Submitted in Support of the U.S. Navy's 2023 Annual Marine Species Monitoring Report for the Pacific

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Migration route and timing through the NWTT of Chinook salmon acoustically tagged in the Gulf of Alaska

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Executive Summary

The migration route and timing of Chinook salmon along the coast of Washington State is not well understood. To determine when and where Chinook salmon of different genetic stocks enter and transit through the U.S. Navy Northwest Training and Testing Area (NWTT), we tagged 298 maturing adult salmon across five locations throughout the Gulf of Alaska. The tagging locations included Kodiak in October 2020 (n = 80), Yakutat in March 2021 (n = 32), Chignik in August 2021 (n = 36), Craig in June 2022 (n = 51), and Sitka in June 2022 (n = 99). We have detected 61 acoustically tagged Chinook salmon (tagged in Kodiak = 10, Yakutat = 5, Chignik = 4, Craig = 12, Sitka = 30). The 298 tagged Chinook salmon included ten different genetic stocks that were from Southeast Alaska, British Columbia, Washington, or Oregon. This included two Evolutionary Significant Units (ESU), Lower Columbia River and Upper Willamette River, that are listed as threaten by the Endangered Species Act (ESA), and one ESU, the Oregon Coast, that is a candidate for ESA listing. The Lower Columbia River ESU fish were detected in Pacific Northwest waters (Canadian and Washington Coast) in August and October. The Upper Willamette River ESU fish were detected in Pacific Northwest waters in April, June, and July and by receivers within the NWTT in July. The Oregon Coast ESU fish were detected in the Pacific Northwest waters in September and October and by receivers with the NWTT in September and October. This study has provided novel evidence that fish tagged in Alaska transit through the NWTT.

Background

The United States (U.S.) Navy conducts military training and testing activities in the Pacific Northwest range areas. These activities are crucial for preparing combat-ready military forces capable of defending the nation. At the same time, the National Oceanic and Atmospheric Administration (NOAA) Fisheries is charged with managing and protecting threatened and endangered marine species in these waters. Part of their responsibility includes issuing permits to the U.S. Navy, allowing them to conduct their training and testing activities. Both NOAA Fisheries and the U.S. Navy share common objectives, which include minimizing the impact of military training and testing activities on protected species without compromising the effectiveness of training and testing. Additionally, they aim to reduce adverse environmental effects resulting from such activities. To achieve these goals, close collaboration and communication between the two entities are essential. The data generated from these cooperative efforts provide critical information about the geographical distribution and habitat of marine species within the Navy's range areas. This information enables the Navy to adapt its training and testing activities accordingly, while implementing protective measures for salmonids and other vulnerable species. Consequently, this approach allows for a balance between the Navy's mission requirements and the conservation of protected marine life in the Pacific Northwest region.

This particular project is dedicated to the study of Pacific salmonids in the offshore waters encompassing the existing Northwest Training Range Complex (NWTRC) and the offshore Naval Undersea Warfare Center Keyport Range Complex. These two areas collectively form the Northwest Training and Testing (NWTT) Study Area. The research conducted within this project is specifically focused on a region that is crucial for both the Navy's monitoring objectives and the conservation of species of interest, as outlined in current and future monitoring plans. By concentrating on this vital region, the project aims to support the U.S. Navy's commitment to minimizing the impact of its training and testing activities on Pacific salmonids and other marine species while ensuring the effectiveness of its operations. This research will provide essential information to inform decision-making and enable the implementation of protective measures for the marine ecosystem in the NWTT Study Area.

In an effort to understand the migratory patterns and behavior of Chinook salmon tagged in the Gulf of Alaska, we used acoustic tags to track individual fish to determine if and when they transit through the Navy's NWTT Study Area. In addition to tracking their movements, genetic stock identification (GSI) was used to determine the distinct populations of Chinook salmon. By monitoring the movements and genetic makeup of these important fish, this study aims to provide crucial insights to mitigate potential impacts of Navy activity on their migration, as well as to inform future conservation and management efforts to protect and sustain this species.

Methods

Tagging: Chinook salmon were tagged in five locations along the Gulf of Alaska (Figure 1). Chinook salmon were caught with hook and line. Each individual was immediately put into anesthetic (25 mg/L; AQUI-S® 20E) until the fish reached level III anesthesia (i.e., total loss of equilibrium and no reaction to touch stimuli, ~4 min.). Chinook salmon were surgically implanted with Innovasea 69 kHz V16-4x transmitters (diameter = 16 mm, length = 68 mm, weight = 24 g in air, power output = 158 dB, battery life = 1910 d, random ping rate between 70 and 110 s). The use of AQUI-S® 20E was used under Investigational New Animal Drugs (INAD) permit #11-47. Once anesthetized the fork length (nearest cm) was measured, scales were taken from the preferred area for aging, and a fin clip was taken from the anal fin for genetic analysis. To implant the transmitter a 20 mm incision was made with a sterile scalpel, the V16 transmitter and a passive integrated transponder (PIT) was inserted into the body cavity, and the incision was sutured with two or three simple interrupted surgeon's knots using an Ethicon Y513 4-0 Monocryl suture with a 19 mm reverse cutting needle. After surgery, the fish was placed in a recovery tank of fresh seawater with an aerator until the fish was vigorously swimming and recovered (~5-10 min.). After recovery the fish was released near the capture location. The latitude, longitude, and the time of fish release was recorded for each individual.

The tagging locations included Kodiak in October 2020 (n = 80), Yakutat in March 2021 (n = 32), Chignik in August 2021 (n = 36), Craig in June 2022 (n = 51), and Sitka in June 2022 (n = 99) (Figure 1, Table 1).

Genetic samples were taken for each tagged fish and additional fin clip samples were taken from individuals that were either not adequate size for tagging or not in good enough condition for tagging (Table 1). Therefore, the number of fish tagged and analyzed were different. Genetic analysis was performed by the NWFSC Conservation Biology Division to determine genetic stock. The percentage of each stock group was determined for each location.

Table 1. Sample size in each location including the number of individuals tagged and the number of individuals with fin clips taken for genetic samples.

Samples	Chignik	Kodiak	Yakutat	Sitka	Craig
Number tagged	36	80	32	99	51
Number genetic samples	40	91	48	128	47

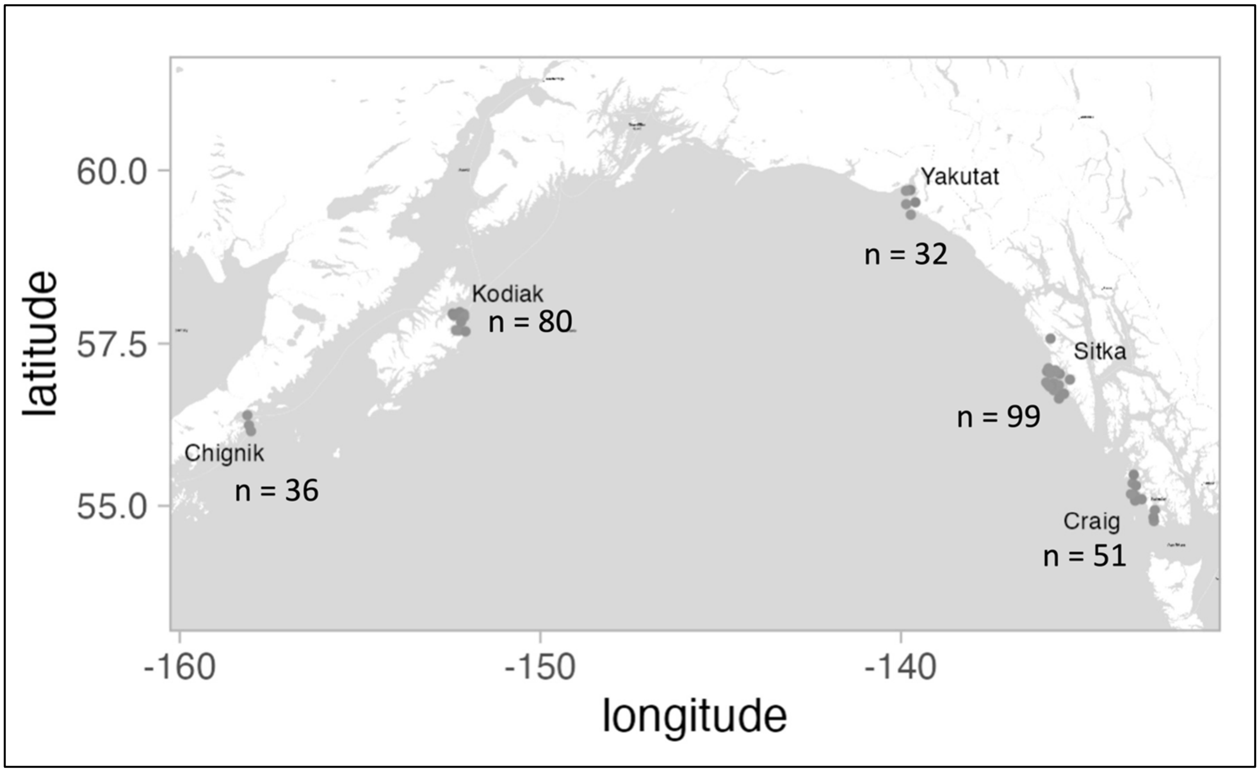

Figure 1. Chinook salmon tagging locations and the number tagged within the Gulf of Alaska.

Fish detection: We deployed InnovaSea 69 kHz VR2AR acoustic receivers along the coast of Washington State to detect acoustically tagged Chinook salmon. Individuals were also detected by acoustic receivers deployed by other groups including Department of Fisheries and Oceans Canada, Olympic Coast National Marine Sanctuary, University of Victoria, University of British Columbia, and Kintama consulting company. Additionally, detections were reported via the Ocean Tracking Network (OTN).

Data analyses: Detection histories for each individual that include individual ID, tagging date, genetic stock ID, detections locations colored by year and month of detection, and date of last detection were mapped using Program R. Histograms of the number of unique individuals detected by month were plotted for fish detected anywhere in the Pacific Northwest (Canada, Washington, Oregon) and for fish detected by receivers deployed within the NWTT.

Results

The proportion of different genetic stock IDs varied across tagging locations (Table 2, Figure 2). In Chignik (n = 40), the highest proportion of individuals originated from West Vancouver Island (70.0%), followed by Southeast Alaska (22.5%), and Upper Columbia River summer/fall (7.5%). In Kodiak, (n = 91), most individuals originated from Southeast Alaska (60.4%), followed by Upper Columbia River summer/fall (11.0%), West Vancouver Island (9.9%), Willamette River spring (7.7%), South Thompson River (4.4%), North/Mid Oregon coast

(3.3%), West Cascade spring (2.2%), and West Cascade fall (1.1%). In Yakutat (n = 48), most individuals originated from West Vancouver Island (41.7%), followed by Southeast Alaska (27.1%), Willamette River spring (18.8%), Upper Columbia River summer/fall (6.3%), West Cascade spring (2.1%), West Cascade fall (2.1%), and East Vancouver Island (2.1%). In Sitka (n = 128), most individuals originated from Upper Columbia River summer/fall (32.0%), North/Mid Oregon coast (19.5%), West Vancouver Island (15.6%), Southeast Alaska (14.8%), South Thompson River (12.5%), East Vancouver Island (2.3%), West Cascade fall (2.3%), and Snake River fall (0.8%). In Craig (n = 47), most individuals originated from West Vancouver Island (36.2%), Upper Columbia River summer/fall (19.1%), Southeast Alaska (17.0%), West Cascade fall (10.6%), North/Mid Oregon coast (6.4%), South Thompson River (4.3%), East Vancouver Island (4.3%), and South Puget Sound (2.1%).

Table 2. The percentage of each stock group at each location.

Genetic stock group	Chignik	Kodiak	Yakutat	Sitka	Craig
North/Mid Oregon coast	0.0%	3.3%	0.0%	19.5%	6.4%
Snake River fall	0.0%	0.0%	0.0%	0.8%	0.0%
Upper Columbia River summer/fall	7.5%	11.0%	6.3%	32.0%	19.1%
Willamette River sping	0.0%	7.7%	18.8%	0.0%	0.0%
West Cascade spring	0.0%	2.2%	2.1%	0.0%	0.0%
West Cascade fall	0.0%	1.1%	2.1%	2.3%	10.6%
South Puget Sound	0.0%	0.0%	0.0%	0.0%	2.1%
South Thompson River	0.0%	4.4%	0.0%	12.5%	4.3%
West Vancouver Island	70.0%	9.9%	41.7%	15.6%	36.2%
East Vancouver Island	0.0%	0.0%	2.1%	2.3%	4.3%
Southeast Alaska	22.5%	60.4%	27.1%	14.8%	17.0%

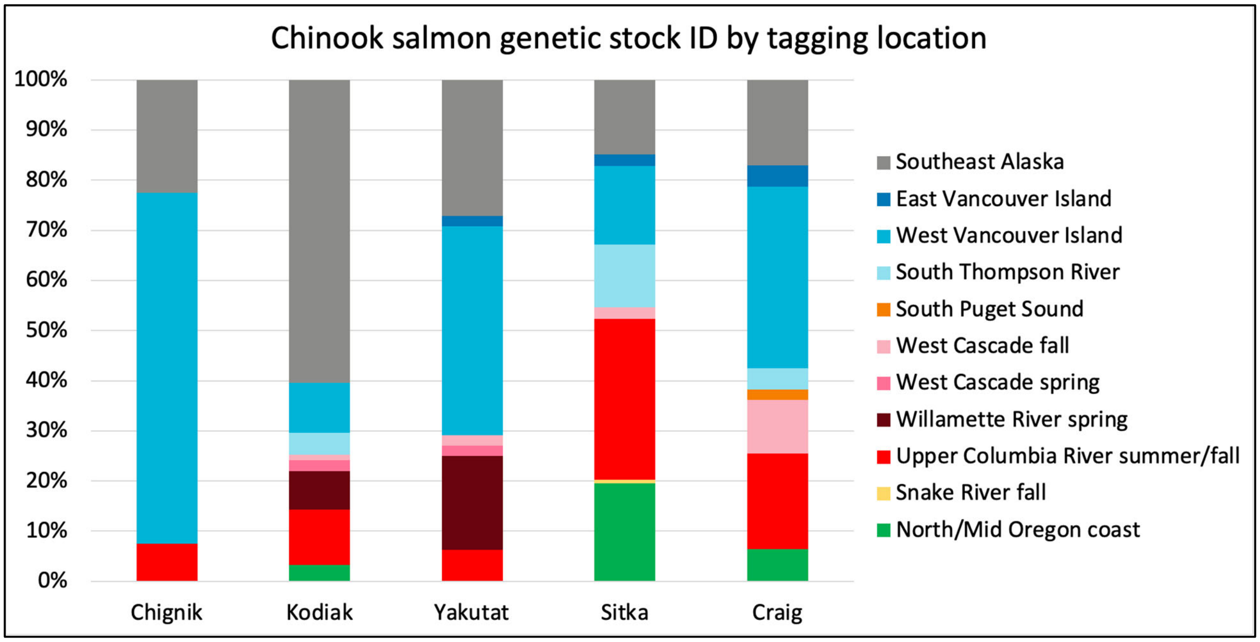

Figure 2. Stacked bar plot showing the percent of different genetic stock IDs captured at each of the tagging locations. Colors indicate genetic stock ID.

Genetic analysis identified three genetic stocks that are within ESUs listed as threatened under the ESA. These include South Puget Sound (n=1 in Craig), Snake River fall (n=1 in Sitka), and Willamette River spring (n = 7 in Kodiak, n = 9 in Yakutat). Additionally, Oregon Coast fish which are a candidate for ESA listing were tagged (n = 3 in Kodiak, n = 25 in Sitka, and n = 3 in Craig)

We have detected 61 (20.5%) out of 298 acoustically tagged Chinook salmon (Kodiak = 10, Yakutat = 5, Chignik = 4, Craig = 12, Sitka = 30). Individuals were detected 18 to 804 days after tagging (Table 3). The detection trajectory of each of the 61 detected fish is presented in the supplementary material at the end of this document. Fish were detected within the Pacific Northwest waters between March and October, except for May (Figure 3). The Lower Columbia River ESU was detected in Pacific Northwest waters (Canadian and Washington Coast) in August and October. The Upper Willamette River ESU fish were detected in Pacific Northwest waters in April, June, and July. The Oregon Coast ESU fish were detected in the Pacific Northwest waters in September and October. Fish were detected on receivers within the NWTT between June and October (Figure 4). The Upper Willamette River ESU fish were detected by receivers within the NWTT in July. The Oregon Coast ESU fish were detected by receivers with the NWTT in September and October.

Table 3. The unique fish ID, tag date, fork length (cm), ESU, number of detections, number of unique stations, date of last detection, and number of days from tagging until the last detection for each detected Chinook salmon.

Unique fish ID	Tag date	Fork length (cm)	Genetic stock	ESU	Detections	Stations	Last detect date	Days to last detect
Chignik_013	8/15/21	53	W_Vancouver_Is	NA	490	7	10/22/22	433
Chignik_017	8/15/21	62	W_Vancouver_Is	NA	56	8	10/18/22	429
Chignik_033	8/17/21	71	W_Vancouver_Is	NA	30	2	10/30/23	804
Chignik_035	8/17/21	58	W_Vancouver_Is	NA	17	2	9/2/23	746
Craig_007	5/28/22	68	SSE_AK	NA	1	1	8/28/22	92
Craig_009	5/28/22	72	W_Vancouver_Is	NA	263	5	9/13/22	108
Craig_013	5/28/22	64	SSE_AK	NA	59	2	9/6/22	101
Craig_014	6/7/22	71	NA	NA	21	3	9/6/22	91
Craig_018	5/26/22	70	NA	NA	30	4	9/19/22	116
Craig_027	6/8/22	66	W_Cascade_fa	Lower Columbia River	46	3	10/7/23	486
Craig_028	6/11/22	74	W_Vancouver_Is	NA	1	1	9/7/22	88
Craig_033	6/11/22	44	U_Columbia_R_su/fa	Upper Columbia River Summer/Fall	63	5	9/15/22	96
Craig_036	6/10/22	59	S_Thompson_R	NA	16	3	7/25/22	45
Craig_041	6/11/22	54	NA	NA	2562	6	10/26/22	137
Craig_045	6/8/22	75	W_Vancouver_Is	NA	38	3	10/18/22	132
Craig_046	6/7/22	63	W_Vancouver_Is	NA	13	4	9/3/22	88
Kodiak_010	10/18/20	59	SSE_AK	NA	45	1	5/14/21	208
Kodiak_029	10/18/20	69	W_Vancouver_Is	NA	197	14	11/5/20	18
Kodiak_047	10/21/20	65	U_Columbia_R_su/fa	Upper Columbia River Summer/Fall	11	4	9/3/21	317
Kodiak_048	10/21/20	74	U_Columbia_R_su/fa	Upper Columbia River Summer/Fall	104	7	3/4/21	134
Kodiak_061	10/24/20	65	NA	NA	3	1	7/13/21	262
Kodiak_064	10/24/20	72	S_Thompson_R	NA	1	1	3/5/21	132
Kodiak_065	10/24/20	64	SSE_AK	NA	16	3	8/25/21	305
Kodiak_068	10/24/20	66	Northern	NA	402	10	4/21/21	179

Kodiak_075	10/24/20	63	SSE_AK	NA	124	6	3/23/21	150
Kodiak_077	10/24/20	73	Willamette_sp	Upper Willamette River	17	2	6/25/21	244
Sitka_017	6/16/22	63	N/Mid_OR_Coast	Oregon Coast	76	4	10/4/22	110
Sitka_019	6/17/22	68	W_Vancouver_Is	NA	11	3	9/7/22	82
Sitka_022	6/17/22	67	W_Vancouver_Is	NA	20	1	8/7/22	51
Sitka_023	6/17/22	71	S_Thompson_R	NA	5	1	8/25/22	69
Sitka_035	6/17/22	74	S_Thompson_R	NA	619	9	10/20/22	125
Sitka_038	6/17/22	73	U_Columbia_R_su/fa	Upper Columbia River Summer/Fall	64	8	9/7/22	82
Sitka_042	6/17/22	68	N/Mid_OR_Coast	Oregon Coast	44	3	9/30/22	105
Sitka_044	6/17/22	69	N/Mid_OR_Coast	Oregon Coast	2	1	9/4/22	79
Sitka_047	6/19/22	70	U_Columbia_R_su/fa	Upper Columbia River Summer/Fall	37	3	9/4/22	77
Sitka_048	6/19/22	73	S_Thompson_R	NA	16	4	7/11/22	22
Sitka_051	6/18/22	65	U_Columbia_R_su/fa	Upper Columbia River Summer/Fall	100	10	9/13/22	87
Sitka_052	6/18/22	63	NA	NA	24	3	8/17/22	60
Sitka_053	6/22/22	79	U_Columbia_R_su/fa	Upper Columbia River Summer/Fall	35	4	9/4/22	74
Sitka_054	6/19/22	70	S_Thompson_R	NA	29	4	8/22/22	64
Sitka_056	6/19/22	62	U_Columbia_R_su/fa	Upper Columbia River Summer/Fall	72	5	8/24/23	431
Sitka_057	6/18/22	75	NA	NA	25	2	8/6/22	49
Sitka_060	6/20/22	69	U_Columbia_R_su/fa	Upper Columbia River Summer/Fall	69	6	9/8/22	80
Sitka_065	6/20/22	59	U_Columbia_R_su/fa	Upper Columbia River Summer/Fall	25	3	6/25/23	370

Sitka_066	6/15/22	59	W_Vancouver_Is	NA	36	7	9/18/22	95
Sitka_070	6/14/22	73	NA	NA	22	2	9/15/22	93
Sitka_073	6/14/22	67	U_Columbia_R_su/fa	Upper Columbia River Summer/Fall	53	7	6/30/23	381
Sitka_074	6/14/22	69	U_Columbia_R_su/fa	Upper Columbia River Summer/Fall	57	4	9/12/22	90
Sitka_077	6/14/22	70	U_Columbia_R_su/fa	Upper Columbia River Summer/Fall	125	8	9/14/22	92
Sitka_080	6/14/22	70	NA	NA	107	10	8/28/22	75
Sitka_082	6/15/22	63	N/Mid_OR_Coast	Oregon Coast	59	4	9/24/22	101
Sitka_085	6/15/22	59	NA	NA	238	5	9/4/22	81
Sitka_092	6/15/22	69	NA	NA	73	7	8/28/22	74
Sitka_093	6/16/22	69	U_Columbia_R_su/fa	Upper Columbia River Summer/Fall	20	1	7/20/23	399
Sitka_097	6/15/22	56	NA	NA	18	2	9/1/22	78
Sitka_098	6/16/22	58	U_Columbia_R_su/fa	Upper Columbia River Summer/Fall	17	3	9/17/22	93
Yakutat_001	3/9/21	84	Willamette_sp	Upper Willamette River	23	4	7/8/21	121
Yakutat_005	3/8/21	70	U_Columbia_R_su/fa	Upper Columbia River Summer/Fall	23	4	8/22/21	167
Yakutat_012	3/26/21	79	Northern	NA	18	2	6/11/21	77
Yakutat_018	3/9/21	67	Willamette_sp	Upper Willamette River	24	3	4/24/21	46
Yakutat_026	3/8/21	70	W_Vancouver_Is	NA	37	4	8/16/21	161

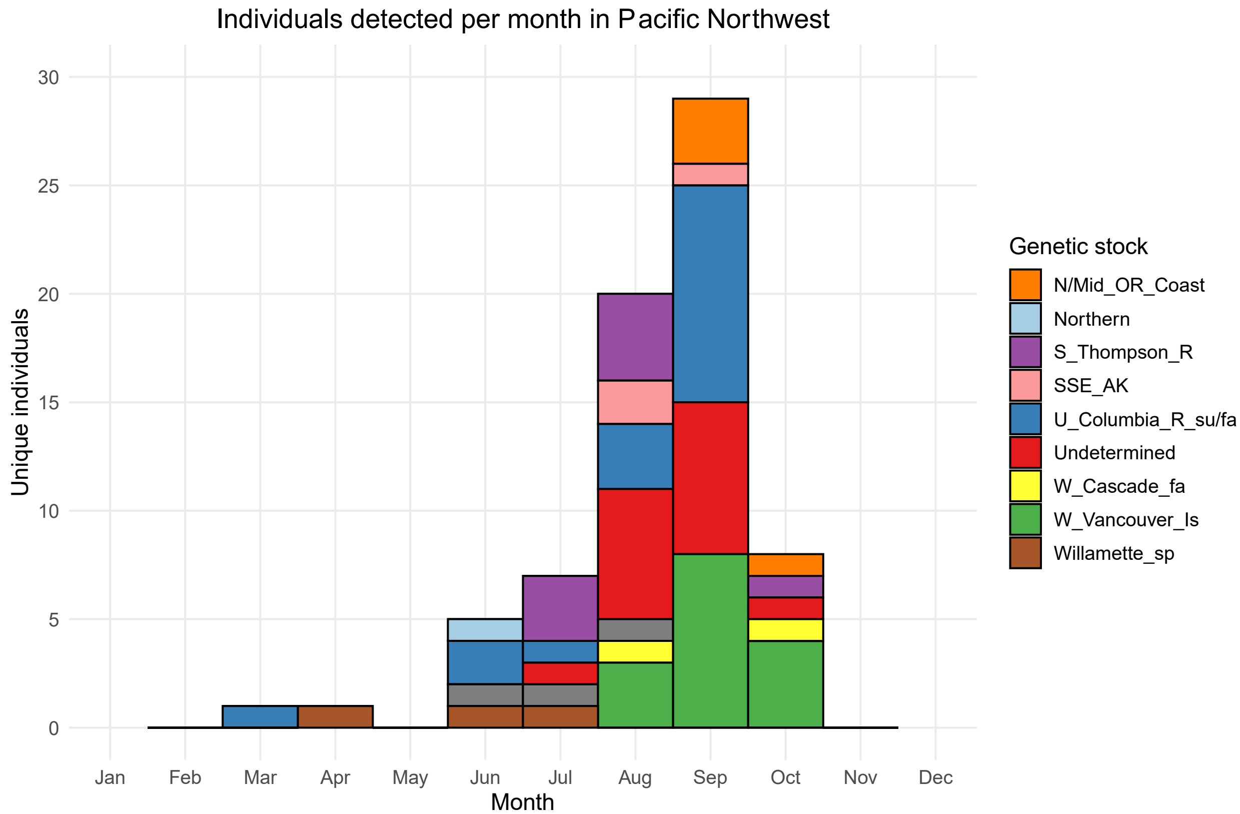

Figure 3. The number of unique individuals detected by month within the Pacific Northwest (Canada, Washington, Oregon). Colors indicate the genetic stock.

Conclusion

This study focused on Chinook salmon migration tagged in the Gulf of Alaska provides promising insights into their migratory patterns and behavior by utilizing acoustic tags and genetic stock identification. There were 11 different genetic stocks captured at five different tagging locations across the Gulf of Alaska. There were two ESA threatened ESUs (Lower Columbia River and Upper Willamette River) and one candidate ESU (Oregon Coast) captured in Gulf of Alaska. We successfully tracked individual fish as they transit through the Navy's NWTT Study Area and found that individuals were detected by receivers within the NWTT from June to October, with most individuals detected in the NWTT in August (n = 8) and September (n = 6). The study showcases the potential of this approach to determine the timing of Chinook salmon presence within the NWTT which can help mitigate potential impacts of Navy activities on the migration of Chinook salmon and other marine species.

These results contribute to future conservation and management efforts aimed at striking a balance between the U.S. Navy's mission requirements and the protection of protected marine life in the Pacific Northwest region. The collaboration and communication between NOAA Fisheries and the U.S. Navy have been crucial in achieving these shared objectives. The data generated from this study can inform the development of adaptive strategies and protective measures for the marine ecosystem within the NWTT Study Area, ensuring the effectiveness of Navy activities while safeguarding vulnerable marine species.

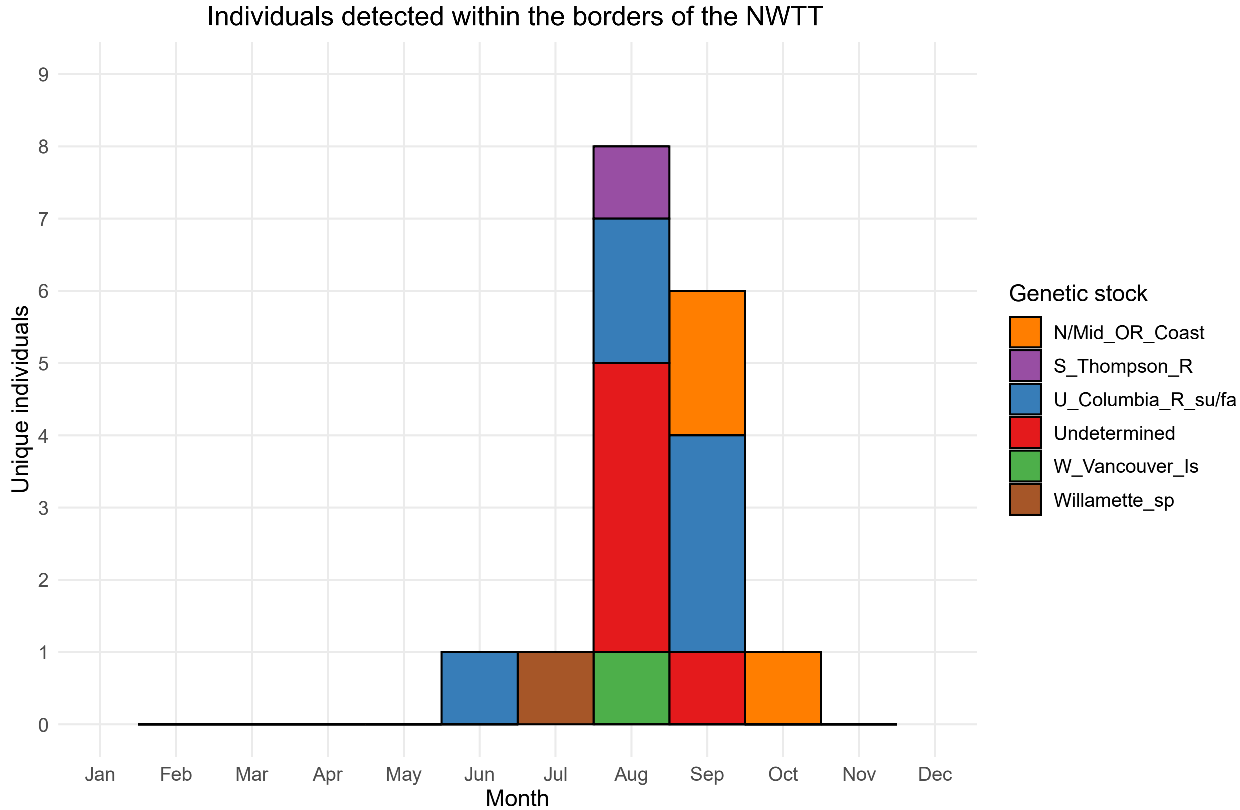

Figure 4. The number of unique individuals detected by receivers within the NWTT. Colors indicate the genetic stock.

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Supplementary Material

The following pages are the detection histories for each acoustically tagged Chinook salmon that was detected after tagging. The top left of each plot gives the unique fish ID, fork length (cm), release date, and genetic stock of the fish. The release locations are indicated with a dark green circle and is connected to the first detection location by a dark green dashed line. The left plot is a zoomed-out view to show the full extent of detection history, and the right plot is zoomed in to show the detailed movements of each Chinook salmon and has the NWTT outlined in red. The color of the circles indicates the month and year of detection and detections are connected by lines base on detection time.