USACE observations showed that 98% of the salmonid kills attributed to C287 indeed occurred at Powerhouse-1. Though probably not an issue with C287, USACE observations do not account for nocturnal predation which may be common for at least some sea lions and/or days (e.g., C930 in Figure 10, O11 in Figure 15).

While observed predation and GPS locations corresponded well, attempts at detecting a "predation signature" in the dive data associated with observed predation events were generally unsuccessful. That is, when examining a dive profile that contained the time of an observed predation event, there generally was not an obvious dive pattern suggesting predation had occurred, compared to dive patterns before or after the event. This may partially be explained by a mismatch in the timestamp recorded by the GPS tag and the time recorded by observers, though this would be expected to be no more than a couple of minutes in either direction. Similarly, it may be that some of the predation signature is revealed in location in addition to depth. That is, after a fish is caught, sea lions will often float downriver while consuming it. This relatively short-duration, post-predation movement downriver probably would not be captured by the GPS tags which only attempt to determine location every 15 minutes.

Pinniped surveys

To the best of our knowledge, our use of tandem boat surveys to estimate sea lion detectability and abundance is the first such use of this method for pinnipeds (similar tandem surveys have been used for bald eagles, bottlenose dolphins, and riverine birds). While weather and other factors imposed logistical difficulties, our attempts established that such surveys were both feasible and informative. The probability of detecting sea lions, which is a function of both availability and perception, ranged from 0.2 to 0.75 for individual vessels. Under similar survey conditions and times of the year, these single-vessel detectability estimates could be used as correction factors for future single-vessel surveys. Besides highlighting the need to account for imperfect detectability of sea lions, the surveys showed that sea lions were not uniformly distributed throughout the river (Figure 17), nor did they occur in great abundance (Table 4). These latter findings were also supported by shore-based behavior observations which only resulted in one predation observation per 36.25 hours of effort.

Effect of removals

The estimated benefit in 2011 from removing California sea lions was due largely to previous removals since only a single animal was removed this year. It is estimated that approximately 1000-3000 additional salmonids would have been consumed in 2011 had these animals not been removed.

In an attempt to see how well model predictions compared to observed predation rates at the dam we used GPS data to check for days in which an animal foraged exclusively within tailrace observation areas during weekday daylight hours. All predation under these circumstances would theoretically be documented by USACE observers and therefore represent an accurate tally of the number of fish eaten by that animal on that entire day. A check of C287's movements showed that it appeared to forage exclusively in Powerhouse-1 during daylight on 15 days from 4/18/11 to 5/6/11. After subtracting fish stolen from fish caught, the average observed number of salmonids consumed was 4.7 per day. This was higher than a model-predicted estimate of 3 Chinook per day for a 750 lb. sea lion (which was C287 weighed) but within the 95% confidence interval of 2-5 Chinook per day. The observed minimum and maximum number of salmonids consumed per day for C287 was 1 to 10; the minimum and maximum numbers over 1000 runs of the bioenergetics model for C287 was 1 to 7. This comparison suggests that the model may be biased low (i.e., predicts fewer fish consumed than it should).

Recommendations for 2012

- Increase removal efforts to regain lost ground from the 2011 season (if granted new LOA). Tangible gains made in 2008-2010 were potentially reversed by allowing the pool of experienced, predatory sea lions to increase unchecked in 2011.

- Decrease boat-based hazing staff time in favor of additional predation observation effort. Given the relative ineffectiveness of hazing to deter pinnipeds, and the overlap in coverage between boat-based hazing and dam-based USDA hazing, a better use of limited staff time

would be to quantify predation immediately below the tailrace observation areas. Many predation events are known to occur in this area that cannot be seen by the USACE dam-based observers.

- Continue river-wide surveys to estimate pinniped abundance. Initiation of novel river wide survey methods in 2011 provided new insight into sea lion distribution and abundance throughout the Columbia River below Bonneville Dam, Multnomah Channel, and Willamette River.

- Discontinue use of acoustic telemetry in favor of GPS-phone telemetry. GPS-phone tags are a major advance in pinniped tracking technology and currently provide the most detailed information possible on sea lion foraging behavior within the Columbia River.

ACKNOWLEDGEMENTS

We wish to acknowledge and thank all those who cooperated in the conduct of this work:

- CRITFC: John Whiteaker, Bobby Begay, Michael McConville, and Laurinda Hill
- NMFS: Robert DeLong, Pat Gearin, Garth Griffin, Brent Norberg, Tom Gelatt, and Brian Fadley.
- ODFW: Charlie Corrarino, Colin Gillin, Rick Hargrave, John North, Susan Riemer, Jessica Sall, Steve Williams, Julia Burco, Tom Murtagh, and Bonneville Hatchery staff.
- PSMFC: Dave Colpo, Dan Heiner, and Matt Tennis.
- USACE: Tony Kirk and the Bonneville Rigging Crew, Ben Haussmann, Andrew Taylor, Glen Smith, Robert Stansell, Karrie Gibbons, and Bjorn van der Leeuw.
- USDA Wildlife Services staff.
- WDFW: Josh Oliver, Mike Brown, Brad Cady, Dean Pyzik, Dyanna Lambourn, and Guy Norman.
- PSU: Mandy Cook, Debbie Duffield, and their students.
- Safety and Security: Jeff Samuels, Oregon State Police; Murray Schlenker, Washington Department of Fish and Wildlife; and Ronald McDonald and Greg Webb, USACE.

Funding was provided by ODFW, WDFW, NOAA-Fisheries, and BPA. Law enforcement support was provided by WDFW Enforcement and Oregon State Police. Research and management activities by Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife at Bonneville Dam were authorized under the ESA, MMPA Sections 109h and 120, and MMPA research permit 14326. This report is intended to fulfill regulatory and contractual reporting requirements; it is not intended to be a comprehensive report on all pinniped-related activities at Bonneville Dam during 2011.

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Table 1. Boat-based hazing activities at Bonneville Dam, 2011. (All boat-based hazing in 2011 were conducted by CRITFC.)

				Take*		Munitions used	
Wk #	Week of	Days	Events	CSL	SSL	Cracker shells	Seal bombs
9	2/27/2011	5	23	7	36	625	213
10	3/6/2011	2	9	0	28	400	163
11	3/13/2011	4	24	9	44	976	377
12	3/20/2011	4	43	27	61	1705	433
13	3/27/2011	5	41	31	45	1097	346
14	4/3/2011	1	3	2	5	140	44
15	4/10/2011	4	22	11	35	1324	382
16	4/17/2011	4	30	27	29	529	240
17	4/24/2011	4	20	23	38	308	83
18	5/1/2011	2	24	17	35	376	76
19	5/8/2011	2	17	18	3	355	82
20	5/15/2011	1	1	1	0	4	0
		38	257	173	359	7839	2439

* Take refers to numbers of animal-harassment events (one animal may be harassed multiple times); CSL=California sea lion, SSL=Steller sea lion.

Table 2. California sea lion marking, instrumentation, and removal activities in the lower Columbia River, 2011.

Date	Location	ID	GPS tag (tag duration, days)	Acoustic tag (tag duration, days)	Weight (lb.)
3/30/2011	Bonneville	C 930	11602-01R (61)		600
3/30/2011	Bonneville	C 287	11888-02R (48)		750
3/31/2011	Bonneville	C 010/B355			300
4/14/2011	Bonneville	C 011		1106252-41756 / 156P (15)	
4/19/2011	Bonneville	C 006		1106254-41758 / 158P (1)	
4/19/2011	Bonneville	C 012		1106253-41757 / 157P (46)	
4/19/2011	Bonneville	C 013		1106256-41760 / 159P (2)	
4/20/2011	Bonneville	C 014			
4/20/2011	Bonneville	C 971		1106255-41759 / 160P (24)	
4/21/2011	Bonneville	C 015			
4/21/2011	Bonneville	C 016			
5/16/2011	Bonneville	C 017			
5/16/2011	Bonneville	C 018 [a]			
5/18/2011	Astoria	B22/B205 [b]			
Total		14	2	5	

[a] Forebay capture.
[b] Euthanized.

Table 3. Steller sea lion marking and instrumentation activities in the lower Columbia River, 2011.

Date	Location	ID	GPS tag (tag duration, days)	Acoustic tag (tag duration, days)	Weight (lb.)
3/30/2011	Bonneville	0 009	11889-03H (62)	1066743-55968 (12)	1100
3/30/2011	Bonneville	0 10	11890-04N (1)	1066745-55970 (21)	800
3/30/2011	Bonneville	0 11	11885-05H (84)	1066744-55969 (1)	750
3/31/2011	Bonneville	0 12	11886-06N (118)		1100
3/31/2011	Bonneville	0 13	11887-07N (83)		1100
4/6/2011	Bonneville			1106265-41796 (8)	1000
4/7/2011	Bonneville	0 14		1106264-41795 (26)	1300
4/7/2011	Bonneville	0 15		1106268-41799 (27)	1700
4/7/2011	Bonneville	0 16		1106267-41798 (30)	1000
4/7/2011	Bonneville	0 17		1106266-41797 (39)	1300
Total		10	5	8	

Table 4. Tandem boat surveys in the lower Columbia River Basin, 2011.

Date	Begin	End	Miles	Hours	Sea lions	Probability *p* of detecting sea lion (95% CI)			*N* (95% CI)
						Boat A	Boat B	≥ 1 boat	
3/8/11[a]	Hamilton Island	Willamette River	42	3	22	0.47 (0.27-0.69)	0.75 (0.45-0.92)	0.87	25.3 (22.7-37.4)
3/22/11[b]	Hamilton Island	Miller Sands	124	9.5	18	0.50 (0.26-0.74)	0.64 (0.34-0.86)	0.82	22.0 (18.9-35.8)
3/23/11[c]	Multnomah C. (bottom)	Multnomah C. (top)	22	1.8	0	-	-	-	-
4/27/11[d]	Hamilton Island	Puget Island	109	8	23	0.27 (0.09-0.59)	0.20 (0.07-0.47)	0.42	55.0 (31.6-142.7)
4/28/11	Multnomah C. (bottom)	Clackamas River	45	3	1	-	-	-	-

[a] Pilot survey to test methodology.
[b] Engine trouble in one vessel ended survey prematurely and prevented tandem survey on 3/23/11.
[c] Single vessel survey prevented use of capture-recapture methodology.
[d] Poor survey conditions in the upper estuary ended survey prematurely.

Table 5. Pinniped abundance estimates in the lower Columbia River Basin, 2011. Location codes: EMB=East Mooring Basin; CR=Columbia River; MC=Multnomah Channel; WR=Willamette River; WF=Willamette Falls. Species codes: HS=harbor seal, SSL=Steller sea lion, CSL=California sea lion; SL=sea lion.

	Estuary[a]	South Jetty[a]		EMB[ab]	CR[c]	Phoca Rk[ac]	Bonneville Dam[d]		MC[c]	WR[c]	WF[e]
Date	HS	SSL	CSL	CSL	SL	SSL	SSL	CSL	SL	SL	CSL
3/8/11					25	1	15	1			3
3/22/11	988	15	3	55	22	31	16	3			
3/23/11							10	3	0		6
4/12/11	2369	231	2	126		4	14	10			5
4/27/11	NA	140	34	109	55	14	18	8			7
4/28/11							27	17	1	0	6

[a] Source: aerial survey, WDFW
[b] Source: ODFW
[c] Source: tandem boat survey, ODFW/WDFW
[d] Source: USACE
[e] Source: Portland State University

Table 6. Predicted numbers of salmonids saved at Bonneville Dam due to California sea lion removals in the lower Columbia River, 2008-2011.

		Predicted number of salmonids saved at Bonneville Dam				
Removal year	Number of eligible animals removed	2008	2009	2010	2011	Total
2008	9 [a]	137-599	188-858	182-901	177-850	684-3208
2009	15		253-814 [b]	386-1297	406-1284	1045-3395
2010	14			215-742 [c]	338-1242	553-1984
2011	1				1-151	1-151
	39	137-599	441-1672	783-2940	922-3257	2283-8738

[a] Includes one animal that died accidentally that was not on the list for removal but had qualified.
[b] Excludes one animal that was removed during fall 2009.
[c] Excludes two animals that were removed during fall 2010.

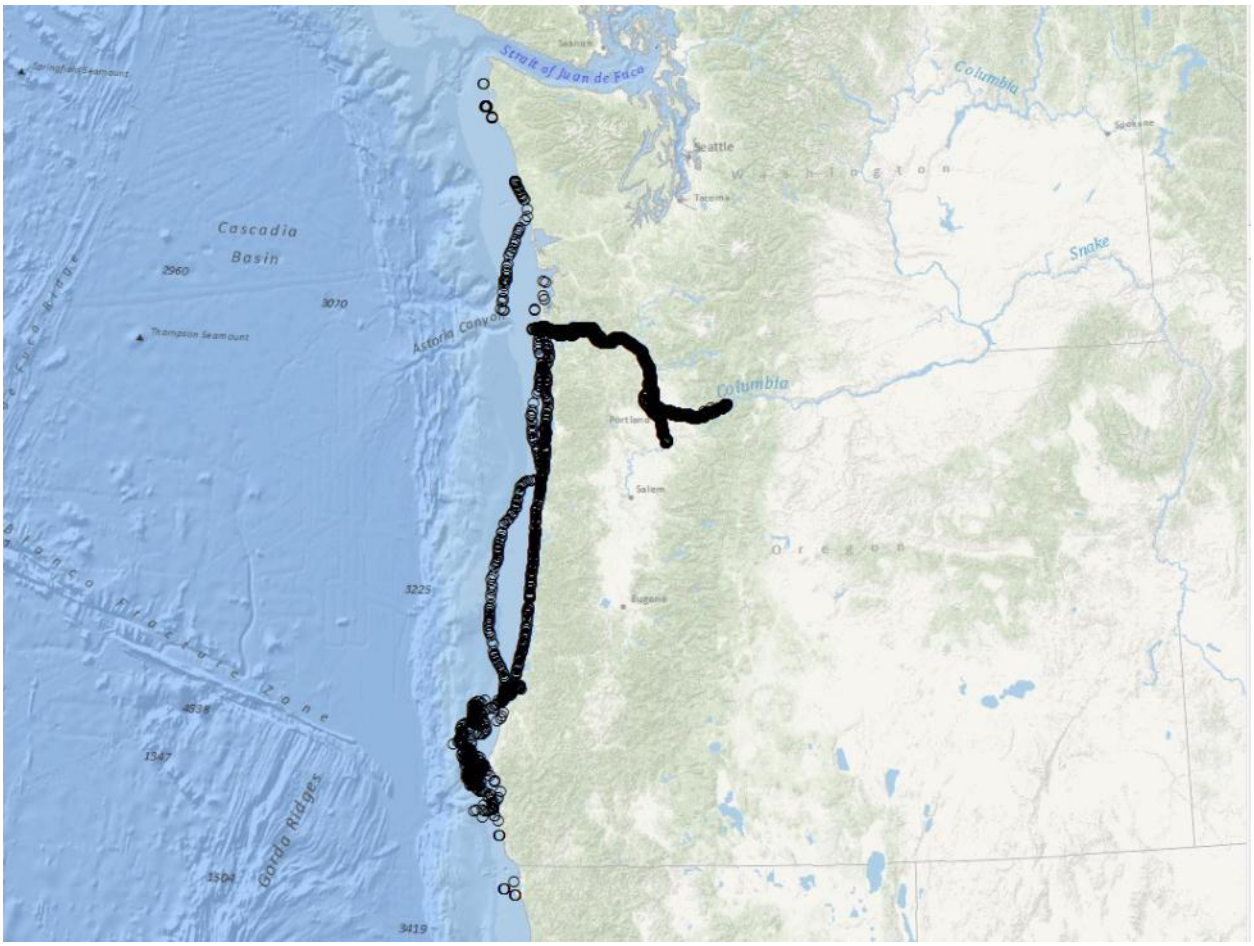

Figure 1. GPS-phone tag locations of California sea lions and Steller sea lions tagged at Bonneville Dam, 2011.

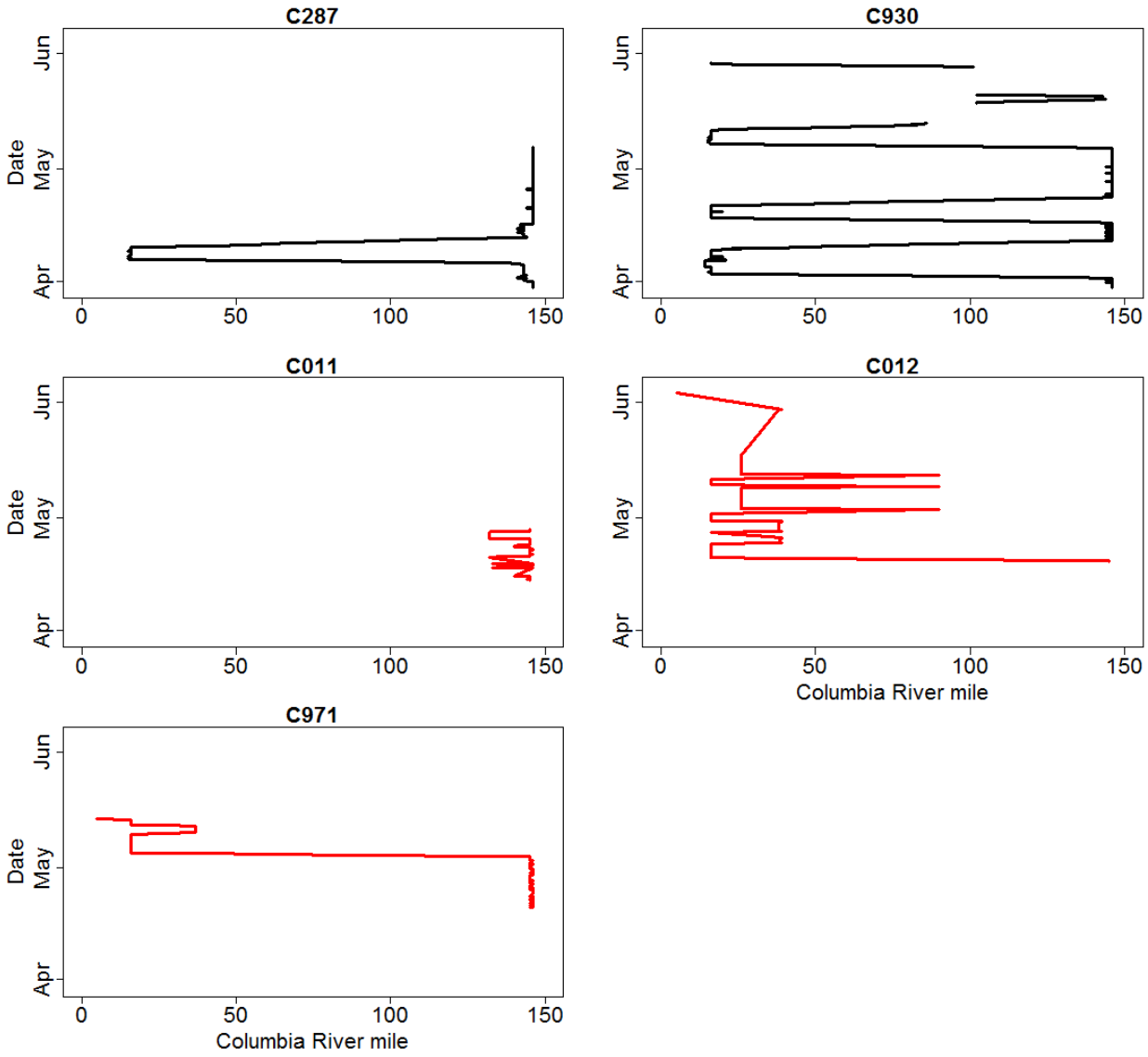

Figure 2. California sea lion locations by date and river mile (1=mouth of Columbia River, 146=Bonneville Dam). Black and red lines indicate GPS and acoustic tag locations, respectively. Breaks in CSL 930 track indicate movements in the Multnomah Channel and Willamette River (see Figure 3).

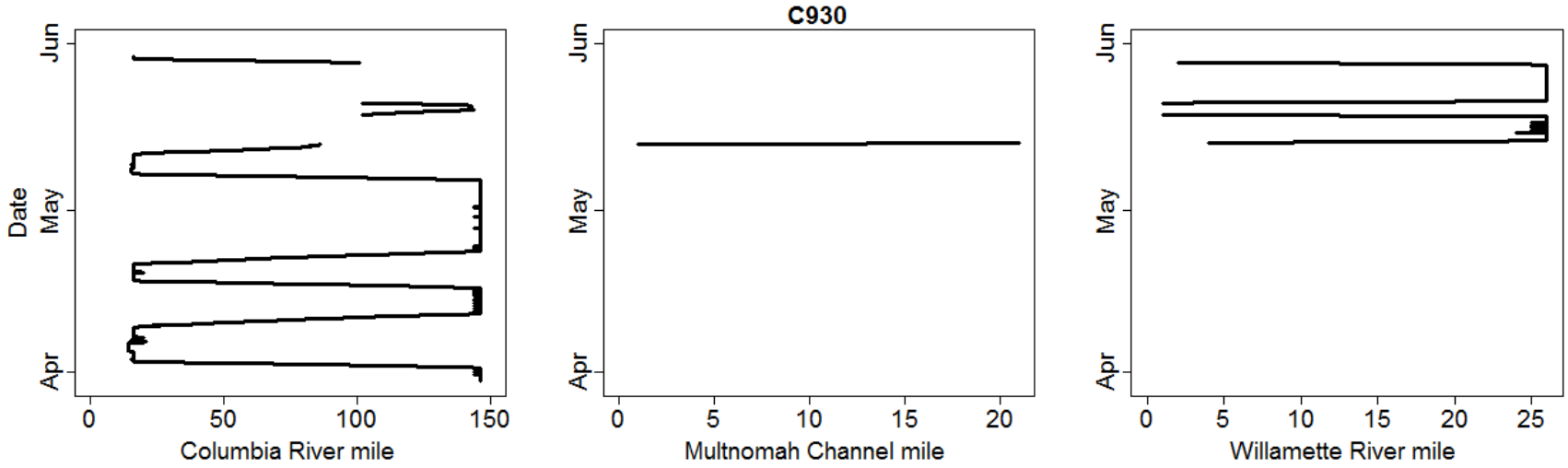

Figure 3. California sea lion C930 locations by date and river mile for the lower Columbia River, Multnomah Channel, and Willamette River.

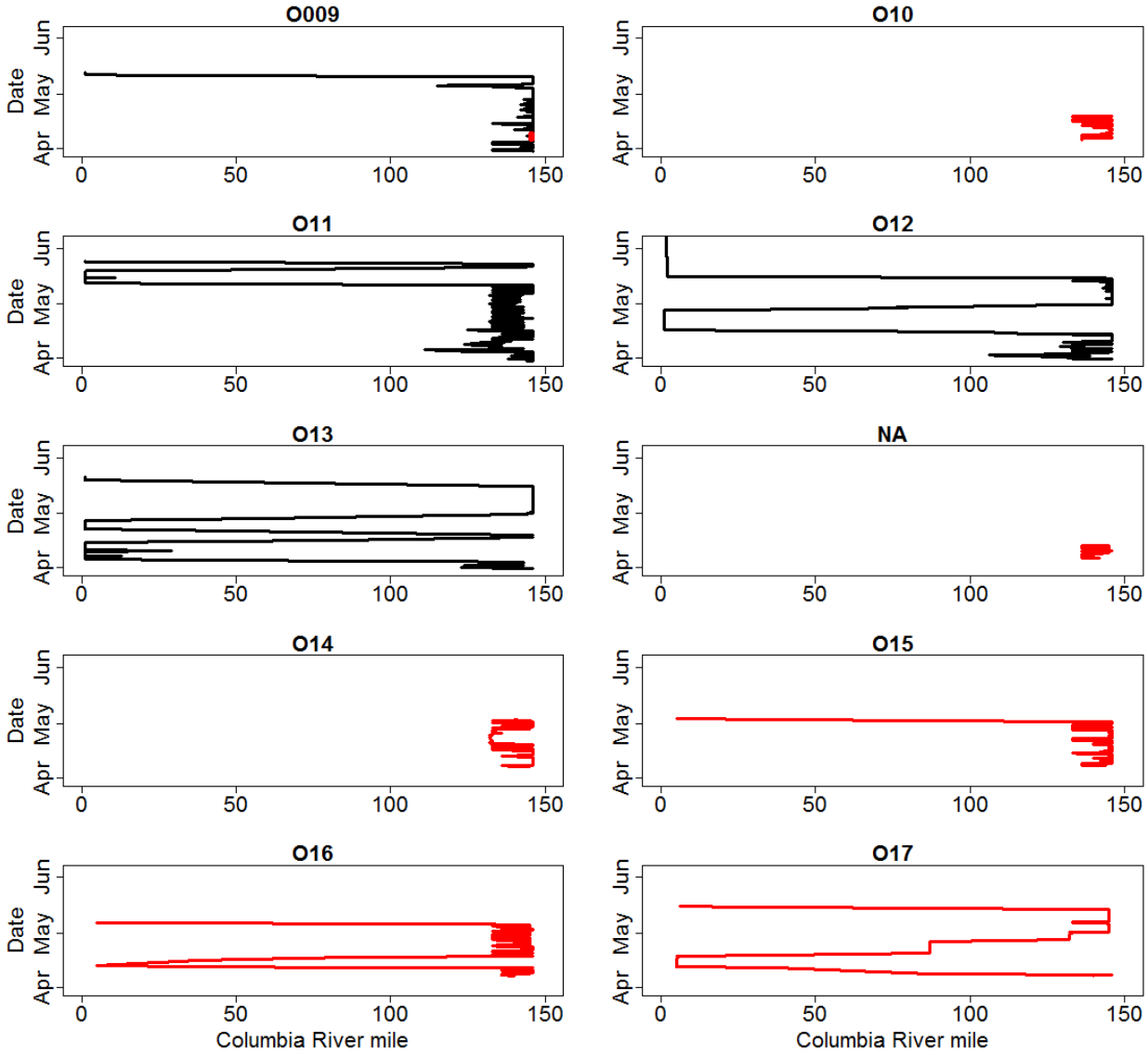

Figure 4. Steller sea lion locations by date and river mile (1=mouth of Columbia River, 146=Bonneville Dam). Black and red lines indicate GPS and acoustic tag locations, respectively.

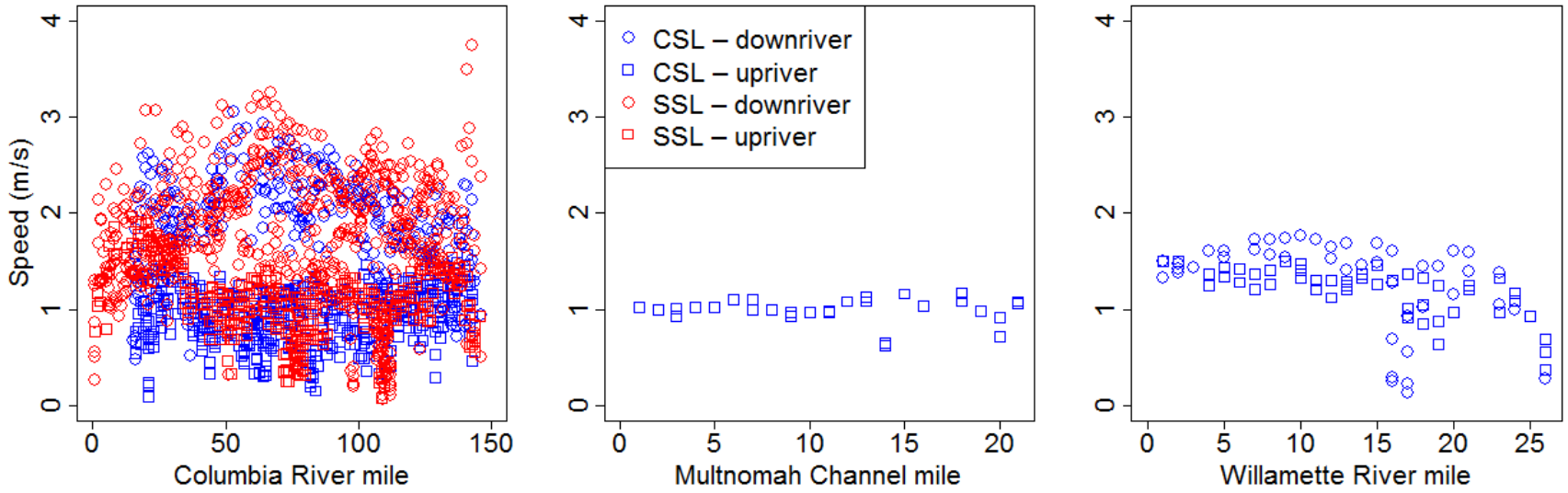

Figure 5. Speed of GPS-tagged California sea lions and Steller sea lions while in transit between upriver foraging areas (Bonneville Dam, Willamette Falls) and estuary haul-out sites (EMB, South Jetty). One meter/second = 2.24 miles/hour.

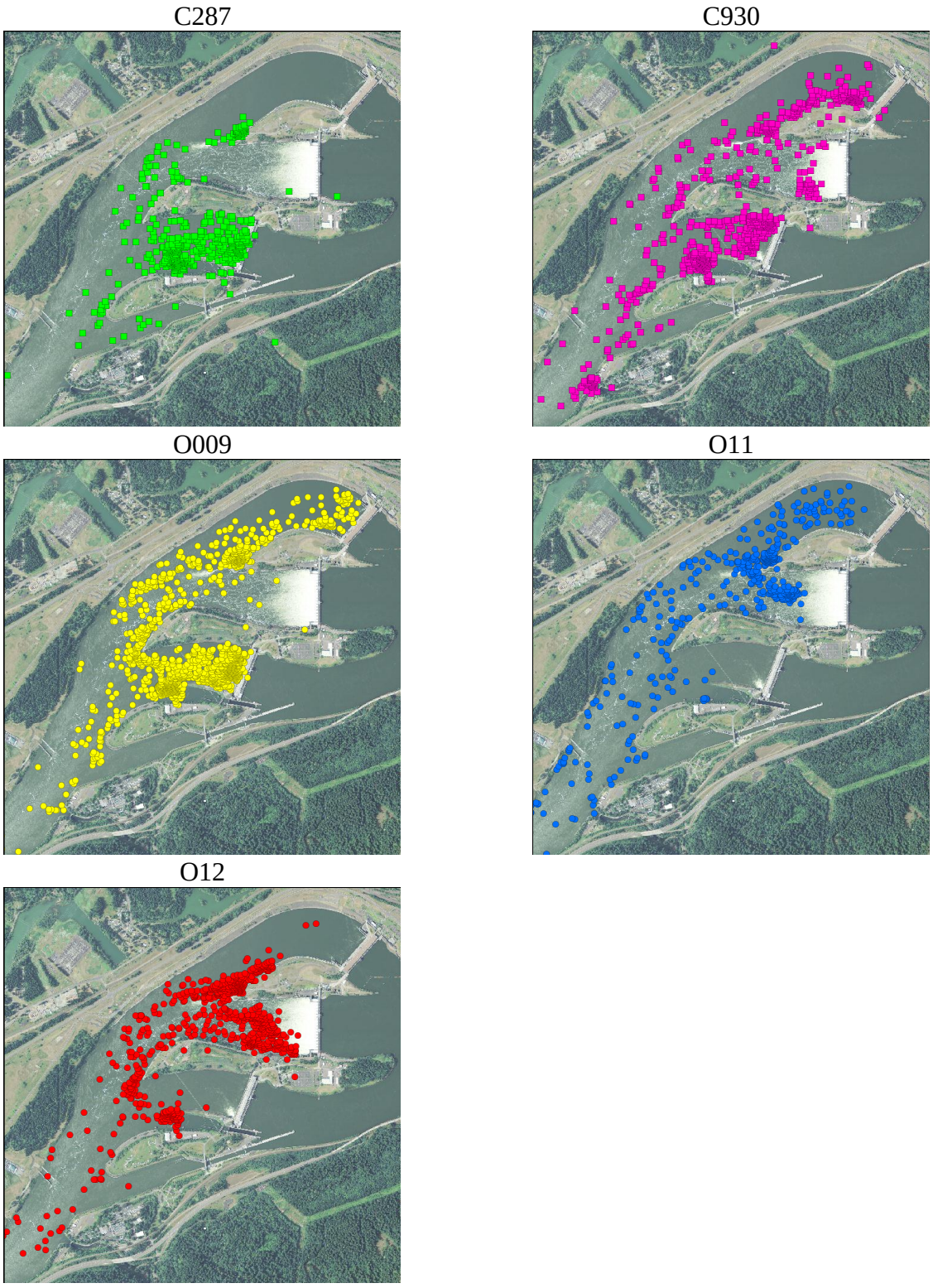

Figure 6. GPS-tag locations for California sea lions (C287, C930) and Steller sea lions (O009, O11, O12) at Bonneville Dam, 2011.

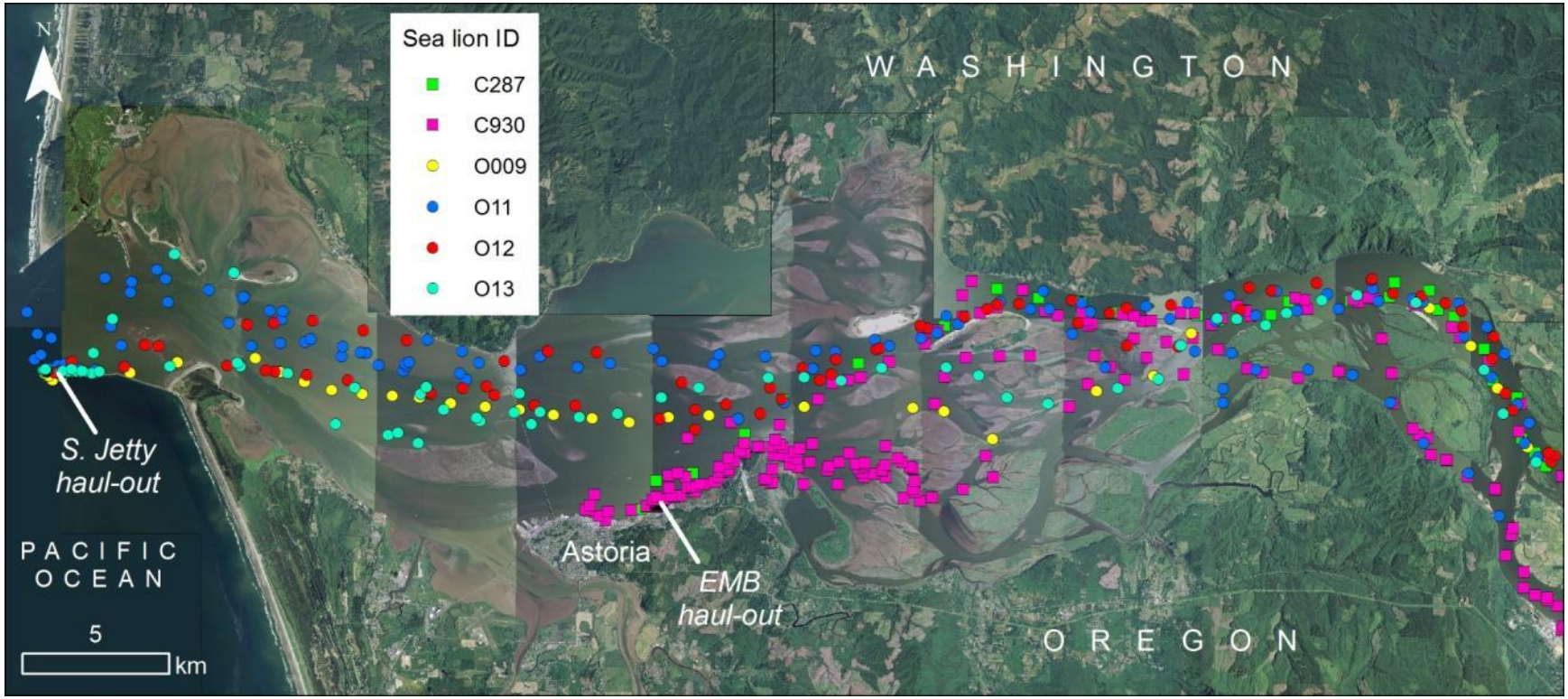

Figure 7. GPS-tag locations for California sea lions (C287, C930) and Steller sea lions (O009, O11, O12) in the Columbia River estuary, 2011. California sea lions hauled out at the East Mooring Basin (EMB) and Steller sea lions hauled out at the South Jetty.

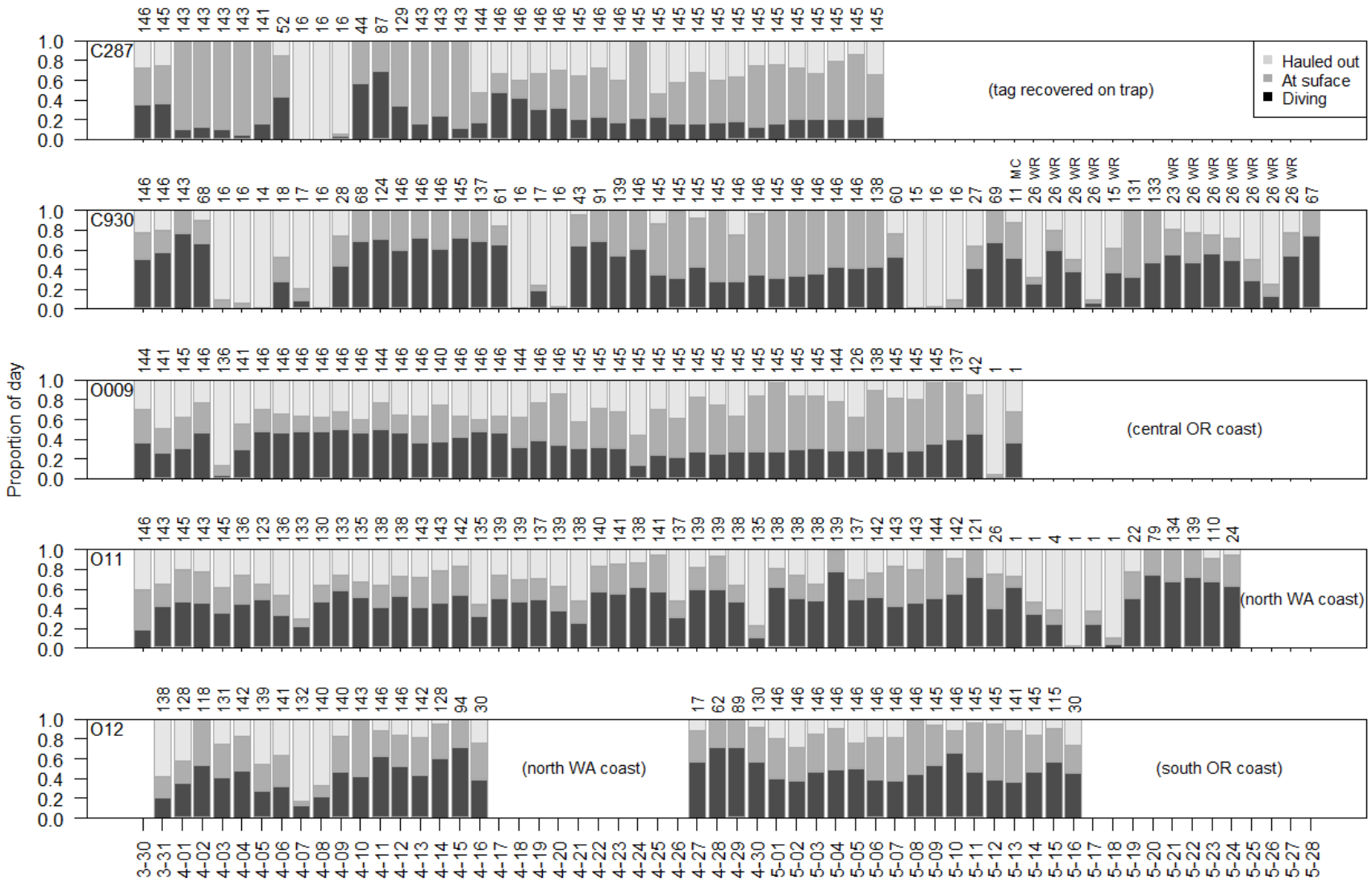

Figure 8. Daily activity budgets for California sea lions (C287, C930) and Steller sea lions (O009, O11, O12) in the lower Columbia River, 2011. Average river mile location per day is denoted atop bar graphs.

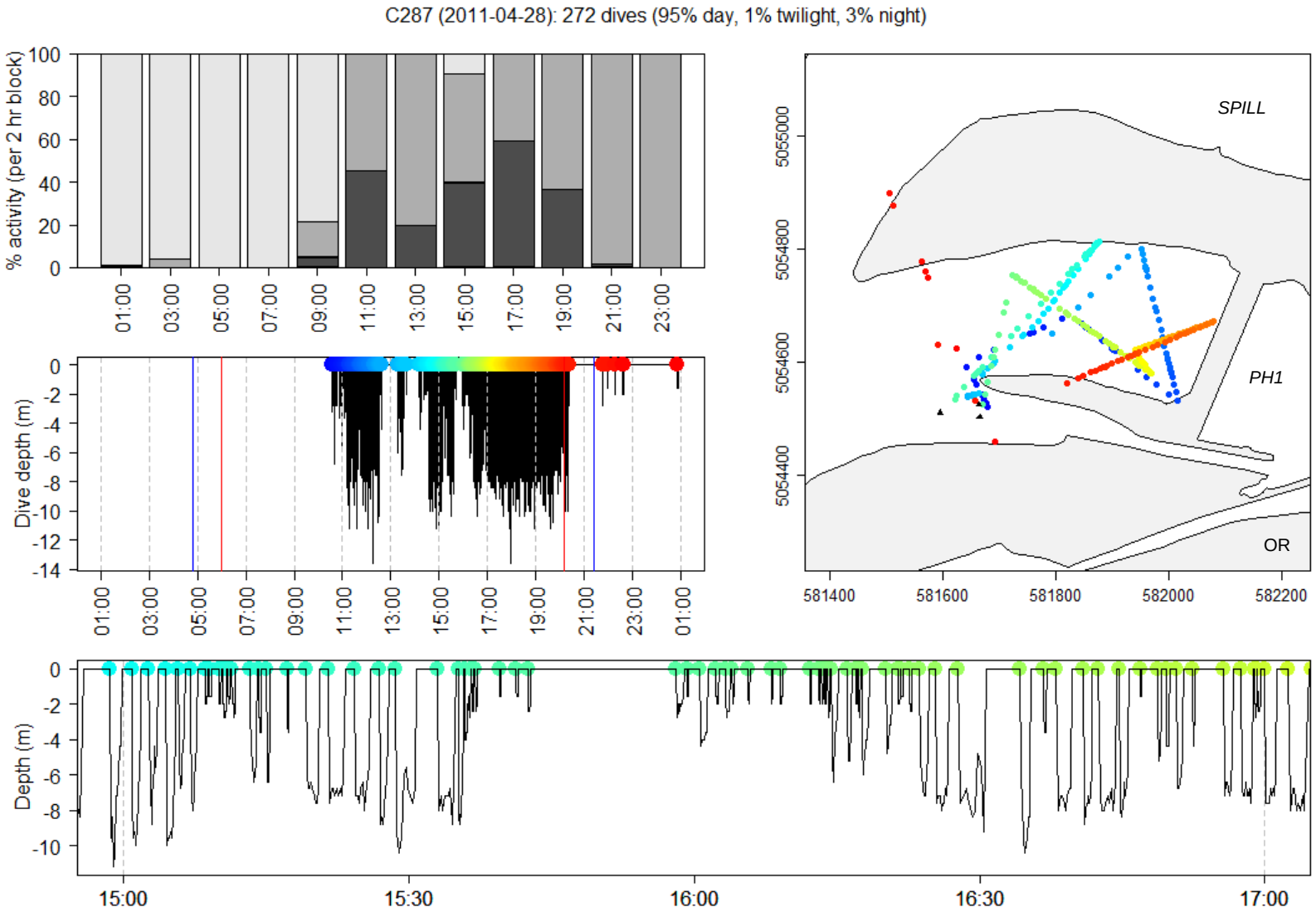

Figure 9. Example daily activity budget and associated dive and movement profile for California sea lion C287. Color ramp in dive profiles corresponds to location in map. Blue and red vertical lines in dive profile indicate start/end of civil twilight and sunrise/sunset, respectively. See Figure 8 for activity budget legend.

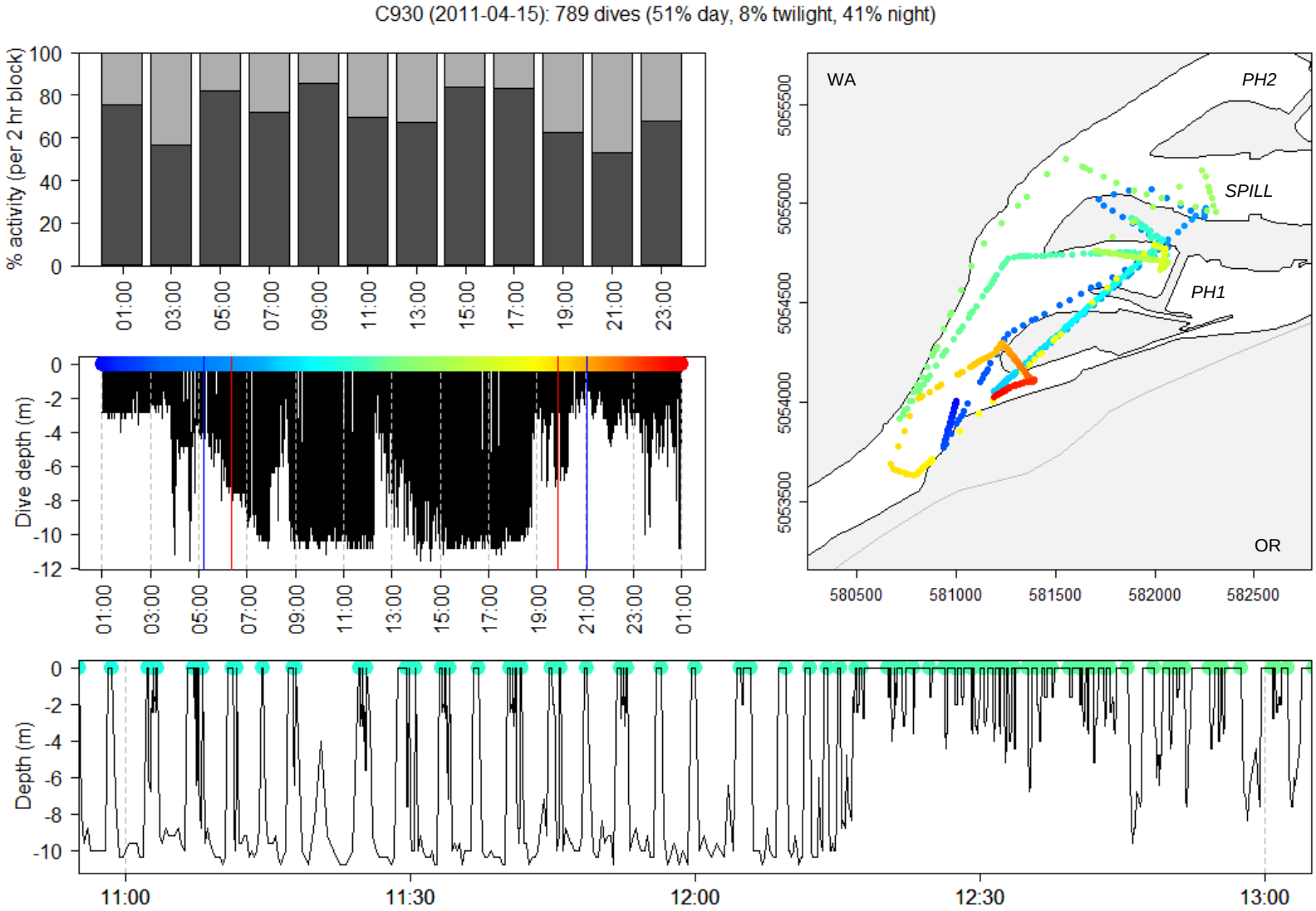

Figure 10. Example daily activity budget and associated dive and movement profile for California sea lion C930. Color ramp in dive profiles corresponds to location in map. Blue and red vertical lines in dive profile indicate start/end of civil twilight and sunrise/sunset, respectively. See Figure 8 for activity budget legend.

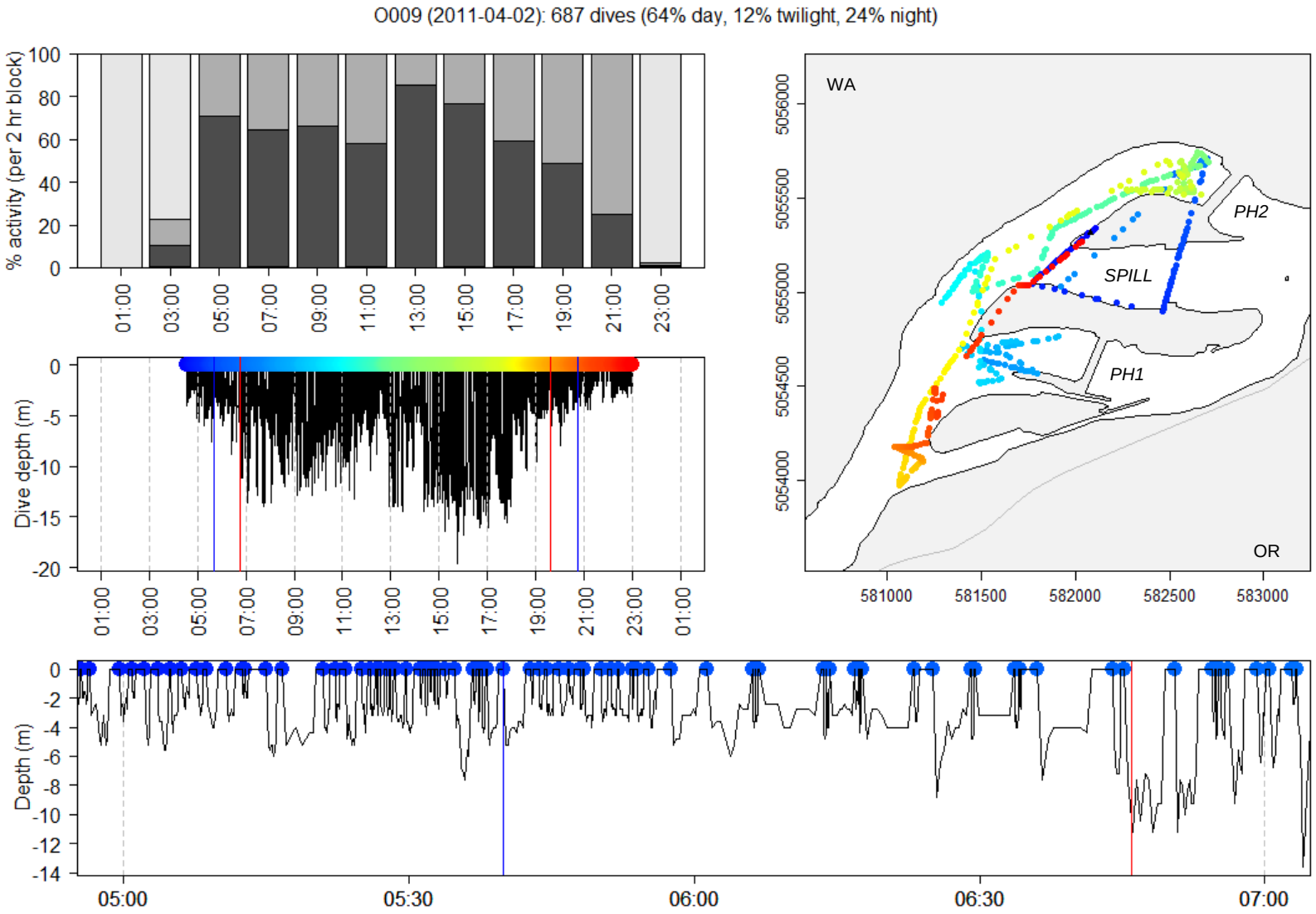

Figure 11. Example daily activity budget and associated dive and movement profile for Steller sea lion O009. Color ramp in dive profiles corresponds to location in map. Blue and red vertical lines in dive profile indicate start/end of civil twilight and sunrise/sunset, respectively. See Figure 8 for activity budget legend.

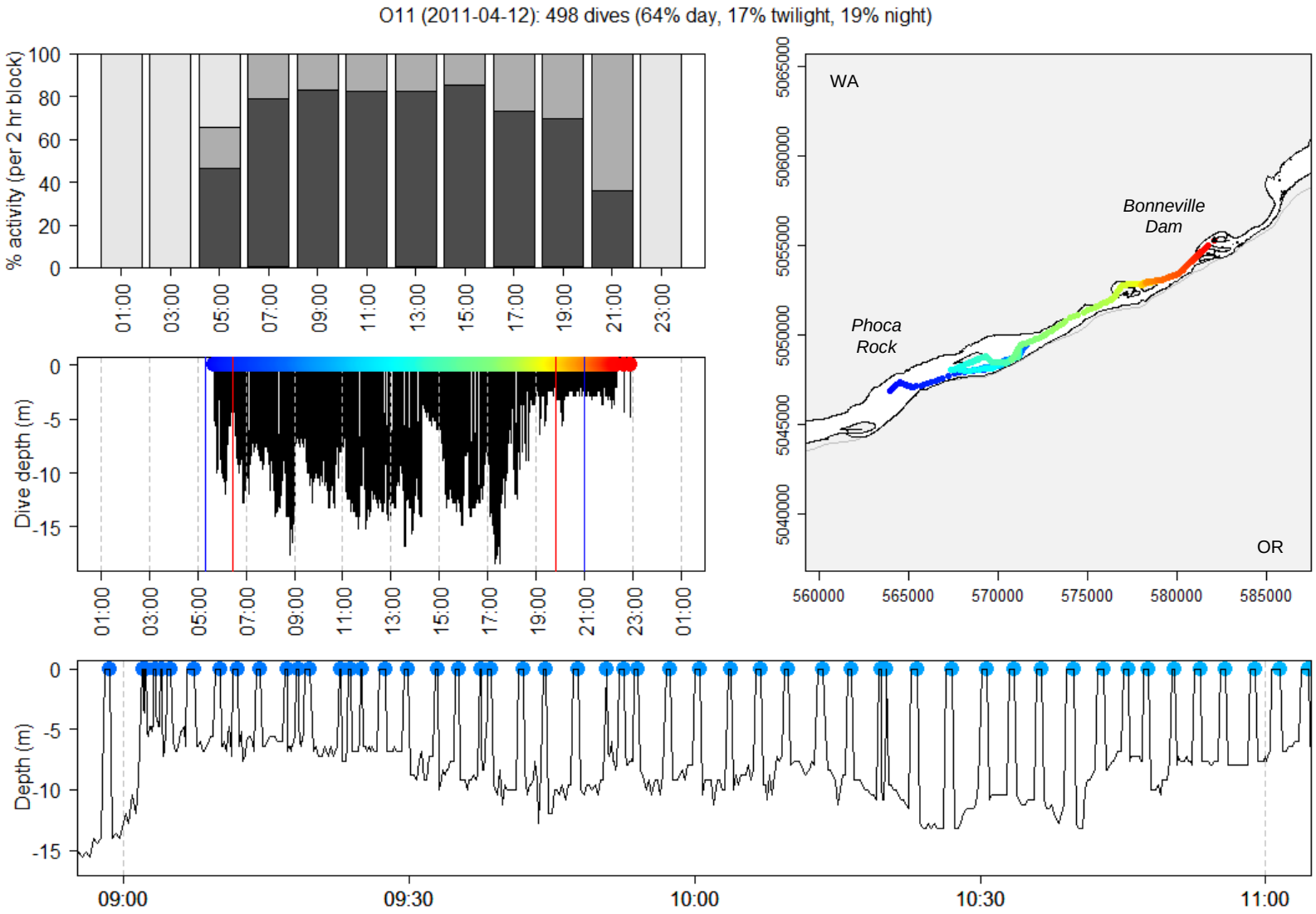

Figure 12. Example daily activity budget and associated dive and movement profile for Steller sea lion O11. Color ramp in dive profiles corresponds to location in map. Blue and red vertical lines in dive profile indicate start/end of civil twilight and sunrise/sunset, respectively. See Figure 8 for activity budget legend.

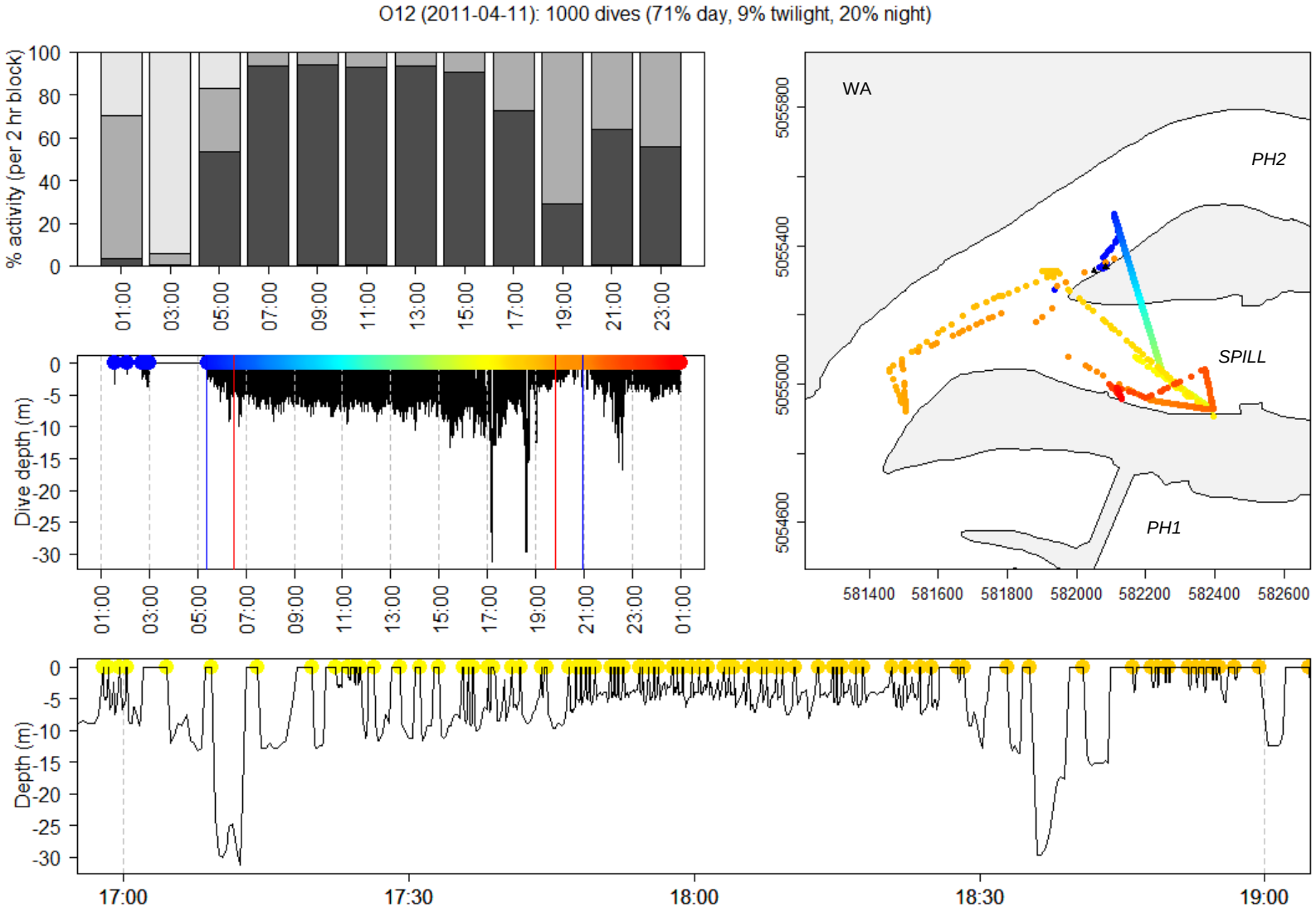

Figure 13. Example daily activity budget and associated dive and movement profile for Steller sea lion O12. Color ramp in dive profiles corresponds to location in map. Blue and red vertical lines in dive profile indicate start/end of civil twilight and sunrise/sunset, respectively. See Figure 8 for activity budget legend.

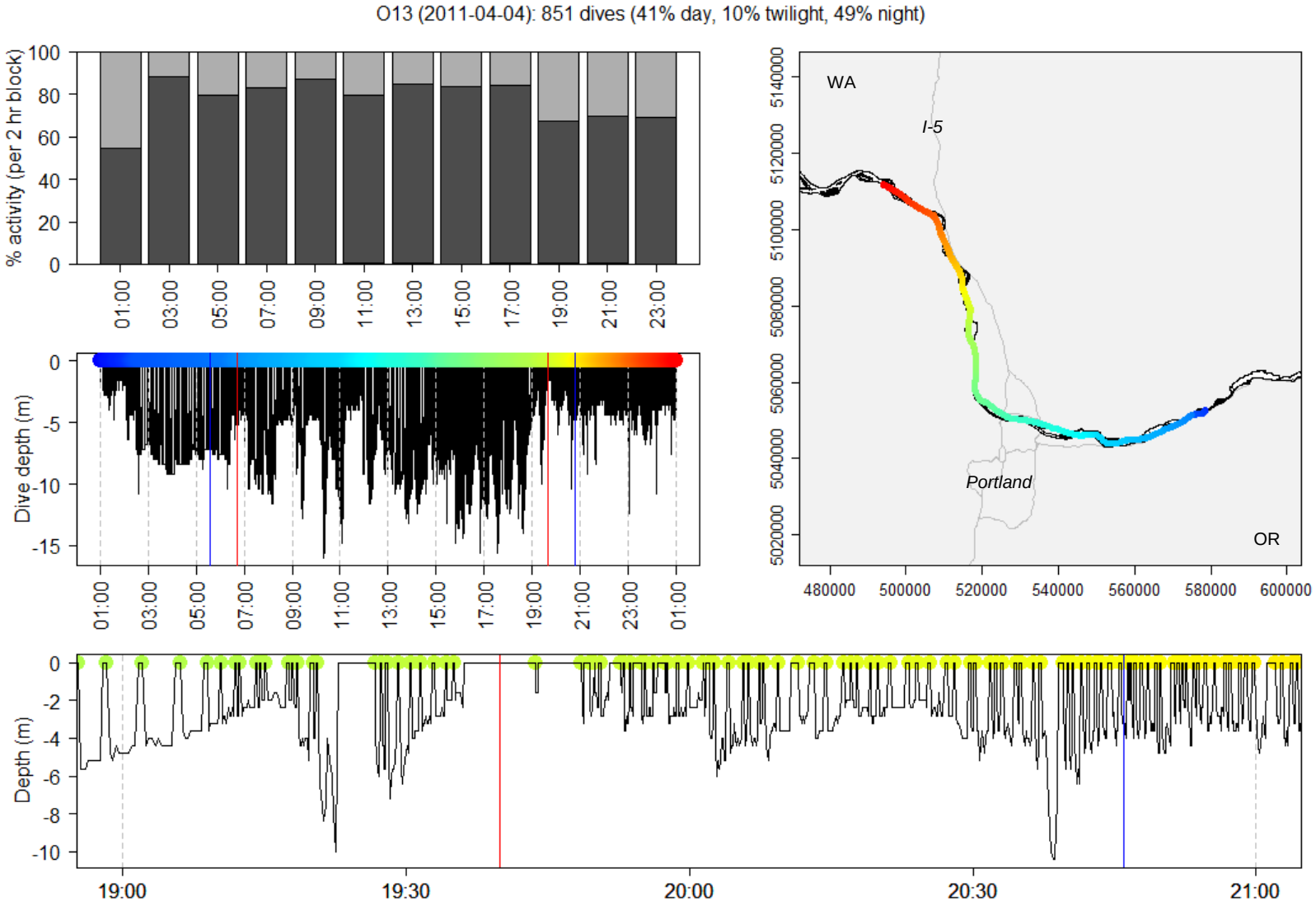

Figure 14. Example daily activity budget and associated dive and movement profile for Steller sea lion O13. Color ramp in dive profiles corresponds to location in map. Blue and red vertical lines in dive profile indicate start/end of civil twilight and sunrise/sunset, respectively. See Figure 8 for activity budget legend.

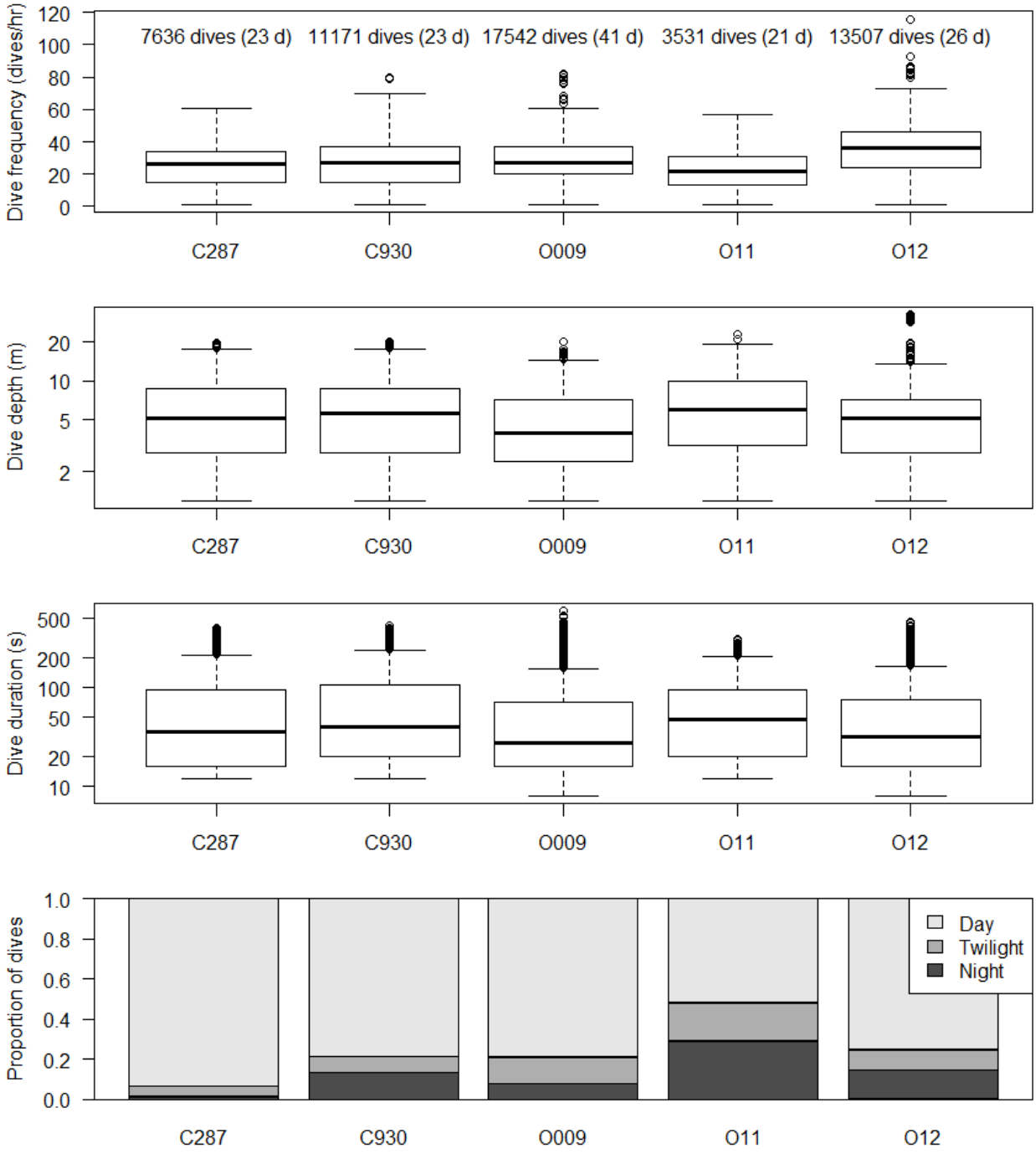

Figure 15. Summary of California sea lion (C287, C930) and Steller sea lion (O009, O11, O12) dive activity at Bonneville Dam, 2011. Note log scale on y-axis of dive depth and duration boxplots.

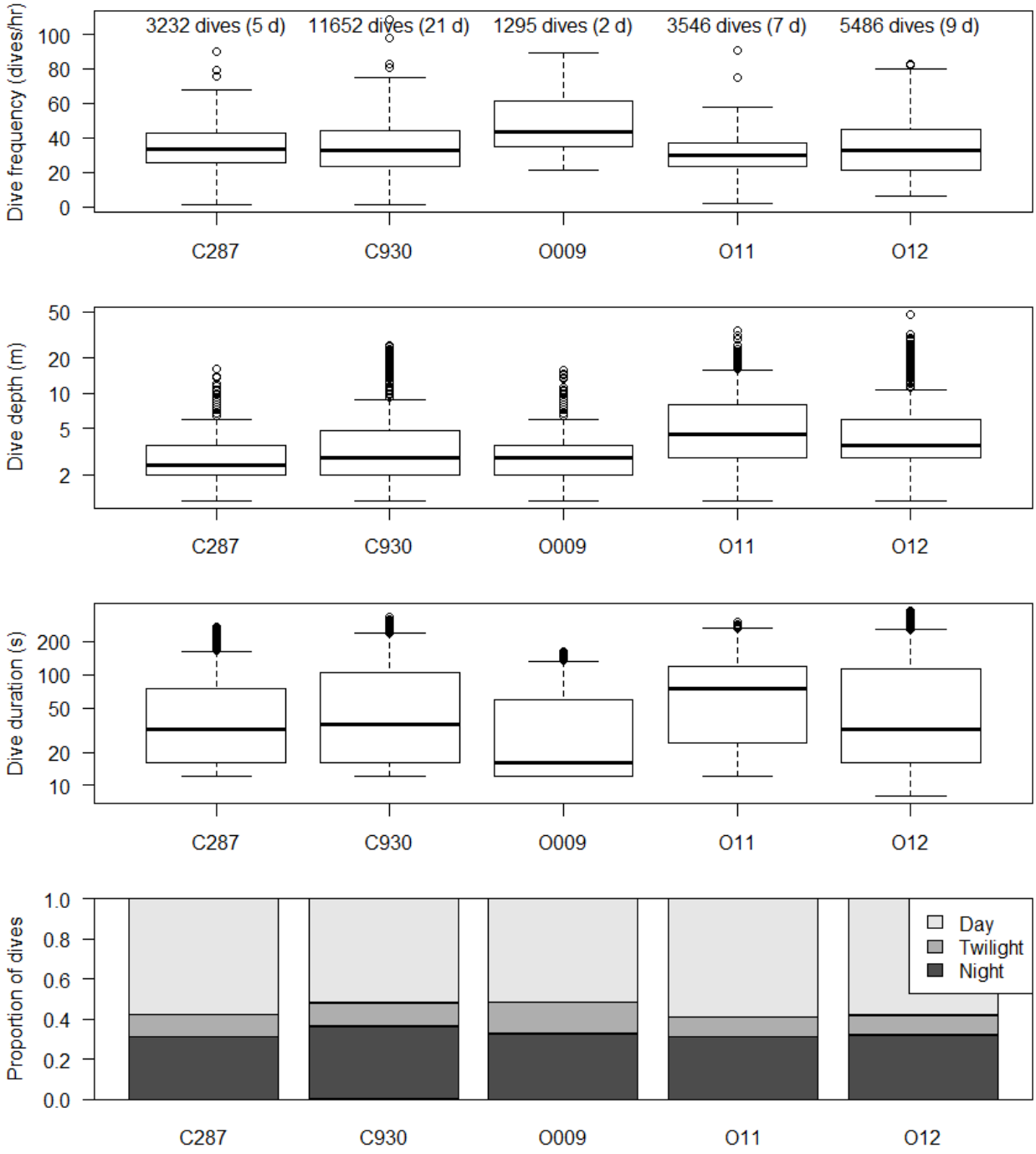

Figure 16 Summary of California sea lion (C287, C930) and Steller sea lion (O009, O11, O12) dive activity during transit between upriver foraging areas (Bonneville Dam, Willamette Falls) and estuary haul-outs (EMB, South Jetty), 2011. Note log scale on y-axis of dive depth and duration boxplots.

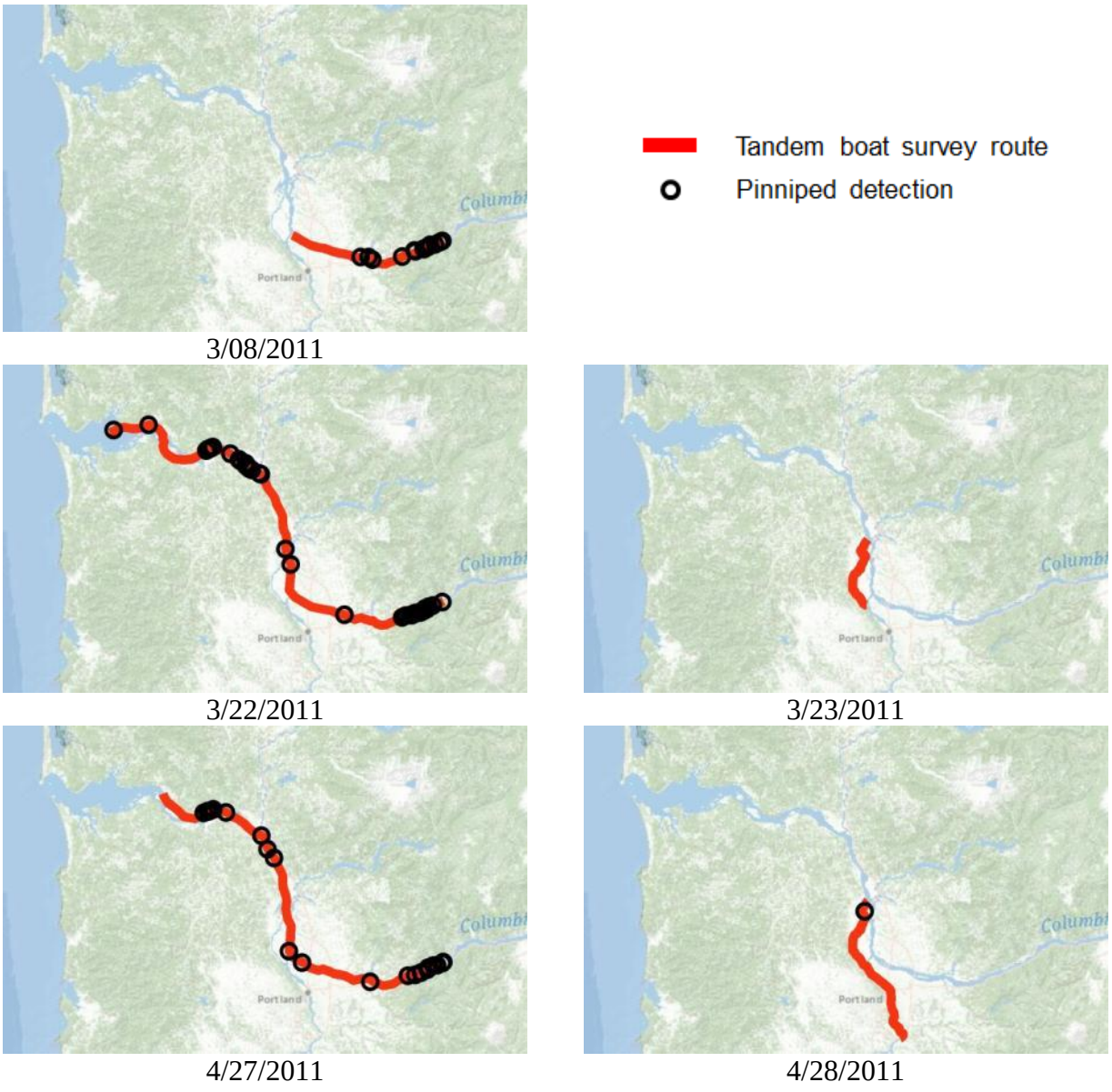

Figure 17. Tandem boat survey routes and associated sea lion sightings.