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CHARACTERIZING THE DISTRIBUTION OF ESA LISTED SALMONIDS IN THE NORTHWEST TRAINING AND TESTING AREA WITH ACOUSTIC AND POP-UP SATELLITE TAGS
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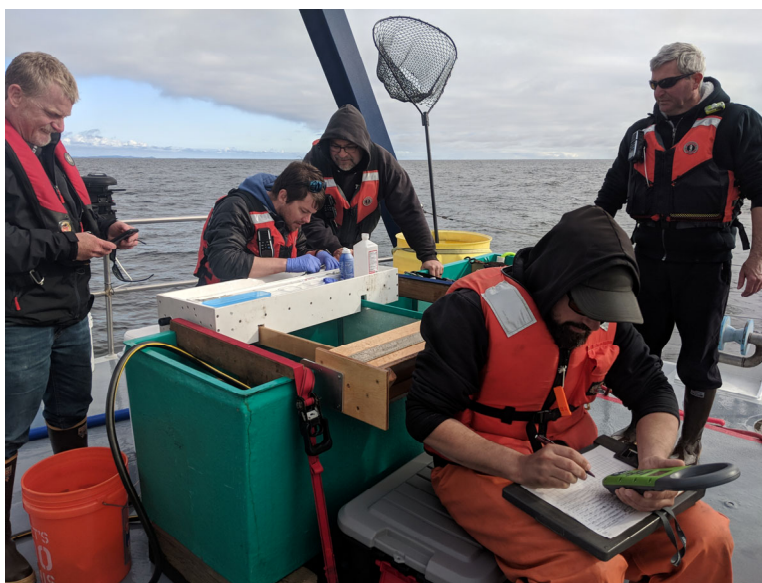
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14. ABSTRACT
The Northwest Fisheries Science Center conducted a study to characterize the distribution of salmonids (Chinook salmon, coho salmon, bull trout) within the Northwest Training and Testing (NWTT) area. In May 2019, we deployed 107 stationary receivers in a grid pattern along the coast of Washington State. In April of 2019 we tagged bull trout in the Hoh River (n = 6) and in Kalaloch Creek (n = 11). From May to August 2019 we tagged 142 Chinook salmon and 35 coho salmon along the coast of Washington State. We collected fin clips to perform genetic stock identification of Chinook salmon and coho salmon. We retrieved, downloaded, and redeployed stationary receivers in September 2019. At all receiver locations combined we detected 87% of tagged Chinook salmon and 71% of tagged coho salmon between May and September 2019. We detected 100% of the tagged bull trout. The projected battery life of the tags is two years. We retrieved and download receivers in March 2020. Further analyses examining the distribution of salmon will be completed once the complete detection history of each fish is obtained.

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Abstract:

The Northwest Fisheries Science Center conducted a study to characterize the distribution of salmonids (Chinook salmon, coho salmon, bull trout) within the Northwest Training and Testing (NWTT) area. In May 2019, we deployed 107 stationary receivers in a grid pattern along the coast of Washington State. In April of 2019 we tagged bull trout in the Hoh River (n = 6) and in Kalaloch Creek (n = 11). From May to August 2019 we tagged 142 Chinook salmon and 35 coho salmon along the coast of Washington State. We collected fin clips to perform genetic stock identification of Chinook salmon and coho salmon. We retrieved, downloaded, and redeployed stationary receivers in September 2019. At all receiver locations combined we detected 87% of tagged Chinook salmon and 71% of tagged coho salmon between May and September 2019. We detected 100% of the tagged bull trout. The projected battery life of the tags is two years. We retrieved and download receivers in March 2020. Further analyses examining the distribution of salmon will be completed once the complete detection history of each fish is obtained.

Background:

The U.S. Navy conducts military training and testing in Pacific Northwest range areas to prepare combat-ready military forces, whereas NOAA Fisheries is responsible for managing threatened and endangered species in marine waters and providing permits to the U.S. Navy for incidental take and letters of authorization for training and testing activities. NOAA Fisheries and the U.S. Navy share the common goals of minimizing the impact of military training and testing activities on endangered species without compromising training and testing efforts and of reducing adverse environmental effects. This work provides vital geographic and distributional data within the Navy's range areas, allowing the Navy the flexibility to proceed with training and testing activities while providing protective measures for both salmonids and killer whales.

The U. S. Navy Pacific Fleet funded an unprecedented study at the NOAA Northwest Fisheries Science Center to fill an important knowledge gap regarding the relationship between salmonids and critically endangered southern resident killer whales (SRKW) along the Washington Coast. This project characterized the ocean distribution of salmon using acoustic and satellite tags to understand how salmon affect the distribution and effort expended by foraging SRKW, thus affecting their survival. This internationally coordinated effort with scientists from the Canadian Department of Fisheries and Oceans, the University of Washington, Oregon State University, and others largely began in late April 2019; acoustic receivers have been deployed along hundreds of miles of the Washington Coast and 142 Chinook salmon, 35 coho salmon, and 17 bull trout have been captured, tagged, and tracked.

Summary of Tasks:

This study had the following tasks:
Task 1 – Purchase and program tags.

Task 2 – Capture, tag, and release salmonids.
Task 3 – Determine the occurrence and timing of salmonids within the Navy training ranges.
Task 4 – Describe the influence of environmental covariates on salmonid occurrence.
Task 5 – Describe the occurrence of salmonids in relation to Southern Resident Killer Whale distribution.

Task 1 – Purchase and program tags.

We purchased 69 kHz VEMCO acoustic tags that were different sizes in order to tag a range fish sizes: V7-2L (n = 5), V7-4L (n = 5), V8-4L (n = 5), V9-6L (n = 20), V9-1L (n = 20), and V9-2L (n = 145), and V9-2LT (n = 100). All acoustic tags were programmed with a random ping rate between 60 s and 120 s with a mean of 90 s to maximize tag life and minimize interference between tags. The V9-2LT tags also measured temperature. The expected detection range of tags is between 200 m and 500 m and the tags have an expected battery life of 172 to 651 days, depending on the battery size and power output (V7 = 136 dB, V8 = 144 dB, V9 = 145 dB) of the tag. We have purchased three reference tags that ping every 10 minutes for each of three power output levels (total of 9 reference tags). The three tags for each power output were placed at three different distances from a receiver to determine empirical detection ranges for this study over a range of environmental conditions. We also purchased Wildlife Computers miniPAT tags (n = 5) that log depth, temperature and light intensity and transmit data via satellite.

Task 2 - Capture, tag, and release salmonids.

Bull trout: We implanted acoustic tags in 6 bull trout (365 – 518 mm fork length) in Hoh River on April 25, 2019 and 11 bull trout (300 – 606 mm fork length) in Kalaloch Creek on April 26, 2019. All 17 of the tagged bull trout (100%) were detected 157,408 times at 6 receiver locations (5 river location and 1 marine location). A single bull trout that was tagged in Kalaloch Creek was detected 8 times at a single receiver location within the NWTT study area on August 25, 2019 between 11:15 and 11:28 Pacific Local Time. This location (47.4286 latitude, -124.4746 longitude) was 5.6 nautical miles from shore between the Queets River and Quinault River.

Chinook salmon: We implanted 142 Chinook salmon with acoustic tags (142 – 840 mm fork length) from May 2, 2019 to August 28, 2019 along the coast of Washington State (Figure 1). Caudal fin clips were obtained to determine genetic stock including run type (spring-run return to rivers in the spring and fall-run return to rivers in the fall), and sex. There were 123 tagged Chinook salmon (87%) detected 50,533 times at 103 receiver locations.
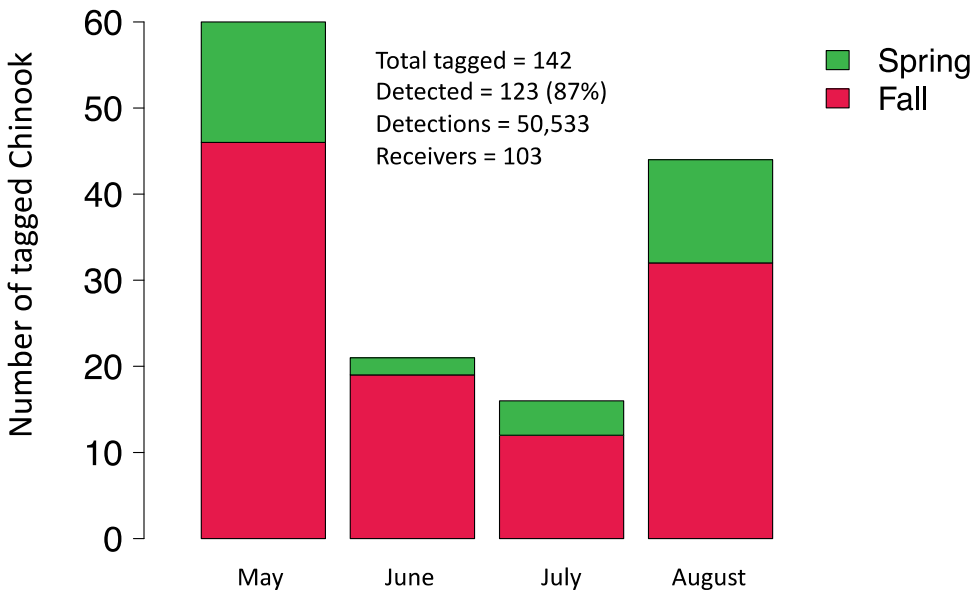
Figure 1. Bar plot indicating the number of Chinook salmon tagged for each month of sampling in 2019. Green indicates spring-run and red indicates fall-run.

Coho salmon:

We implanted tagged 35 coho salmon with acoustic tags (187 – 646 mm fork length) from May 2, 2019 to August 29, 2019 along the coast of Washington State (Figure 2). Caudal fin clips were obtained to determine genetic stock and sex (coho do not have different run types). There were 25 tagged coho salmon (71%) detected 3,267 times at 87 receiver locations.

Green sturgeon:

We detected 124 green sturgeon at 102 receiver locations. There were 378 green sturgeon tagged in 2011-2012 by other researchers and detection data were shared. These fish were implanted with large tags that last 8-9 years. The batteries of these tags are projected to die soon.

Total tagged = 35
Detected = 25 (71%)
Detections = 3,267
Receivers = 87
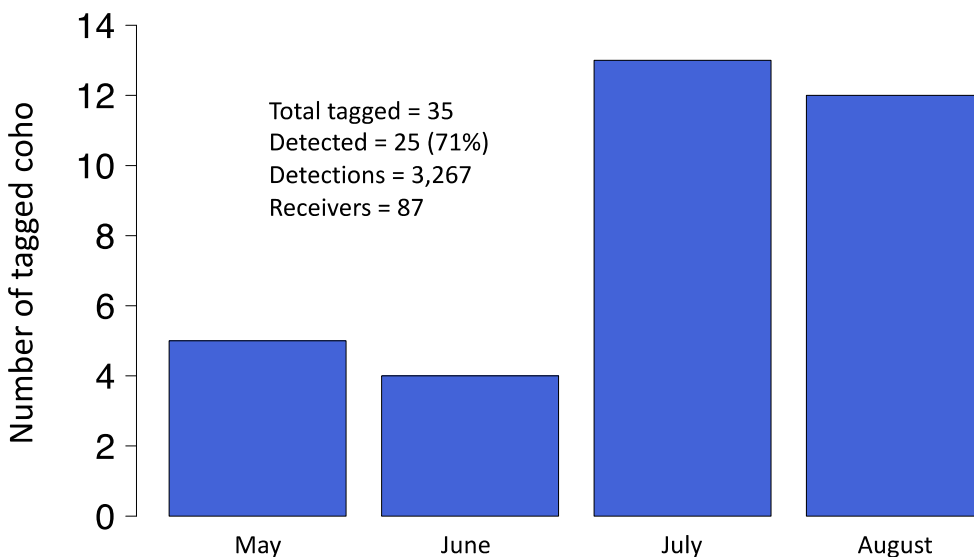
Figure 2. Bar plot indicating the number of coho salmon tagged for each month of sampling in 2019.

Task 3 – *Determine the occurrence and timing of salmonids within the Navy training ranges*. There were 97 stationary receivers deployed (May 14-16, 2019) within coastal waters of Washington State (between 3 nm and 12 nm offshore). An additional 9 receivers were deployed south of Grays Harbor on June 5, 2019. One additional receiver was deployed at Swiftsure Bank in Canadian waters by DFO just north of the NWTT study area. There were 97 receivers within the NWTT study area and 10 receivers were outside of the NWTT study area. Additionally, three receivers were deployed within the Hoh River (April 24-25, 2019), two receivers were deployed within Kalaloch Creek (April 24-26, 2019), and four receivers were deployed within the Columbia River (August 1 – September 5, 2019). The 107 stationary receivers within coastal waters were download and redeployed between August 31 – September 4, 2019. The receivers within the Hoh River and Kalaloch Creek were downloaded on September 9, 2019. The receivers in Kalaloch Creek were redeployed, but the receivers within the Hoh River were removed from the system due to high winter flow conditions. One receiver within the Columbia River was downloaded and redeployed on August 30, 2019. The other Columbia River receivers will be downloaded in spring 2020. The receivers were also able to detect green sturgeon that were previously tagged by other researchers.

The number of unique individuals detected at each stationary receiver location was plotted for Chinook salmon (Figure 3), coho salmon (Figure 4), bull trout (Figure 5), and green sturgeon (Figure 6). A single bull trout that was tagged in Kalaloch Creek was detected at an offshore receiver (5.6 nautical miles from shore) that was in-between the Queets River and the Quinault River (Figure 5).

At each receiver the mean residence time was calculated and then interpolated through space

using kriging. Residence time was calculated for each fish by summing the time spent at each receiver location until the fish was either not detected for one hour or was detected at another receiver. Analyses were done for fall-run and spring-run Chinook separately. There were not enough detections at offshore receivers to perform this analysis for bull trout. Residence time maps show that fish spent time in different locations depending on month for fall-run Chinook salmon (Figure 7), spring-run Chinook salmon (Figure 8), coho salmon (Figure 9), and green sturgeon (Figure 10). There were not enough coho salmon tagged to examine residence time in May and June (Figure 9). Although there were many green sturgeon detected they did not spend much time at any receiver locations (Figure 10). The tag information, species, weight, fork length, number of detections, and number of receivers detected for each tagged Chinook salmon, coho salmon and bull trout is shown in Appendix 1.

Chinook Unique Individuals May−Sept 2019

Figure 3. The number of unique individual Chinook salmon detected at each receiver location from May to September 2019. A total of 142 Chinook salmon were tagged. The size of the circle is relative to the number of individuals that were detected at each location. The number within the circle is the number of individuals detected at that receiver location.
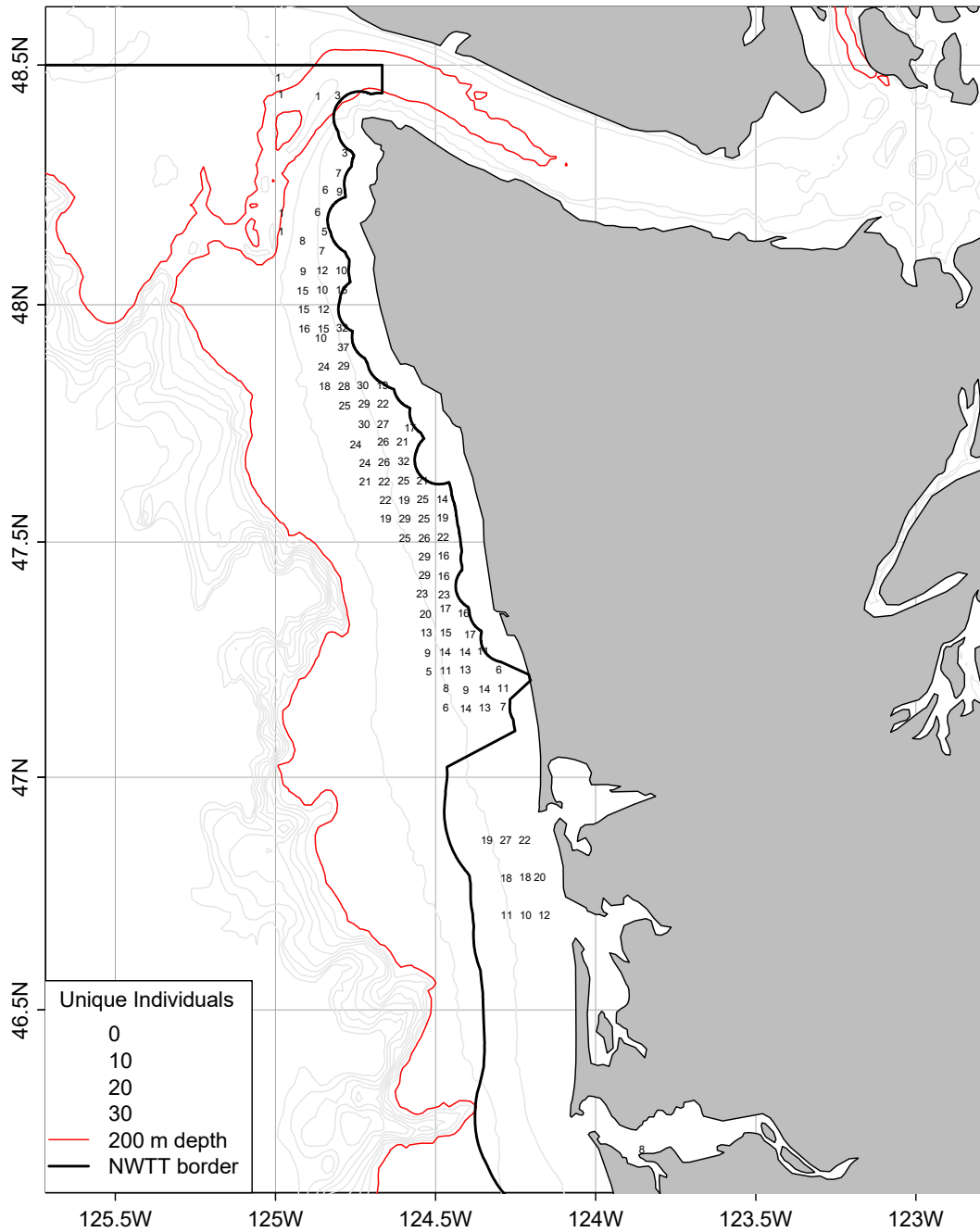
Coho Unique Individuals May−Sept 2019
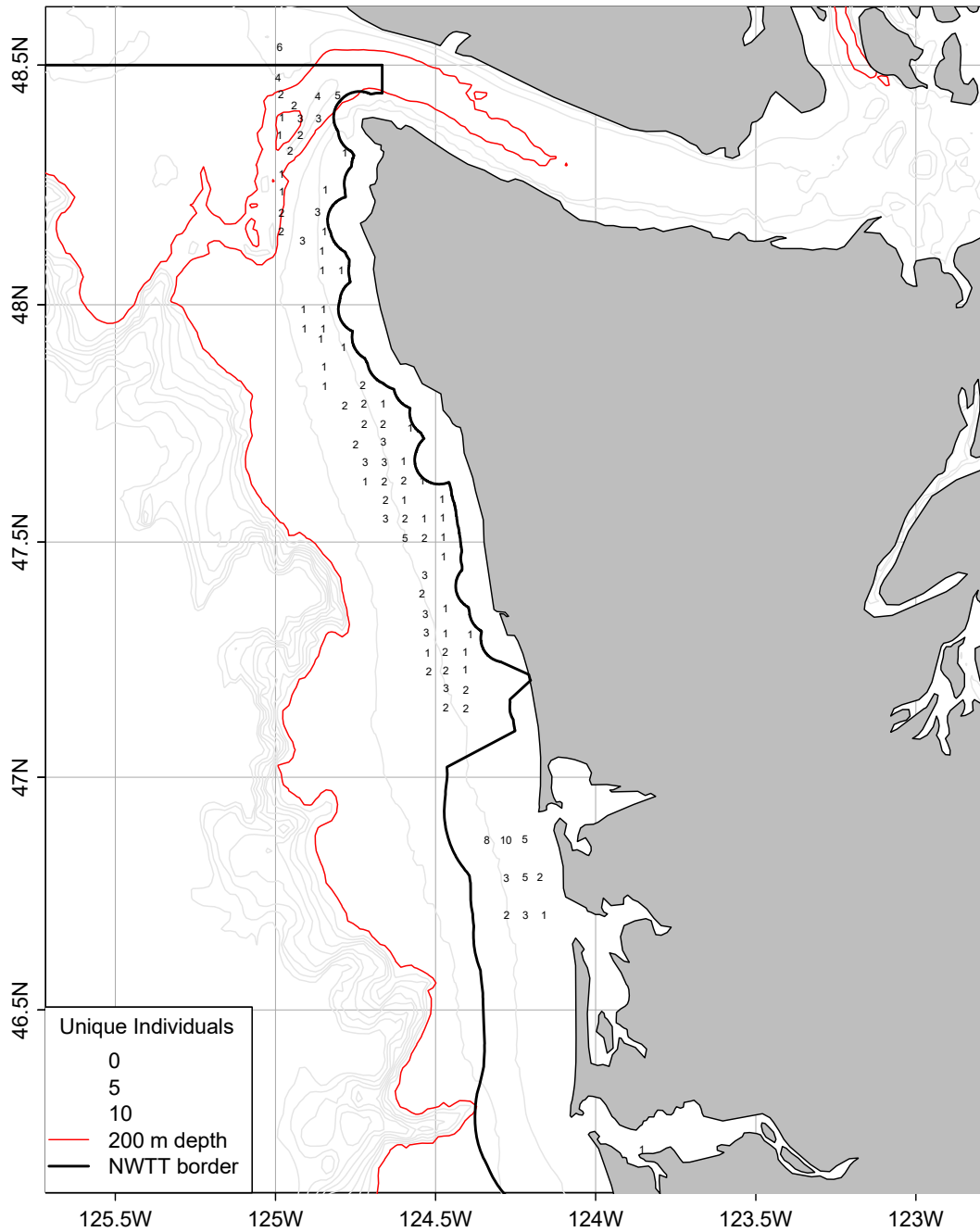
Figure 4. The number of unique individual coho salmon detected at each receiver location from May to September 2019. A total of 35 coho salmon were tagged. The size of the circle is relative to the number of individuals that were detected at each location. The number within the circle is the number of individuals detected at that receiver location.

Bull Trout Unique Individuals May−Sept 2019
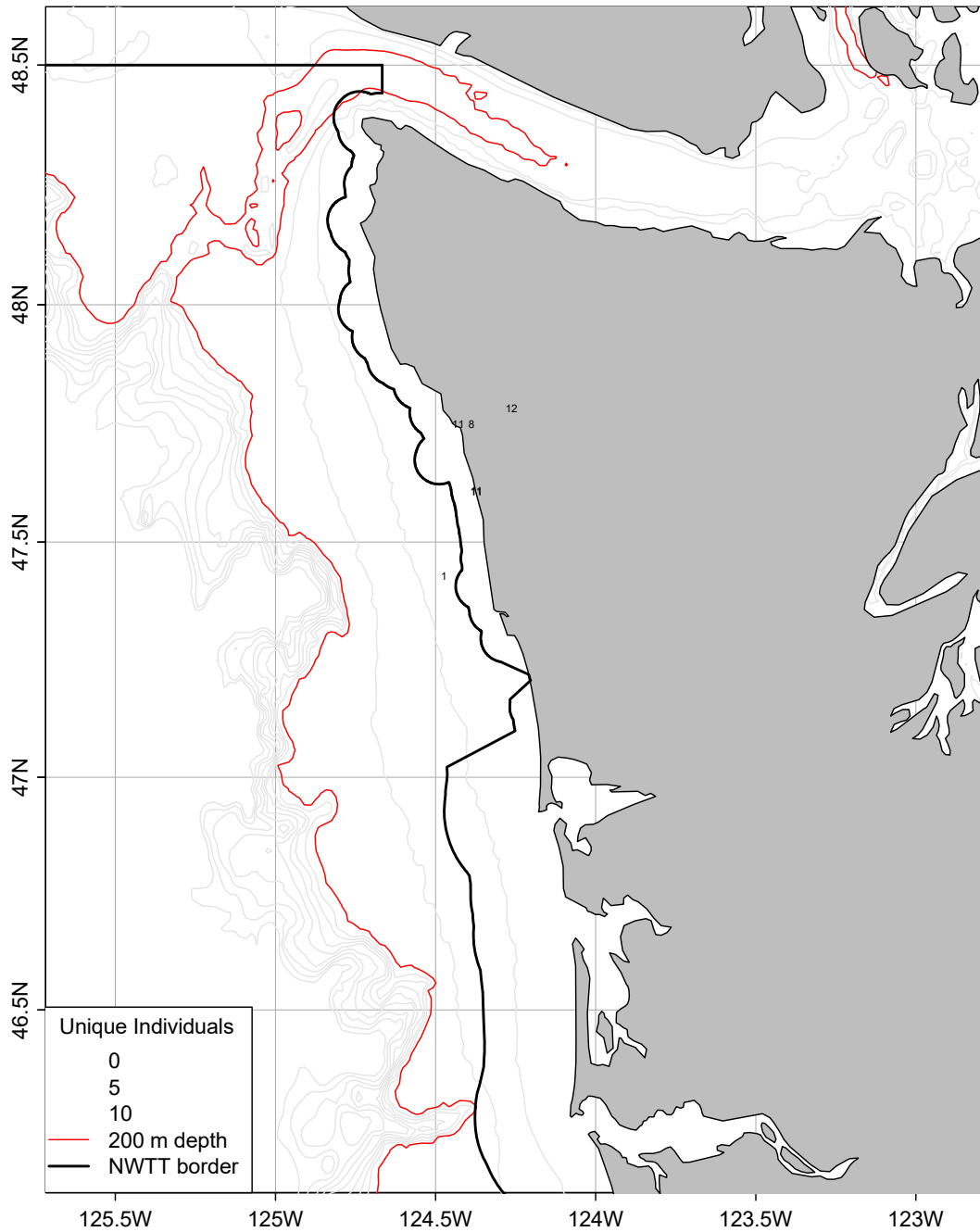
Figure 5. The number of unique individual bull trout detected at each receiver location from May to September 2019. A total of 17 bull trout were tagged. The size of the circle is relative to the number of individuals that were detected at each location. The number within the circle is the number of individuals detected at that receiver location.

Green Sturgeon Unique Individuals May−Sept 2019
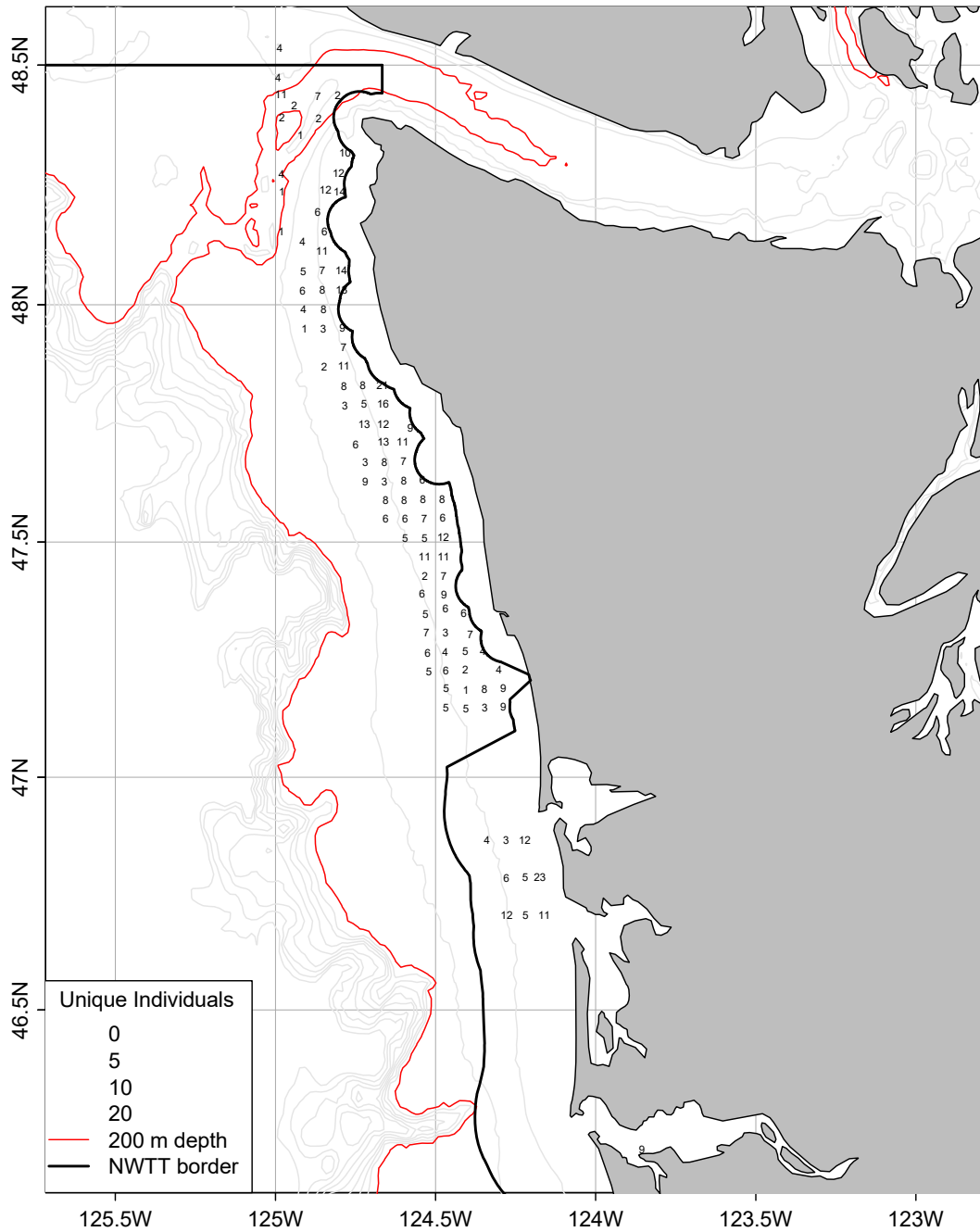
Figure 6. The number of unique individual green sturgeon detected at each receiver location from May to September 2019. The size of the circle is relative to the number of individuals that were detected at each location. The number within the circle is the number of individuals detected at that receiver location.

Chinook Salmon Fall-Run Mean Residence Time
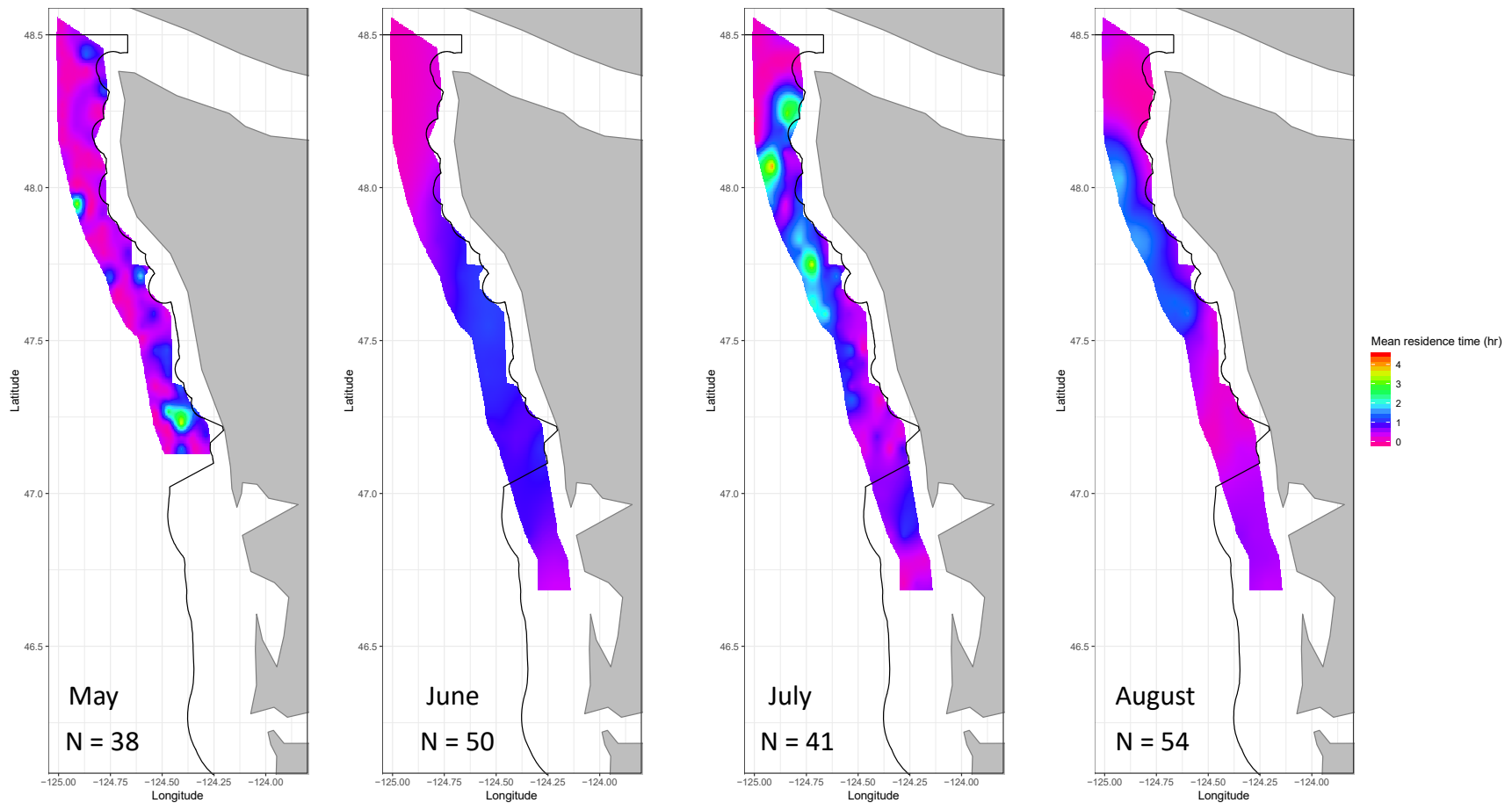
Figure 7. Kriging interpolation of mean residence time for fall-run Chinook salmon for each month. The sample size in each plot indicates the number of tagged fish with recorded residence times for that month. The May plots are smaller because southern receivers were not deployed until June. Black dots indicate receiver locations.

Chinook Salmon Spring-Run Mean Residence Time
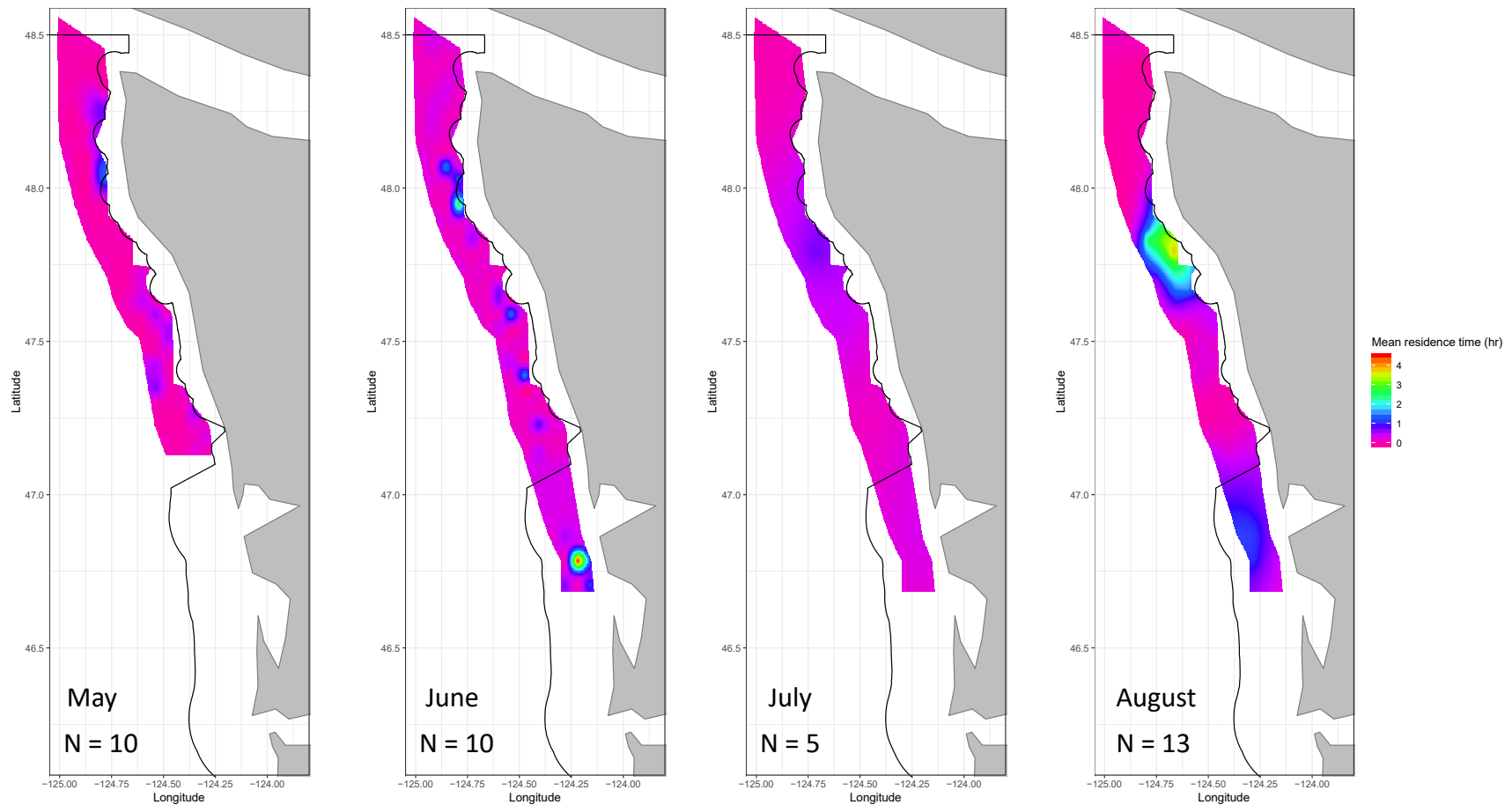
Figure 8. Kriging interpolation of mean residence time for spring-run Chinook salmon for each month. The sample size in each plot indicates the number of tagged fish with recorded residence times for that month. The May plots are smaller because southern receivers were not deployed until June. Black dots indicate receiver locations.

Coho Salmon Mean Residence Time
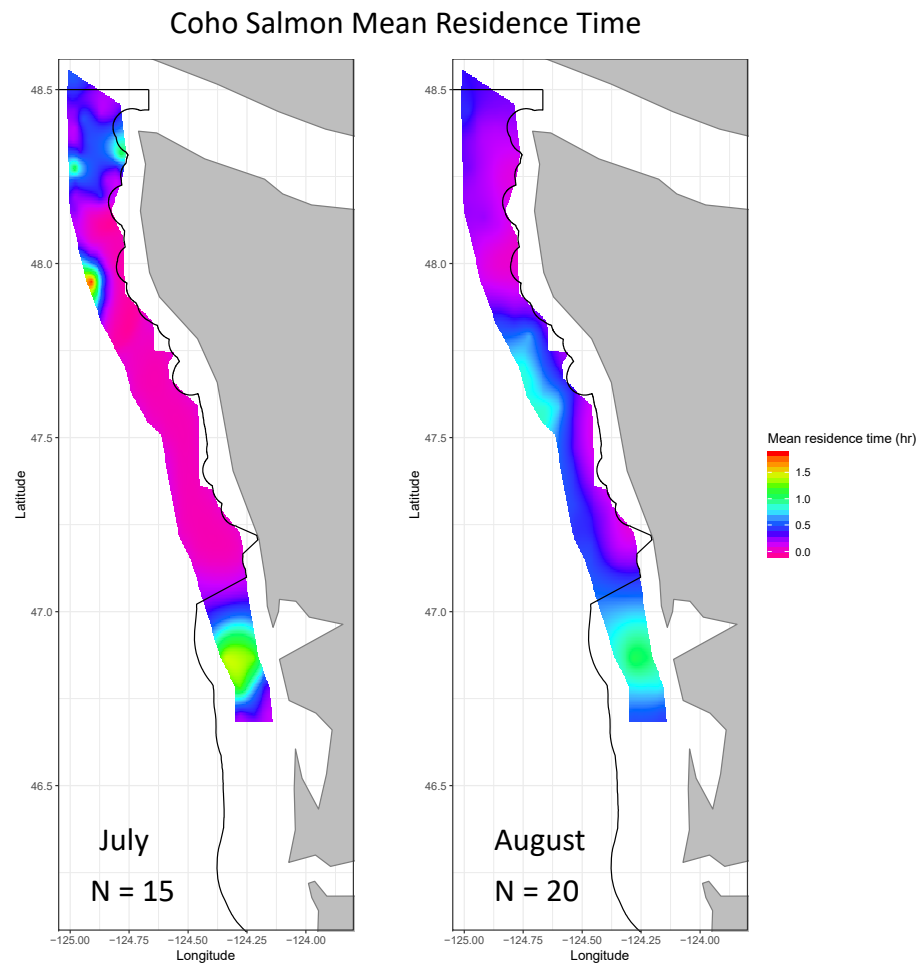
Figure 9. Kriging interpolation of mean residence time for coho salmon for each month. The sample size in each plot indicates the number of tagged fish with recorded residence times for that month. There were not enough tagged coho salmon in the months of May and June to perform this analysis. Black dots indicate receiver locations.

Green Sturgeon Mean Residence Time

Figure 10. Kriging interpolation of mean residence time for green sturgeon for each month. The sample size in each plot indicates the number of tagged fish with recorded residence times for that month. The May plots are smaller because southern receivers were not deployed until June. Black dots indicate receiver locations.

Task 4 – *Describe the influence of environmental covariates on salmonid occurrence*.

We will use oceanographic models to determine spatially explicit environmental conditions within the ocean. Coupling this information with tempora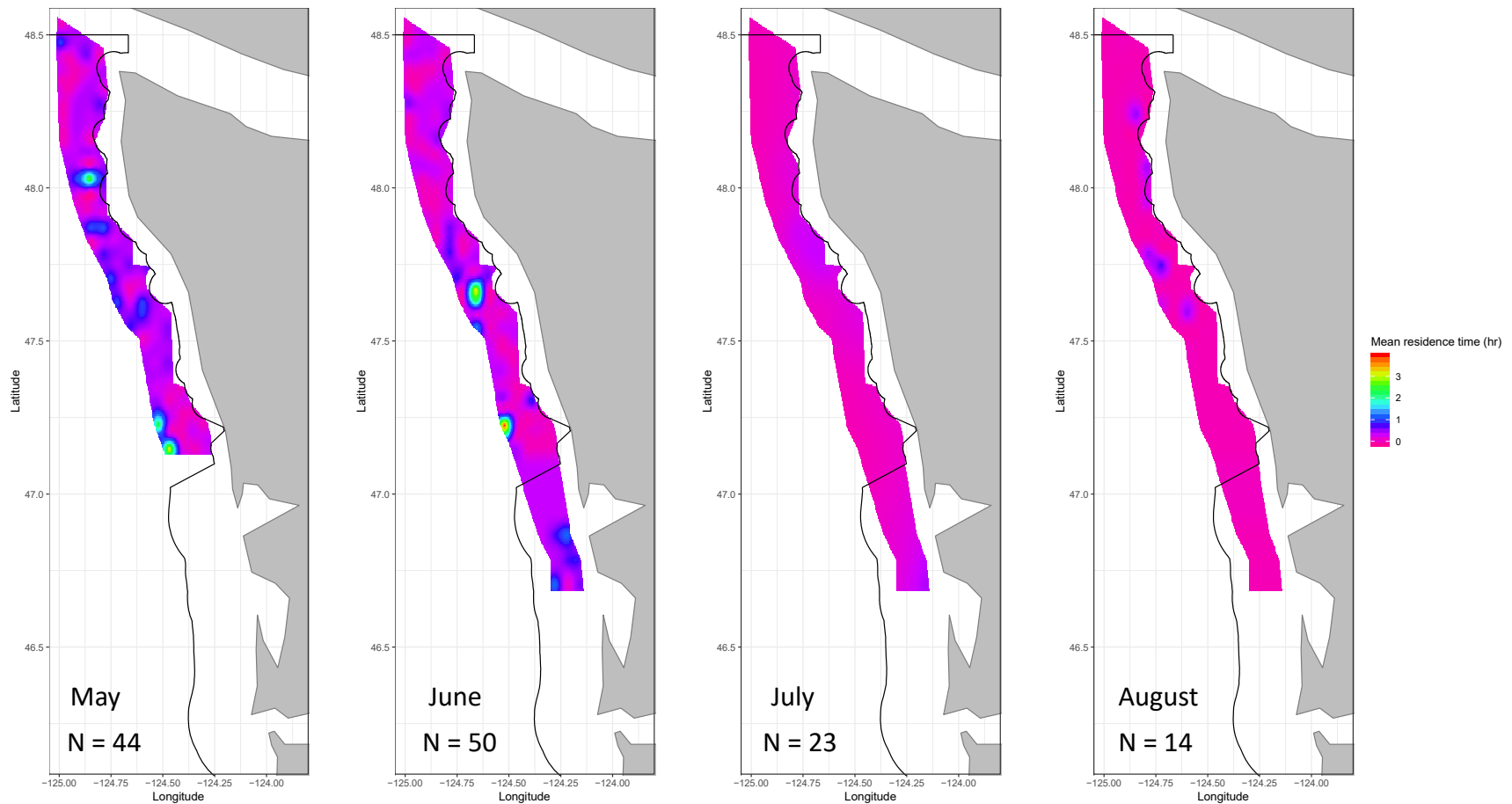lly explicit detection data we can determine the relationship between salmonid distributions and specific habitat attributes. Using this information, we will estimate the travel route, residence time and rate of movement for each tagged fish. Eventually this information will be used to build a species distribution model that determines suitable habitat for each species.

Task 5 – *Describe the occurrence of salmonids in relation to Southern Resident Killer Whale distribution*.

We will coordinate and devise a specific analysis plan with Brad Hanson (NOAA, Northwest Fisheries Science Center) to examine the degree to which tagged salmonids and piscivorous ("resident" ecotype) killer whales overlap through space and time. Salmonids make up the dominant component of resident killer whale diets (Hanson et al. 2010). However, there is very little information about salmonid distribution in the ocean, especially in the winter. Data from this study will provide key insights into the role of salmonids as a prey source for killer whales and how fish occurrence and movements may influence whale occurrence patterns. The distribution of salmon prey that are large enough to be killer whale forage is seasonally dynamic among species and among populations within species. This work will fill this data gap by elucidating the behavior and spatiotemporal distribution of salmonids in the ocean. Additionally, this study will give the Navy information regarding areas of spatial overlap of killer whales and salmonids within the NWTT study area.

Appendix 1. The VEMCO code, serial number, date of tagging, weight (g), fork length (mm), number of total detections, and number of receivers with detections from April-August 2019.

Code	SN	Date	Species	Weight (g)	Length (mm)	# detections	# receivers
14926	1314282	5/2/19	Chinook	250	271	18	2
14929	1314285	5/2/19	Chinook	260	279	13	2
14930	1314286	5/2/19	Chinook	1050	426	1716	40
14931	1314287	5/2/19	Chinook	200	255	133	7
14933	1314289	5/2/19	Chinook	500	338	1074	35
14934	1314290	5/2/19	Chinook	450	320	2048	42
14935	1314291	5/2/19	Chinook	220	253	52	4
14936	1314292	5/2/19	Chinook	520	338	540	26
14937	1314293	5/3/19	Chinook	1400	495	67	2
14940	1314296	5/3/19	Chinook	250	274	1767	30
14898	1314235	5/5/19	Chinook	500	347	64	6
14943	1314299	5/5/19	Chinook	1300	427	257	10
14944	1314300	5/5/19	Chinook	420	293	287	12
14945	1314301	5/22/19	Chinook	100	239	98	8
14167	1314154	5/23/19	Chinook	45	171	49	2
14168	1314155	5/23/19	Chinook	50	169	140	5
14169	1314156	5/23/19	Chinook	150	228	80	5
14170	1314157	5/23/19	Chinook	90	143	374	24
14946	1314302	5/23/19	Chinook	250	280	78	5
14947	1314303	5/23/19	Chinook	350	300	248	9
14958	1314314	5/23/19	Chinook	500	342	1758	46
14959	1314315	5/23/19	Chinook	250	271	147	4
14960	1314316	5/23/19	Chinook	245	272	148	8
14948	1314304	5/25/19	Chinook	250	275	100	5
14949	1314305	5/25/19	Chinook	260	273	163	11
14950	1314306	5/25/19	Chinook	250	258	16	1
14511	1314164	5/26/19	Chinook	140	222	120	9
14521	1314194	5/26/19	Chinook	1200	448	400	11
14523	1314196	5/26/19	Chinook	750	394	135	8
14524	1314197	5/26/19	Chinook	920	405	9	2
14525	1314198	5/26/19	Chinook	350	290	272	16
14526	1314199	5/26/19	Chinook	700	369	27	6
14527	1314200	5/26/19	Chinook	1350	461	1693	41
14951	1314307	5/26/19	Chinook	1000	433	225	11
14952	1314308	5/26/19	Chinook	800	391	2172	45
14953	1314309	5/26/19	Chinook	740	375	1052	39

14954	1314310	5/26/19	Chinook	750	368	770	23
14955	1314311	5/26/19	Chinook	700	367	167	9
14956	1314312	5/26/19	Chinook	900	393	86	6
14957	1314313	5/26/19	Chinook	850	399	1027	25
14528	1314201	5/28/19	Chinook	1300	446	1671	38
14529	1314202	5/28/19	Chinook	620	365	576	9
14530	1314203	5/28/19	Chinook	560	349	396	12
14531	1314204	5/28/19	Chinook	250	259	67	6
14512	1314165	5/29/19	Chinook	250	270	67	2
14513	1314166	5/29/19	Chinook	225	240	278	7
14532	1314205	5/29/19	Chinook	1300	445	511	17
14533	1314206	5/29/19	Chinook	650	368	1481	40
14534	1314207	5/29/19	Chinook	560	357	2404	42
14535	1314208	5/29/19	Chinook	1500	462	127	6
14899	1314236	5/29/19	Chinook	1600	470	51	5
14900	1314237	5/29/19	Chinook	750	362	82	3
14901	1314238	5/29/19	Chinook	350	292	1212	47
14902	1314239	5/29/19	Chinook	520	345	1664	47
14903	1314240	5/31/19	Chinook	850	405	25	2
14904	1314241	6/6/19	Chinook	1400	461	848	44
14905	1314242	6/6/19	Chinook	840	388	1337	35
14906	1314243	6/6/19	Chinook	900	408	321	19
14907	1314244	6/6/19	Chinook	850	403	233	4
7466	1321506	6/20/19	Chinook	700	384	34	1
14908	1314245	6/20/19	Chinook	900	400	447	17
14909	1314246	6/20/19	Chinook	950	402	955	23
14910	1314247	6/20/19	Chinook	600	348	898	16
14911	1314248	6/21/19	Chinook	NA	712	729	32
14914	1314251	6/22/19	Chinook	600	352	1321	29
14915	1314252	6/22/19	Chinook	9000	840	241	12
7508	1321548	6/23/19	Chinook	900	405	1446	23
7509	1321549	6/23/19	Chinook	1000	416	224	9
7510	1321550	6/23/19	Chinook	900	408	228	16
7511	1321551	6/23/19	Chinook	1600	478	809	29
14515	1314168	6/23/19	Chinook	2000	513	663	40
14912	1314249	6/23/19	Chinook	200	258	1831	40
14913	1314250	6/23/19	Chinook	540	378	28	3
17296	1321304	6/23/19	Chinook	660	375	196	12
17297	1321305	6/23/19	Chinook	1150	435	407	17
14510	1314163	6/25/19	Chinook	100	196	78	6
7472	1321512	7/9/19	Chinook	480	315	82	6
7513	1321553	7/9/19	Chinook	400	305	193	14
17298	1321306	7/9/19	Chinook	100	201	51	7
7501	1321541	7/11/19	Chinook	780	375	211	11
17300	1321308	7/11/19	Chinook	NA	655	298	21
7506	1321546	7/23/19	Chinook	NA	435	192	13

17301	1321309	7/23/19	Chinook	240	265	27	1
7495	1321535	7/24/19	Chinook	280	269	264	5
7480	1321520	7/29/19	Chinook	NA	395	579	11
7481	1321521	7/29/19	Chinook	NA	274	109	7
7493	1321533	7/29/19	Chinook	NA	283	70	8
17302	1321310	7/29/19	Chinook	NA	202	91	3
17303	1321311	8/5/19	Chinook	3200	625	136	7
17304	1321312	8/5/19	Chinook	1200	439	372	9
17305	1321313	8/5/19	Chinook	1200	443	262	12
7482	1321522	8/6/19	Chinook	1900	490	335	10
7483	1321523	8/6/19	Chinook	900	374	474	17
7484	1321524	8/6/19	Chinook	500	310	16	1
17307	1321315	8/6/19	Chinook	2400	500	30	5
17308	1321316	8/6/19	Chinook	3500	630	344	15
17309	1321317	8/6/19	Chinook	1400	428	448	12
17310	1321318	8/6/19	Chinook	1900	478	436	10
7474	1321514	8/13/19	Chinook	230	257	143	10
7477	1321517	8/13/19	Chinook	460	331	52	2
7486	1321526	8/13/19	Chinook	390	316	3	1
7507	1321547	8/13/19	Chinook	130	218	30	2
17315	1321323	8/13/19	Chinook	350	297	65	10
17316	1321324	8/13/19	Chinook	390	308	172	7
17317	1321325	8/13/19	Chinook	290	278	83	3
7467	1321507	8/14/19	Chinook	240	265	125	9
7470	1321510	8/14/19	Chinook	310	278	72	5
7479	1321519	8/14/19	Chinook	230	263	120	9
7514	1321554	8/14/19	Chinook	240	267	123	8
17318	1321326	8/14/19	Chinook	100	207	12	2
17319	1321327	8/14/19	Chinook	230	256	57	5
17320	1321328	8/14/19	Chinook	3700	590	25	5
17322	1321330	8/14/19	Chinook	530	332	89	3
17323	1321331	8/14/19	Chinook	470	329	24	2
17324	1321332	8/14/19	Chinook	270	275	36	1
7460	1321500	8/15/19	Chinook	190	241	88	8
7461	1321501	8/15/19	Chinook	140	221	10	2
7463	1321503	8/15/19	Chinook	200	250	33	3
7464	1321504	8/15/19	Chinook	1900	474	17	1
7465	1321505	8/15/19	Chinook	740	373	171	13
17325	1321333	8/15/19	Chinook	260	281	112	8
17327	1321335	8/15/19	Chinook	310	292	169	9
17330	1321338	8/15/19	Chinook	320	289	206	10
14932	1314288	5/2/19	Coho	640	390	235	12
14938	1314294	5/3/19	Coho	450	338	212	10
14939	1314295	5/3/19	Coho	650	391	184	8
14941	1314297	5/3/19	Coho	520	359	90	7
14942	1314298	5/3/19	Coho	540	360	220	13

14507	1314160	6/6/19	Coho	180	238	94	9
14509	1314162	6/20/19	Coho	120	195	7	2
7503	1321543	7/23/19	Coho	NA	570	107	4
7504	1321544	7/23/19	Coho	NA	590	9	1
7505	1321545	7/23/19	Coho	NA	570	48	1
7488	1321528	7/24/19	Coho	NA	583	71	3
7491	1321531	7/24/19	Coho	NA	580	9	2
7494	1321534	7/24/19	Coho	380	305	224	12
7498	1321538	7/24/19	Coho	NA	645	246	15
7499	1321539	7/24/19	Coho	340	295	138	12
7500	1321540	7/24/19	Coho	NA	593	367	19
7492	1321532	7/29/19	Coho	NA	612	348	16
17306	1321314	8/6/19	Coho	1700	485	79	5
17314	1321322	8/8/19	Coho	2900	584	157	12
7473	1321513	8/13/19	Coho	440	329	88	8
7475	1321515	8/13/19	Coho	2600	580	142	7
7485	1321525	8/13/19	Coho	2800	557	148	2
7469	1321509	8/14/19	Coho	3000	594	7	1
17326	1321334	8/15/19	Coho	1200	432	31	2
17328	1321336	8/15/19	Coho	2300	554	6	1
14516	1314189	4/25/19	Bull trout	1560	518	7	2
14517	1314190	4/26/19	Bull trout	460	352	2262	4
14518	1314191	4/26/19	Bull trout	480	361	4396	4
14519	1314192	4/26/19	Bull trout	220	300	6494	3
14520	1314193	4/26/19	Bull trout	320	330	32986	4
14896	1314233	4/26/19	Bull trout	245	322	11270	5
14897	1314234	4/26/19	Bull trout	240	319	25264	3
14916	1314272	4/25/19	Bull trout	550	365	34	3
14917	1314273	4/25/19	Bull trout	560	376	30330	2
14918	1314274	4/25/19	Bull trout	800	389	270	2
14919	1314275	4/25/19	Bull trout	525	369	22	2
14920	1314276	4/25/19	Bull trout	1550	490	5	2
14921	1314277	4/26/19	Bull trout	495	364	27277	4
14922	1314278	4/26/19	Bull trout	2000	606	1320	5
14923	1314279	4/26/19	Bull trout	520	382	3346	4
14924	1314280	4/26/19	Bull trout	290	318	733	2
14925	1314281	4/26/19	Bull trout	280	315	11399	4