Nearshore Survey of the Coastal Pelagic Species Assemblage off Washington, Oregon, Northern California, 2021

Results of an Industry-Initiated Collaborative Project

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F/V *Lisa Marie*

Andy Blair, Owner
Ricky Blair, Captain

Westcoast Pelagic Conservation Group (WCP)

NOAA – Southwest Fisheries Science Center

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Introduction

The California Current Ecosystem—stretching from British Columbia to Baja California—is a highly dynamic ecosystem, with oceanographic factors driving fluctuations in species abundance and distribution (Chavez 2017, King 2011). This natural variability contributes to the challenge of assessing and managing fish populations, particularly Coastal Pelagic Species (CPS) such as Pacific sardine (*Sardinops sagax*) and Northern anchovy (*Engraulis mordax*), which fluctuate significantly in abundance in response to environmental changes. The NOAA Southwest Fisheries Science Center (NOAA-SWFSC) California Current Ecosystem Survey (CCES) employing advanced acoustic technology coupled with trawling is a critical tool for understanding the abundances and distributions of CPS along the U.S. west coast. This acoustic-trawl method (ATM) survey provides data for constructing the only index of abundance used in CPS stock assessments. In addition to CPS serving as vital links in marine food webs, CPS fisheries deliver important economic benefits to U.S. west coast fishing communities (PFMC 2021).

Commercial fishing for Pacific sardine dates from the 1860's off California and by the 1930's – 1940's the fishery was landing 25% of all commercially caught fish by weight in the United States (PFMC 2021). In Washington, sardines were first harvested in 1936 and through the heyday of the "cannery row" era, up to 1950 (PMFC 1948). Then, due to a combination of less favorable oceanographic conditions and over-exploitation, the population began to collapse and contracted its range to southern California. The California fishery closed in 1968. A population rebound was evident by the 1990s and sardine were again observed as far north as British Columbia (McFarlane 2005). The latter part of the 1990s saw continued expansion of sardine into waters off Oregon and Washington sufficient to support commercial fishing once again (PMFC 2021). In this uncertain and dynamic context, high-quality data to inform assessments are essential to CPS conservation and fishery sustainability.

On the U.S. west coast, CPS fisheries are managed through the Pacific Fishery Management Council under its Coastal Pelagic Species Fishery Management Plan (CPS FMP). As the sardine population experienced another boom-and-bust cycle from the late 1990's to 2015 (Figure 1), not surprisingly interactions among fishers, scientists, and managers over this period were marked by varying degrees of skepticism and contention regarding the stock assessments, the scientific methodologies that informed them, and fishermen's observations of CPS finfish behavior and stock dynamics. Born out of long-running tension and concern that management actions prescribed by the CPS FMP were reducing allowable catch, the West Coast Pelagic Conservation Group (WCP) was organized by Pacific Northwest (PNW) based fishermen and seafood processors in 2016.

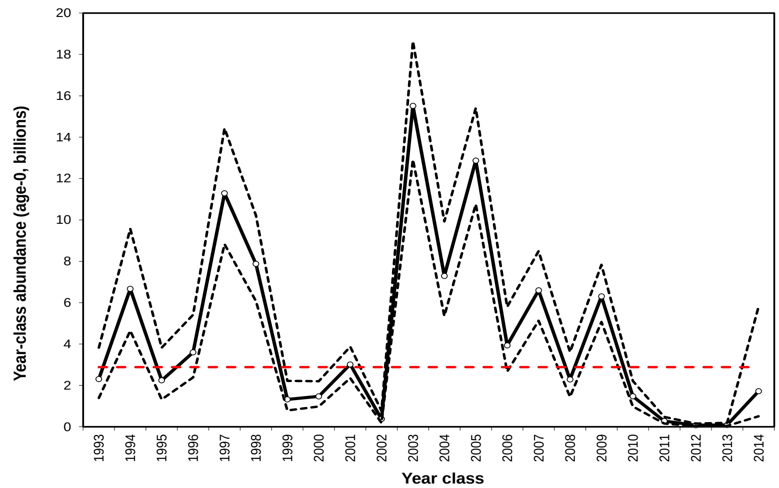

Figure 1. Pacific sardine recruitment trends from 1993 through 2014, from Assessment of the Pacific Sarine Resource in 2015 for USA Management in 2015-2016, Hill et. al. 2015. The red line represents R-zero or model estimate of recruitment in the absence of fishing.

Central to its genesis, was the WCP's dual interest in better understanding the science informing sardine management and in incorporating fishermen's expertise into the process. Of particular concern for industry was the lack of NOAA-ATM survey coverage of nearshore waters, where commercial CPS fishers routinely observed and harvested sardine. Proceeding from previous industry-led research (NWSS 2013), WCP initially conducted aerial flights to photograph and document nearshore sardine biomass off the PNW coast. Dissatisfied with the outcome, WCP, after conferring with NOAA-SWFSC, altered its approach. Instead, under direction of NOAA-SWFSC scientists, the WCP outfitted a commercial purse seine vessel to conduct complementary nearshore acoustic/seine transects off Washington in conjunction with the 2017 NOAA-ATM survey. Adding project management and biological support from the Washington Department of Fish and Wildlife (WDFW) in 2019, the WCP surveyed the CPS assemblage off Washington, Oregon, and Northern California.

The concept of fishermen and fishery scientists cooperating is not novel and dates from 1900 and some of the earliest fisheries work in the United States (NRC 2004). Yet, as evidenced by the number of articles published in scientific literature over the past twenty years, interest in partnering arrangements compared to previous decades has grown considerably (Steins 2019). Partnerships like this one, that evolved between the WCP, NOAA-SWFSC, and WDFW, have been identified as a means of expanding federal fisheries research capacity in order to address the need for timely and accurate data; and that by leveraging fishermen's expertise, the science informing management may be improved and trust fostered (NOAA 2023). In general usage, the terms "cooperative" and "collaborative" may be synonymously used to describe such partnerships. However, in relation to fisheries research they typically mark a continuum from limited fisher involvement in execution, i.e., cooperative, on one end to full participation or collaboration in developing the research project at the other (NRC 2004). This multi-faceted project embodies elements of both and in the Discussion section we address some of the benefits and challenges of this industry-federal-state venture.

Established in 1954, the Saltonstall Kennedy (SK) program funds U.S. marine fishery research. This report presents the work accomplished in 2021 under SK grant NA20NMF4270167 *Utilize an industry-seine fishing vessel to enhance data collection and improve assessment of Pacific Coast Coastal Pelagic Species.* The original award and plan to conduct this project in 2020 were postponed due to the Covid-19 pandemic and cancellation of the NOAA CCES survey for human health and safety concerns. During the interim, WCP, F/V *Lisa Marie*, and WDFW adapted shipboard operational guidelines for crew and staff to prepare for the additional challenge posed by the pandemic when field operations resumed in 2021.

How this Report is Organized

The first section, Background, relates the research questions and concerns that motivated WCP to pursue this project. The work accomplished by F/V *Lisa Marie* under this SK grant fulfilled two separate tasks dubbed "Part 1" and "Part 2" and these are described in Project Objectives. Appendix A provides a high-level summary of the work accomplished under Part 1. Although Part 1 work was funded by the SK award, the survey was conducted wholly in conjunction with the NOAA-SWFSC. The objective of Part 1 was to complete the nearshore survey and deliver the acoustic, catch, and biological data to NOAA-SWFSC, thus no analyses or results are reported here. The remaining sections – Methods, Results, and Discussion – relate mostly to Part 2 which encompassed the field work accomplished independently by the WCP, F/V *Lisa Marie*, and WDFW with analytical support by NOAA-SWFSC.

Background

The acoustic trawl survey method (ATM) uses sophisticated hull-mounted instruments to identify CPS by sending sound signals through the water column and receiving the distinctive "echoes" off the highly reflective swim bladders of CPS, and then uses trawl catch to apportion the CPS acoustic backscatter signal or echoes by species (Stierhoff et al. 2020). Although the NOAA-ATM survey employs the latest in technology and the design has been endorsed for informing CPS biomass (PFMC 2018), it has certain limitations. First, due to safety concerns, the NOAA research vessel (FSV *Reuben Lasker*) does not survey acoustically in waters shallower than 20 meters (m), and does not trawl in waters shallower than 50 m. As CPS distribution is known to extend into much shallower depths, a point of concern – the potential bias of survey estimates of CPS biomass – has been identified in peer reviews of the ATM survey and in Pacific sardine stock assessments, by the Pacific Fishery Management Council Scientific and Statistical Committee, and fishermen (PFMC 2018, 2018a).

A second limitation relates to gear. Species and size composition sampling is conducted with surface trawl gear at night after the daytime acoustic portion of the survey. Small catches with trawl gear have been noted as a concern in ATM survey and stock assessment reviews because sardine population models and projection forecasts rely on age and size-at-age information, (PFMC 2017, PFMC 2018b). In contrast to the NOAA research vessel, industry-operated purse seine vessels can fish in waters as shallow as six meters which, in some cases where the continental shelf is broad, may be over 10 miles closer to shore than the 20-50 m depth curve. Industry seiners can collect large numbers of fish specimens and release un-sampled catch with low mortality. Seiners can also be equipped to collect acoustic data in nearshore waters.

Recognizing these limitations and opportunities, NOAA-SWFSC collaborated with the WCP in 2017 and 2019 to conduct a new project to capitalize on the abilities of fishermen, their vessels, and their specialized harvest equipment. The pilot proved successful, demonstrating an effective proof-of-concept for a collaborative survey methodology. The approach – using an industry vessel to sample (acoustic and biological) the nearshore – has been cited among preferred methods for addressing the potential bias of the ATM survey because it supports direct synoptic observation of the nearshore CPS assemblage and is most comparable to that survey (PFMC 2019).

The seasonal timing of the NOAA-ATM survey was also of interest to PNW fishers with experience in the primary sardine purse seine fishery (from 2000 to its closure in 2015). They opined the early summer (late June-July) ATM survey was conducted too early based on fishing observations. Management of Pacific sardine allocates the annual coastwide (Washington, Oregon, California) harvest guideline to three periods (beginning January 1, July 1, September 15). Once the period allocation is attained, the fishery closes until the next period. In some years, period allocation closures constrained fishing in the PNW, i.e., the January 1 period allocation was achieved by fishers off California before sardine were present in commercially viable amounts off Oregon and/or Washington. However, even when the fishery remained open throughout an allocation period, sardine landings typically did not occur in the Washington fishery until late June, and generally peaked around August and September and, in some years, continued through October. From this perspective, WCP as part of this project sought to explore temporal differences in the nearshore assemblage off Washington, particularly for the presence of Pacific sardine, by repeating the survey in mid-late August.

Project Objectives

The overarching goal of this project was to expand survey spatial coverage for Pacific sardine and other CPS via collaborative fisheries research, in order to facilitate and improve sustainable management and to provide environmentally compatible socioeconomic benefit to CPS harvesters and processors. This aligned with the 2019 SK program Priority #2 Science or Technology that Promotes Sustainable U.S. Seafood Production and Harvesting. The founding role that industry had in this project also links it with the Priority #1 – Promotion, Development, and Marketing. In publicizing the results of the project, marketing strategies can strongly position US producers and appeal to consumer values by demonstrating industry's commitment to ensuring sustainably sourced seafood.

Composed of two parts, the goal of this study was to accomplish the nearshore survey in conjunction with the SWFSC to address needs identified in methodology peer reviews, and separately address concerns and questions posed by industry.

Part 1 – Complimentary Nearshore Survey with NOAA FSV Reuben Lasker, 2021

Part 1 of the project was accomplished wholly under the guidance of NOAA-SWFSC CCES (Renfree 2022). The deliverables for this aspect of the project included acoustically surveying nearshore transects from the U.S.-Canada border to Bodega Bay, California following prescribed procedures and collecting species composition and biological data from acoustically observed CPS. F/V *Lisa Marie* accomplished the acoustic survey July 16, 2021 to August 5, 2021, and all data were provided to NOAA-SWFSC. These data were included in the summer 2021 ATM estimate of biomass (Kuriyama 2022). A NOAA-SWFSC blog of the 2021 CCES can be found at 2021 California Current Ecosystem

Survey | NOAA Fisheries, and brief summary of F/V *Lisa Marie* Part 1 work is presented in Appendix A.

Part 2 – Survey of Washington Nearshore CPS Assemblage, WCP and WDFW

The F/V *Lisa Marie* repeated survey of the nearshore distribution of CPS biomass along transects only off Washington between August 18 and 26, 2021. The same 25 Washington transects from Part 1 were surveyed and for this report are referred to as "primary" lines. In addition, 25 "intermediate" transect lines which fell between primary lines were acoustically surveyed specifically to support Part 2 study objectives. These objectives included:

- a qualitative comparison of the nearshore CPS assemblages between Part 1 and Part 2,
- evaluate an alternative purse seine set timing by modifying standard survey protocols to allow opportunistic setting on putative CPS encountered on a transect,
- evaluate for interference with simultaneous operation of sonar and acoustic equipment,
- and as a chief objective, assess the sample sizes (number of scoops) needed to collect representative species and size compositions.

In this report, we present our findings including vessel captain observations, sampling strategy results, and share insights on the successes and challenges of our collaboration.

Methods

Some methods described here pertain to both Part 1 and Part 2 of the project. Aspects of the coordination process and acoustic equipment or echosounder specifications were applicable to both. The remaining sections describe when and how methods in Part 2 differed from Part 1.

Coordination Process

Frequent and extensive communication between NOAA-SWFSC, WCP, F/V *Lisa Marie*, and WDFW staff was vital to this project's success. Beginning in early 2021, staff members from all organizations began having check-ins via phone, email, and/or video conferencing to develop and report on the progress of contracts, permitting, staffing, scheduling, training, onboard responsibilities, and data collection procedures. WCP coordinated contracting with SWFSC, with F/V *Lisa Marie*, and with WDFW. Together, WDFW and WCP completed applications for state (Oregon and California) scientific collection permits and federal exempted fishing permits. The SWFSC provided WDFW staff protected species compliance training to ensure that all protected species were handled according to established protocol. WDFW developed species composition and biological data collection protocols for inclusion in the overall SWFSC ATM project manual. WDFW also conferred with California Fish and Wildlife staff involved in a separate but similar project with California industry (Renfree 2022) to standardize sampling methods and data collected where possible.

Prior to the start of Part 1, SWFSC staff calibrated F/V *Lisa Marie's* echosounder in Yaquina Bay, Oregon on June 5, 2021. Once calibration was complete, WDFW staff was in contact with both SWFSC staff and F/V *Lisa Marie* staff to ensure that all settings and instructions were understood prior to the departure of the vessel from port.

Once underway, WDFW biologists onboard the vessel were responsible for notifying each state once its waters were entered and ensuring that survey activities, either acoustic data collection and/or seining, were consistent with regulatory restrictions for various marine protected areas. Daily coordination between FSV *Reuben Lasker* and F/V *Lisa Marie* was accomplished by WDFW staff who emailed location information and set details (location and species captured) to SWFSC. Finally, shore based WDFW project managers were available on standby to provide general guidance as needed or to address specific unanticipated circumstances with sampling.

Echosounder

The F/V *Lisa Marie* was outfitted by NOAA-SWFSC with a Simrad EK80 General Purpose Transceiver (GPT) connected to F/V *Lisa Marie*'s Simrad 38 kHz transducer (ES38-B), and Furuno CH-250 sonar transceiver. In advance of fieldwork, a NOAA-SWFSC acoustician installed, tested, and calibrated the EK80 recording system. NOAA-SWFSC and vessel captain tested equipment to evaluate any crosstalk between the vessel's sonar and the echosounder. The echosounder system sampled acoustic backscatter from CPS between 5 and 60-m isobaths along survey grid transects.

Survey Grid

Starting at Cape Flattery and ending at approximately the Washington-Oregon border, the Part 2 survey grid was comprised of 50 total transect lines. The survey grid included the same 25 NOAA-SWFSC transects from Part 1. These primary transects were spaced 5 nautical miles apart (Appendix B. Table 1, Figure 2). For Part 2, 25 intermediate lines at 2.5 nmi intervals were added to increase coverage and to allow testing alternative setting approaches and possible sonar interference without compromising the ability to compare acoustic data collected along primary lines during both Parts 1 and 2 of the survey. All 50 transects were nominally 4 nautical miles long. Transect lines were completed in either direction and as near to shore as safely navigable following the planned transect lines. Transiting of each transect occurred on a straight line between inshore and offshore waypoints. Acoustic surveying began most mornings around 0630 PST (sunrise) and ended around 1900 PST (sunset). A WDFW biologist was onboard for the duration to monitor the acoustic equipment, maintain a log of seining operations, and to collect species composition and biological data.

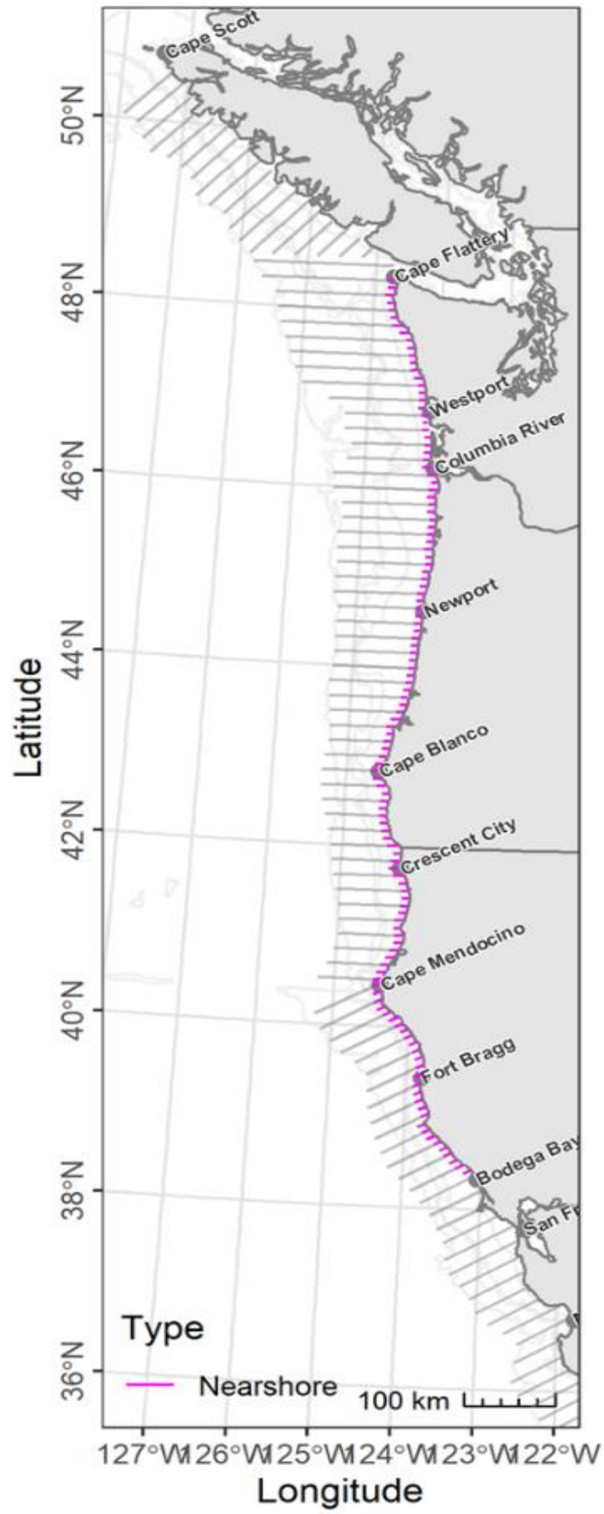

Figure 2. Transect lines (pink) from Cape Flattery, WA to the Columbia River were surveyed by the F/V Lisa Marie August 18 – 26, 2021. Figure courtesy of Kevin Stierhoff, SWFSC.

Alternate Purse Seine Set Timing and Sonar/Acoustic Interference

Part 2 acoustic surveying of transects and purse seine setting strategies followed Part 1 protocols along primary transects. When putative CPS schools were observed in the echogram along primary transects, F/V *Lisa Marie* completed the transect, then used a purse seine net to sample CPS schools in the area as the standard protocol. Due to the temporal and possible spatial lag, schools selected for sampling may not have been the same as those acoustically surveyed. For the alternative setting strategy, along several intermediate transects (i.e., 2.5nmi interval line), acoustic surveillance was paused to set on and sample putative CPS schools observed on the line and resumed once gear was retrieved onboard.

A target of 30 sets was established, but practically the number of sets to be accomplished daily (or in total for the study) was opportunistic, depending on the presence of CPS, the capacity of the biologist to process samples, and the need to fully accomplish all 50 transects during the study period. For each set, to the best ability of the captain, crew, and WDFW staff, the date, time, location, hail, and visual/acoustic approximation of species composition were logged. The F/V *Lisa Marie*'s seine net is approximately 440 meters long and 40 meters deep with a 17-millimeter-wide mesh (A. Blair, pers. comm.).

In addition, on intermediate lines, sonar was left on to detect if it interfered with the acoustic equipment. All Part 2 acoustic data collected from primary and intermediate lines were provided to NOAA-SWFSC for potential future exploration and are not analyzed here.

To avoid or mitigate interactions with protected species, visual watches of fifteen minutes were completed prior to each set. The net was not set around pinnipeds but could be set if only a few were visible in the area. Pinnipeds may be attracted to the net and easily jump into and out of the net; hence, the net was not opened if only pinnipeds entered it. If any dolphins or porpoises were seen within 500 m of the vessel, the move-on rule was applied. If killer whales were seen at any distance, the move-on rule applied. If any cetaceans were seen within the net, the purse was to be opened immediately. The move-on rule was also applied to avoid setting on salmon, even at the cost of forgoing setting on CPS schools. For the duration of this project, no marine mammals were seen within 500 meters of the vessel.

Species Composition Sample Size Assessment

Throughout the day as transect lines were ran, schools of CPS were actively scouted and if seen on the echosounder, were set on either after the transect line was finished (if on a primary line) or immediately upon sight of CPS (if on an intermediate line). Samples of seined fish were taken to determine the species composition of CPS schools and to obtain biological information including weight, length (Northern anchovy and Pacific sardine, standard length; all other species, fork length), otoliths), and macroscopic maturity following California Coastal Pelagic Species Project guidelines (Bishop 2015).

With F/V *Lisa Marie*'s ample deck space, all sets were sampled onboard immediately after capture for species composition and biological information. Standard survey protocols entail collecting three scoops per set. This was established during the pilot effort in 2019 and followed WDFW commercial groundfish sampling protocols in which three baskets are randomly selected from trawl or fixed gear landings to determine species composition of mixed species catches. For this study, ten sequential baskets of one scoop each were attempted per set from spatially different parts of the net (Figure 3). Each basket was individually sorted and speciated, with each species being enumerated and weighed. Once all baskets were sorted, 50 of each CPS species were randomly sampled from the entire species population for individual biological information (weight, length, sex, maturity, and age structure for CPS).

The data were processed by WDFW and transmitted to NOAA-SWFSC for exploratory analysis of species composition and structure. Where CPS were present in a set, species composition and whether more species were observed with successive baskets was evaluated per set by determining the relative weight of each species in each basket (i.e., basket weight/sum (basket weights)) and similarly by determining the relative counts of each species in each basket (i.e., basket count/sum (basket count)). Because length data were not collected from all specimens in a basket, the change in average weight across all baskets for each set was used as proxy for specimen weight to examine changes in size structure across baskets.

Figure 3. Brailing from set (left), dumping brailed scoop into basket (right). Each basket contained one scoop.

Results

The F/V *Lisa Marie* completed surveillance of the Washington nearshore distribution of CPS biomass during Part 1 from July 16 to July 18, 2021. After completion of Part 1 on August 8 in California, F/V *Lisa Marie* returned to Washington and repeated surveillance of only the Washington nearshore from August 18 to August 26, 2021. This represented a 31-day lag between survey events in Washington waters. All acoustic data were submitted to NOAA-SWFSC. Pacific sardine otoliths were submitted to WDFW age readers for immediate analysis, all other collected otoliths were submitted and stored for later analysis as time permits.

Alternate Purse Seine Set Timing and Sonar/Acoustic Interference

Fishing north to south, from Cape Flattery to the Columbia River, respectively, the F/V *Lisa Marie* surveyed the same 25 NOAA-SWFSC prescribed lines from July-August 2021, with the addition of 25 "intermediate" transect lines placed directly between. In total, the F/V *Lisa Marie* completed the planned 50 acoustic transects and 25 purse seine sets on acoustically observed CPS (Appendix B, Tables 1 and 2).

The 25 purse-seine set locations are depicted in Figure 44 (and Appendix B, Table 2). The majority of sets, 76%, were located along the mid to southern Washington coast with clusters off Grays Harbor and at the Columbia River. Bottom depth associated with sets ranged from 9 to 62 meters and surface water temperature ranged from 53.21°F to 59.15°F. Sets were accomplished on each day of the survey. Most sets were initiated between 0900 and 1700 with one set started at approximately 2000. Due to fouled gear, two of the 25 sets were unsuccessful; 19 of the 25 sets were comprised of CPS. In four of the 19 sets, Jack mackerel were noted as having evaded being pursed. Hailed weights – the captain's estimate of wrapped biomass – ranged from 455 kg to 22,700 kg.

To evaluate the practicality of the alternative set timing, the FV *Lisa Marie* completed four sets following the alternative approach (which allowed the vessel to pause acoustic surveillance to set on and sample putative CPS schools observed on the line). The other 19 sets were accomplished following standard protocols (which entails completing acoustic surveillance before any setting activity is initiated). The captain, based on his fishing expertise and experience utilizing the standard approach, did not observe any negative outcomes with the alternative approach.

To evaluate potential interference of the EK 80 by sonar, during Part 1, specific portions of some transect lines were run while the sonar remained on and were noted as such. No noticeable interference was found by the SWFSC upon analysis. For a fuller examination, during Part 2, three intermediate lines were selected and purposely ran with the sonar and the EK80 on simultaneously. The captain and biologist observed for interference as evidenced by visual changes in the EK80 readout. Their observations did not detect any indication of interference.

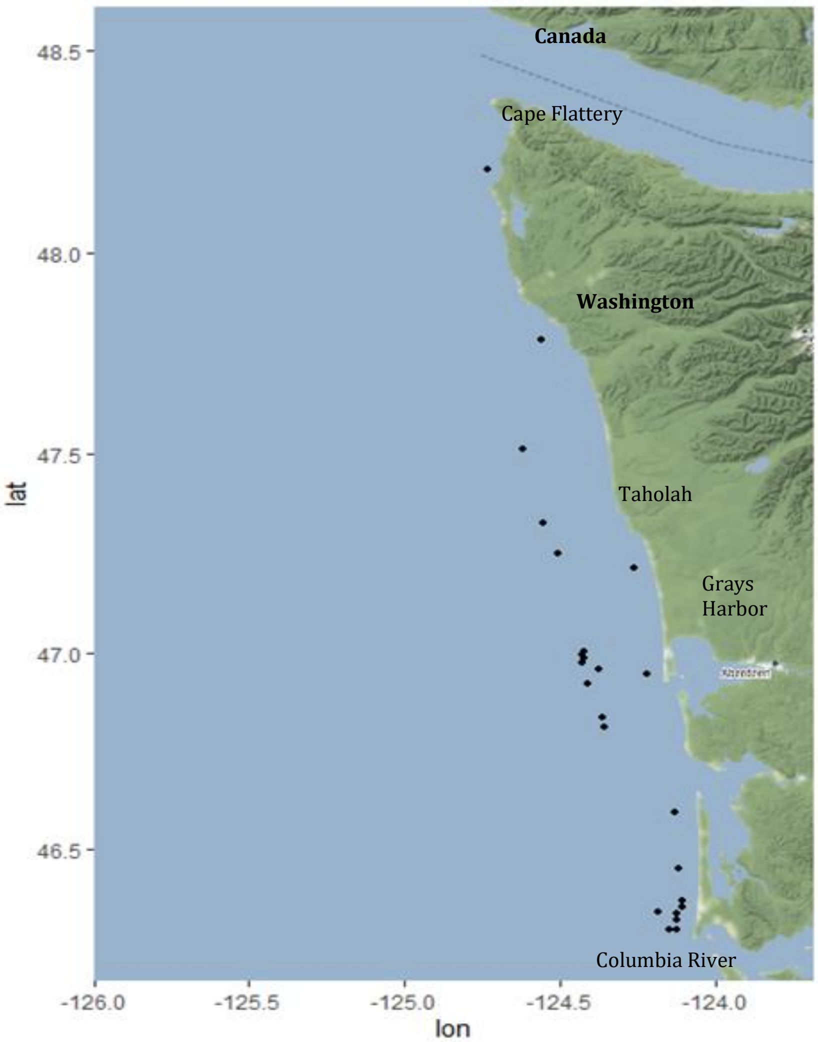

Figure 4. Part 2 set locations, along Washington coast.

Species Composition and Sample Size Assessment

<u>Species and Biological Observations</u>

Catch summed for all 25 sets and all species totaled 684.9kg (Table 1). CPS included six species and totaled 338.5kg (Table 2). Jack mackerel (*Trachurus symmetricus*) and jellyfish (Cnidaria) by weight and frequency comprised most species collected from all sets (Table 1). Only two CPS species occurred in more than one set: Jack mackerel and Pacific herring, 6 sets each (Table 1). All other species occurred in fewer than two sets.

Pacific sardine were collected from a single set on August 21 approximately 10 miles offshore of Taholah, Washington (Figure 5). Northern anchovy[1] were observed in only one set, just north of the Columbia River, and included only four individuals (Figure 5). Notably, when fishing in areas where it was common during prior surveys (2017, 2019) to catch Northern anchovy, mainly Pacific herring were observed (R. Blair, personal communication). Mean weight and length of sampled Pacific sardine (n=50) were 276.6g and 257.6 mm, respectively. Figure 6 plots Pacific sardine and Northern anchovy length to weight, by sex. Figure 7 plots Pacific sardine age at length observed in the August 21 set. For the 50-sardine sample, age ranged from 4 to 11 years, with a median of 6 years.

Eight Chinook salmon were caught on August 25 just north of the Columbia River (at Long Beach, WA, Figure 4). These were sampled for individual weight, length, and adipose fin presence/absence. Mean weight and length for seven fish were 23.8g and 127mm, respectively. The weight and length of the eighth fish were 86g and 184mm, respectively. Adipose fins were present on five. Species wrapped and released from the net unsampled included several adult salmon (spp. unidentified), one blue shark (*Prionace glauca*), one Big skate (*Beringraja binoculata)*, and one ocean sunfish (*Mola mola*). One captured Dungeness crab (*Metacarcinus magister*) was released alive.

1 Two populations of Northern anchovy are found off the U.S. west coast. The Northern subpopulation of Northern anchovy (NSNA) ranges from the Queen Charlotte Islands, British Columbia to approximately Eureka, California. The Central subpopulation (CSNA) ranges from approximately San Francisco, California to Punta Baja, Mexico. The boundary between the two subpopulations overlaps and likely fluctuates seasonally and annually; delineation at San Francisco is done for management purposes (PFMC 1983).

Table 1. Weight (kg) by species in descending order, frequency (number of sets) of observation and in proportion to total number of sets.

Species	Weight (kg)	Frequency (number of sets)	Proportion sets (number sets/25)
Jack Mackerel	232.25	6	0.24
Sea Nettle	228.78	7	0.28
Water Jellies	104.68	7	0.28
Pacific Herring	58.21	6	0.24
Pacific Sardine	46.08	1	0.04
Unidentified Juvenile Smelt	4.91	1	0.04
Fried Egg Jelly	2.34	1	0.04
Pacific Tomcod	1.90	1	0.04
Unidentified Jellyfish parts	1.80	1	0.04
Whitebait Smelt	1.03	2	0.08
American Shad	0.93	2	0.08
Pacific Saury	0.81	2	0.08
Surf Smelt	0.38	1	0.04
Salp	0.29	1	0.04
Chinook Salmon	0.25	2	0.08
Northern Anchovy	0.16	1	0.04
Dungeness Crab	0.07	1	0.04
Unidentified Snailfish	0.02	2	0.08
Pacific Sanddab	0.02	1	0.04
Unidentified Gadid	0.002	1	0.04
Market Squid	0.001	1	0.04
Unidentified Larvae	0.001	1	0.04

Table 2. Weight (kg) CPS only, descending order by frequency (number sets), proportion of total sets, and weight.

Species	Weight (kg)	Frequency (number of sets)	Proportion sets (number sets/25)
Jack Mackerel	232.25	6	0.24
Pacific Herring	58.21	6	0.24
Whitebait Smelt	1.03	2	0.08
Pacific Saury	0.81	2	0.08
Pacific Sardine	46.08	1	0.04
Northern Anchovy	0.16	1	0.04

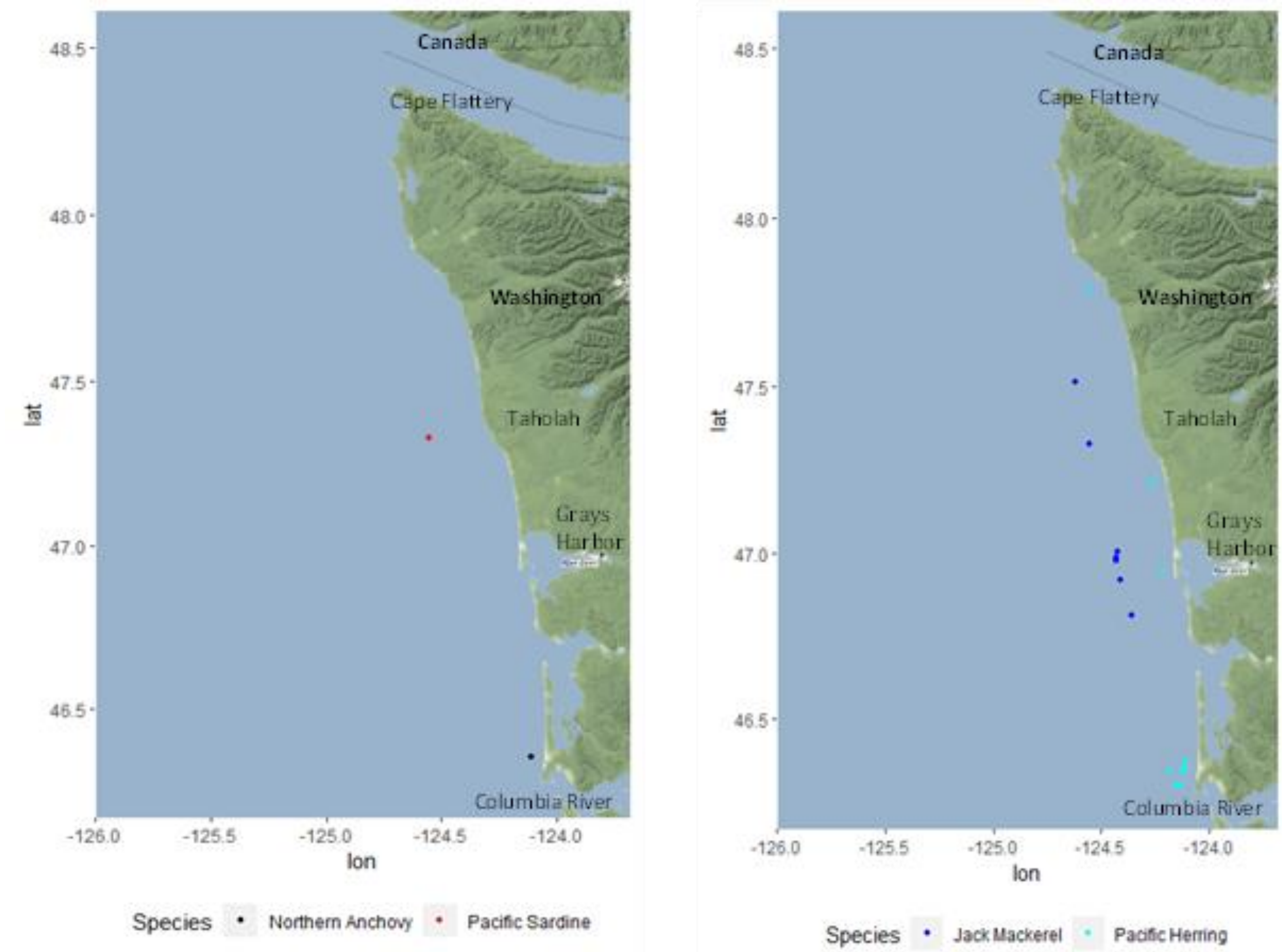

Figure 5. Set locations of sampled Pacific sardine and Northern anchovy (left panel) and Jack mackerel and Pacific herring (right panel), off Washington.

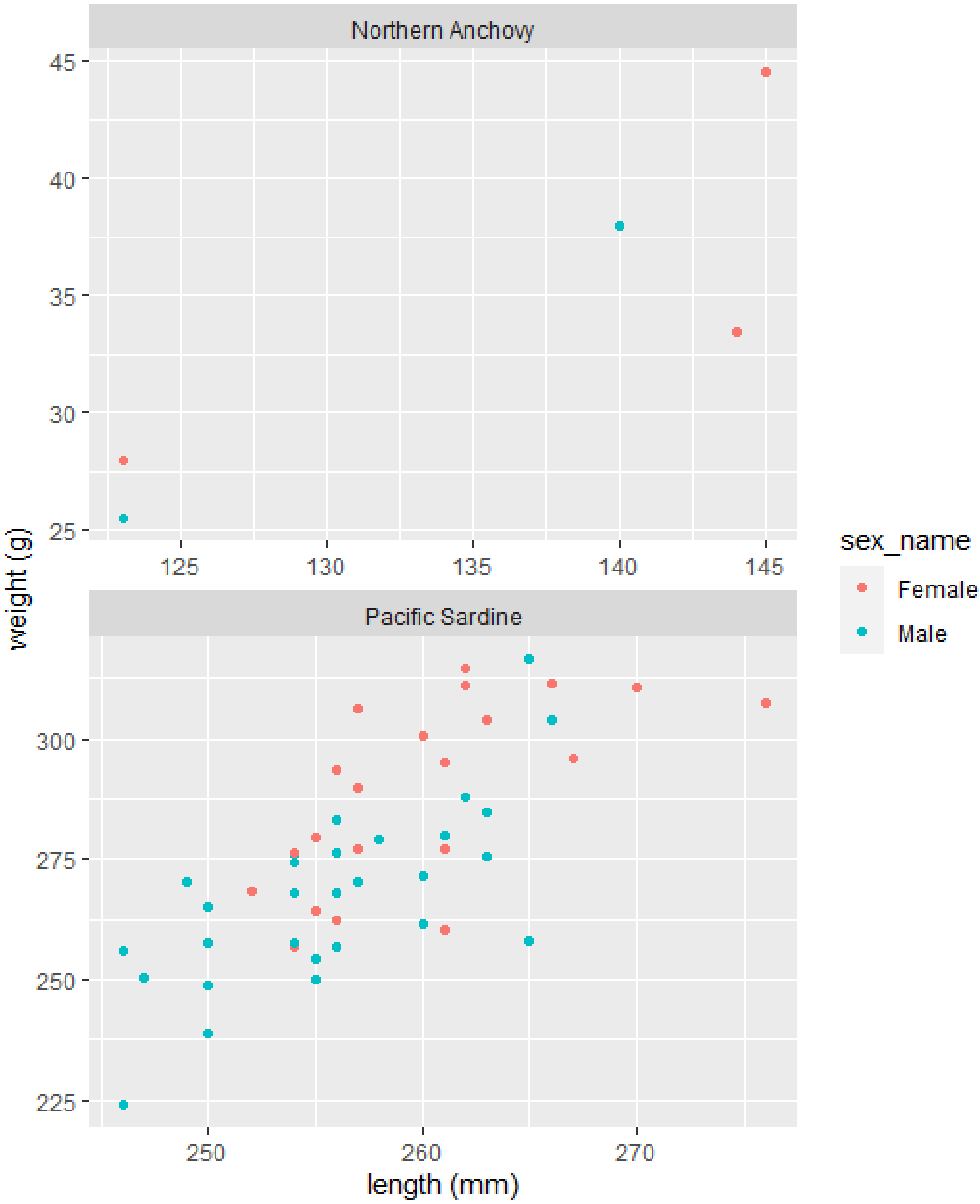

Figure 6. Standard length (mm) and weight (g) by sex of Northern anchovy (top) and Pacific sardine (bottom), sampled during Part 2, August 18-26, 2021.

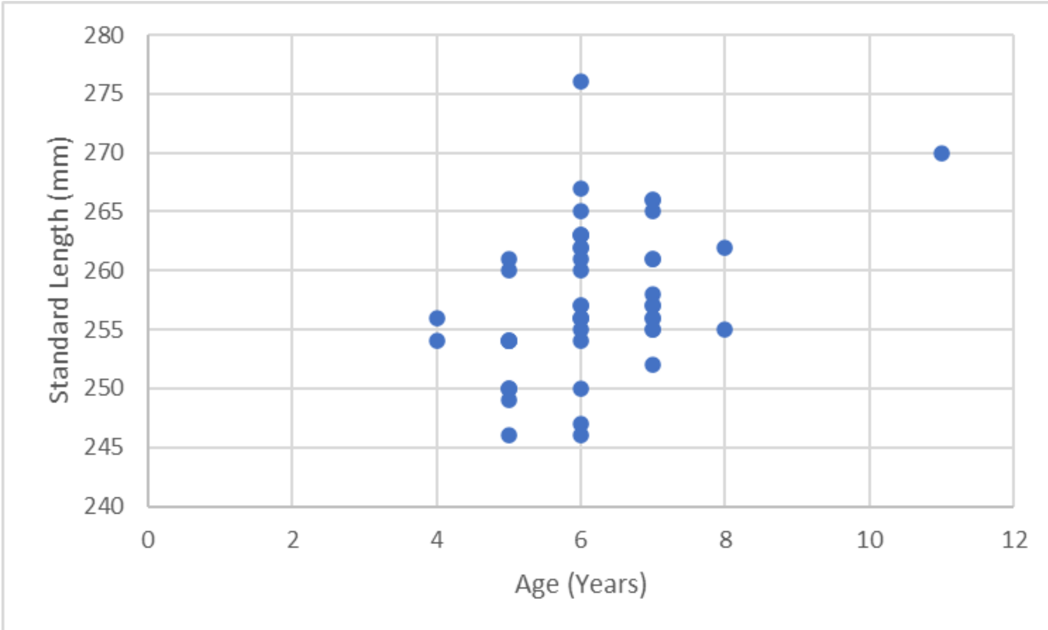

Figure 7. Age at length (mm) of sampled Pacific sardine.

Evaluating CPS Species Composition

Across the 25 total sets, 204 total basket samples were collected. This total is fewer than an expected total of 250 baskets (i.e., 10 baskets per set according to methods) because three sets contained small catches and were fully sampled with fewer than 10 baskets, and two sets were fouled and no species composition sampling occurred. CPS were present in 76 percent or 19 sets and 76 percent or 155 baskets. Considering CPS only, there was little species variability across sets and percent weight and percent count were fairly consistent across baskets within a set (Figure 8 and Figure 9). Of the 19 sets with CPS, 14 were comprised of a single CPS, four included two CPS and only one set included three CPS.

In most baskets with CPS (140), only one CPS was present. However, in three instances a new species occurred after the third basket. Basket samples 1-6 from "2021-08-21 Set 2" contained sardine, and only at basket 7 was a different CPS, Jack mackerel, encountered. Similarly, basket samples 1-6 from "2021-08-23 Set 1" contained only Pacific herring until basket 7, in which whitebait smelt were also present. In the last instance ("2021-08-25 Set 7"), only Pacific herring and Northern anchovy were present in baskets 1-5 before whitebait smelt was encountered in basket 6.

To evaluate CPS size structure across baskets per set, the change in mean weight by species was used as a proxy for specimen weight because individual lengths and weights were not measured for each CPS specimen in a basket (Figure 10). For species occurring in multiple sets, such as Jack mackerel and Pacific herring, size structure represented across baskets 1 – 3 for a given set was generally consistent with size structure in subsequent baskets. In contrast, where a species was rarely encountered, for example, the one set each of Pacific sardine and Northern anchovy, size structure was not consistent across baskets.

Figure 8. Percent or relative weight by set and basket, CPS only. Each panel represents one set, each circle represents a basket.

Figure 9. Percent or relative counts for each CPS species, by set (panel) and basket (circle).

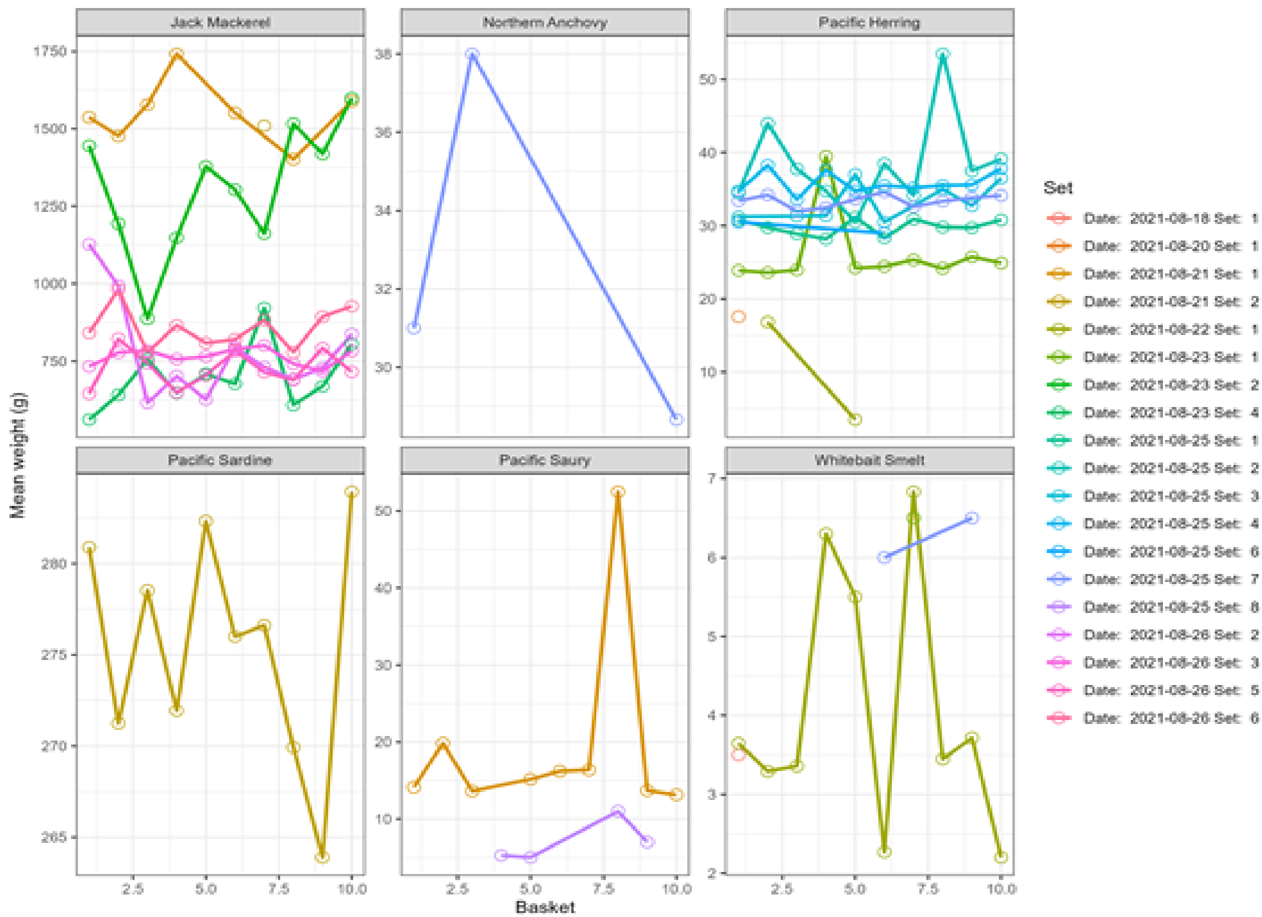

Figure 10. Average weight (g), for each CPS species, by set and basket. Each panel represents a species, each line represents a specific set, and each point a basket.

Discussion

Begun as a proof-of-concept, F/V *Lisa Marie* demonstrated the potential of an industry vessel to complement federal research. To address specific industry concerns and some questions that arose over the initial two years (2017 and 2019), this study (i.e., Part 2) supported an independent survey of the nearshore CPS assemblage of the Washington coast and afforded time for testing not feasible during Part 1. Primary technical matters for exploration included sonar interference with echosounder, setting strategies, and sampling procedures. Insights and experience on collaborative research are shared here as well.

Consistent with commercial CPS fishermen experience, Pacific sardine were observed by F/V *Lisa Marie* in August compared to no observations off Washington in July (Part 1). This supports their understanding of temporal distribution – that sardine are present late summer in Washington waters. Yet, given sardine migratory behavior it cannot be concluded from study results that these fish were not also observed previously by FSV *Reuben Lasker* which caught Pacific sardine in trawls July 18 off Tillamook and Newport, OR (Renfree 2022).

Fishermen use sonar to detect fish and seafloor structure, however, it was uncertain if sonar would interfere with the echosounder (EK80). Qualitative study results did not find any evidence that continuing sonar compromised acoustic data collection. To the extent sonar facilitates efficient operations and detection of fish, allowing it to remain on seems reasonable. Per standard seining protocols, setting on CPS schools follows acoustic surveillance of the transect; for the F/V *Lisa Marie* a transect is completed in two hours. The vessel then either retraces its route to set on putative CPS spotted along the transect or searches while enroute to the next transect. Experience during the 2019 survey spurred interest in testing an alternative approach. The F/V *Lisa Marie* captain asked whether allowing the vessel to interrupt acoustic surveillance to immediately set on observed biomass might improve operational efficiency and effectiveness by reducing search time and/or the likelihood of not locating fish seen while on the transect. Except for adhering to a specific line, this approach is not dissimilar to typical fishing practices. Similar, to the use of sonar, this opportunistic approach may improve operational effectiveness by decreasing the uncertainty of locating CPS when abundance of CPS is low and/or distribution is patchy.

In aligning time of day for conducting acoustic and seine sampling, the F/V *Lisa Marie* demonstrated the feasibility of using a purse seine vessel to address the concern for potential mismatch of species and biological characteristics due to differences in diurnal fish distributions, an issue noted for the ATM survey which pairs daytime acoustics with nighttime trawling. Not unexpectedly, purse seine gear - which is designed to entrap schooling fish such as CPS - was efficient at collecting specimens for size and age information. However, observations during this study also revealed the relative effectiveness of purse seine gear at catching CPS varies with the species. For example, Jack mackerel were observed outrunning the set altogether or escaping as the net was pursed. Consequently, where schools or assemblages of mixed CPS occur, the ability of faster swimming species to evade entrainment could bias the species composition, size/age structure, or both.

Analysis of the species composition by basket show that it was rare for a new species to be encountered after the third basket. However, had only three baskets been sampled, some species present in the set would have been missed, raising the possibility that composition information is lost if too few baskets are taken. However, the logistics of collecting more than three baskets per set need to be considered. Further, the time to sample a set, regardless of the number of baskets, increases depending on how many CPS are present. Sampling CPS includes collecting lengths and otoliths from up to 50 specimens of each species encountered. Working solo, this task may take an experienced biologist from two hours to sort three baskets and collect biological information from one species (i.e., 50 fish) to up to six hours for a haul with multiple CPS species. Alternatively, samples can be frozen for later processing, but this simply shifts and does not reduce workload. Carrying more than one staff onboard as was done during Part 1 is also a possibility, but this is significantly more expensive and accommodating an additional biologist or technician is not inconsequential in terms of impacts to fishing operations as the number of crew need to be reduced to provide bunk space.

Due to the time and effort required to process ten baskets verses three, we recommend an adaptive approach to determine the number of baskets to collect. That is, when a new species is collected in the third basket, additional basket samples should be collected. Our results suggest at least four, however, it may be more practical to collect two supplementary baskets. Additionally, subsampling baskets for individual fish lengths would support direct characterization of size structure. It also should be noted that this study coincided with a period of low biomass of both Pacific sardine and the northern subpopulation of Northern anchovy. Future setting and sampling objectives should anticipate increased workload in circumstances when CPS may be present in multiple sets in a single day. In summary, study results were consistent with fisher experience and expectations that seine gear could produce fish for sampling, yet also demonstrated the logistical constraints to processing large numbers of samples.

Future work surveying the nearshore CPS biomass onboard the F/V *Lisa Marie*, or others interested in pursuing a collaborative project, may benefit from our insights on what we think contributed to achieving positive outcomes from this study. First, the wealth of expertise of NOAA-SWFSC scientists and industry's knowledge of fishery operations were foundational to the success of this study. Industry's desire to foster collaboration and a willingness to heed scientific advice were key. Equally, NOAA-SWFSC was receptive to this interest and provided substantial technical and material support. Second, prior to this study in 2021, project leads invested effort to expand their knowledge of the ATM survey, exemplified by the numerous trips WCP made onboard the FSV *Reuben Lasker* to observe its operations and by WDFW biologists participating as samplers on the FSV *Reuben Lasker* 2015 and 2017. Secondly, in joining forces with WDFW, WCP leveraged agency administrative assistance for grant proposal development and navigating labyrinthine state and federal permitting processes. Additionally, bringing WDFW staff onboard the F/V *Lisa Marie* supplemented NOAA-SWFSC resources and secured comprehensive fishery sampling knowledge including marine species identification, biological data collection, documentation, and processing.

With a project as ambitious and multi-faceted as this, success also rested on good communication. From the outset in 2017 and through this study, WCP and NOAA-SWFSC held in person brainstorming sessions, and regularly exchanged emails and phone calls as did WCP and WDFW. Multiple virtual meetings with WCP, NOAA-SWFSC, and WDFW were held throughout 2020 and 2021. Although no problems arose that undermined the study, and communication amongst WCP, F/V *Lisa Marie*, and WDFW was frequent and thoughtful, we noted a few areas for improvement. These included identifying roles for decision making and scheduling. While overall a significant strength, the study's collaborative structure also meant hierarchy on the F/V *Lisa Marie* was not clear in some instances. For example, different understandings led to some confusion as to whether the captain or biologist had final call to determine when setting might not adhere to marine mammal avoidance "move-on" rules. A pre-departure WCP and WDFW meeting to with all shipboard participants (captain and biologists) included to explore and articulate potential ambiguous decision points and how to resolve them is recommended. Similarly, while Leg 1 survey plans and itinerary provided by the SWFSC were excellent and thorough, expectations by F/V Lisa Marie and WDFW staff did not fully anticipate the need for flexibility once the survey was underway and it wasn't entirely clear who should determine the final survey date or location. Understanding that scheduling once the NOAA-SWFSC survey vessel is underway is subject to many variables (e.g., weather), articulating contingencies nearer to the start is suggested to ensure a common understanding.

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Appendix A.

Summary Part 1 – Complimentary Nearshore Survey with NOAA FSV *Reuben Lasker, 2021*

The F/V *Lisa Marie* completed complimentary acoustic surveys of the nearshore distribution of CPS biomass off Washington, Oregon, and northern California (approximately Bodega Bay) between July 16, 2021 and August 5, 2021. During this period, F/V *Lisa Marie* completed a total of 121 transects (25 transects off Washington, 52 off Oregon and 44 off California) as well as 30 purse seine sets. WDFW biologists were onboard for the duration of the project to collect species composition and biological data, as well as monitor the acoustic equipment and maintain a log of seining operations. All project data were submitted to NOAA-SWFSC. Otoliths were submitted to WDFW age readers for analysis.

Acoustic transect lines were sampled in either direction and as near to shore as safely navigable following the planned transect lines in Figure 11, starting with line number 351 at Cape Flattery and ending with line 228 near Bodega Bay, CA. Transects lines were nominally 4 nautical miles long and spaced 5 nautical miles apart for Part 1. Acoustic surveying began most mornings around 0630 PST (sunrise) and ended around 1900 PST (sunset). Sets were made after the completion of the transect and in proximity to the transect line if fish were observed. Schools of fish observed while transiting to the next transect line were also set on. For all sets, the date, time, latitude, longitude, hail weight, and general species composition were recorded. Set locations are shown in Figure 13. Bottom depth associated with sets ranged from 8.8 to 101 meters. Of the 30 completed sets, one was partially unsuccessful due to skiff operational challenges which allowed fish to escape while setting. Sets were accomplished on each day of the survey.

Three dip net samples of approximately 4.5 kg (10 pounds) each were collected per set from the seine for biological information and species composition. Table 3 presents all retained fish. For each species per set, a total weight in grams and total number were reported. For Pacific sardine, Northern anchovy, Pacific mackerel, Jack mackerel, and Pacific herring, a 50-fish sample was randomly collected from the total combined dip netted sample. Each of the 50 fish were sampled for length, weight, sex, macroscopic maturity, and age structures.

Northern anchovy and Pacific herring comprised most of the retained specimens for sampling by number and weight. One Pacific sardine was collected on 07/22/2021 in set 1 (Figure 142). Figure 11 depicts length-weight plots for Northern anchovy and the single Pacific sardine (bottom).

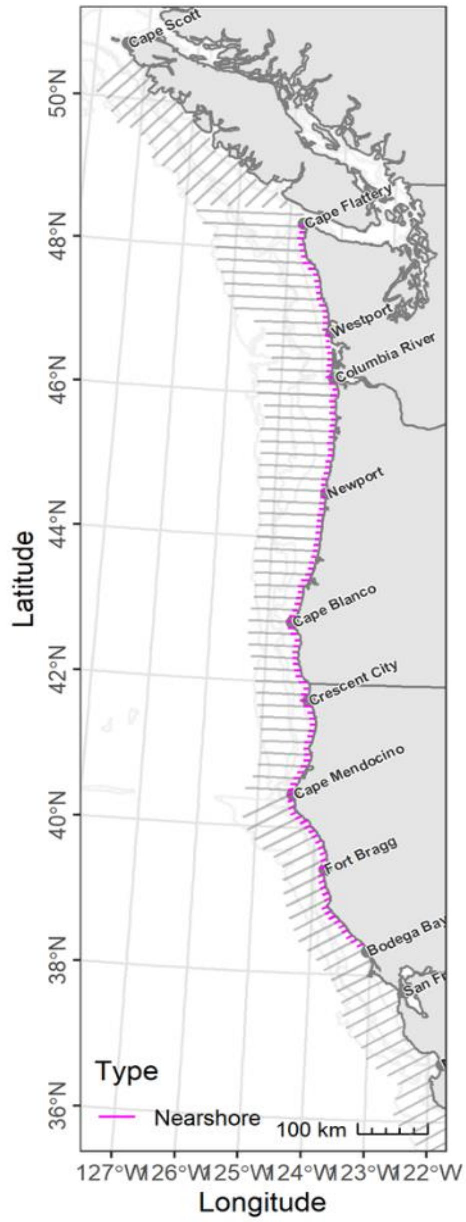

Figure 12. 2021 acoustic transect lines (pink) sampled by F/V Lisa Marie from Cape Flattery, WA to Bodega Bay, CA. Gray lines depict FSV Reuben Lasker acoustic transect lines. Figure courtesy of Kevin Stierhoff, SWFSC.

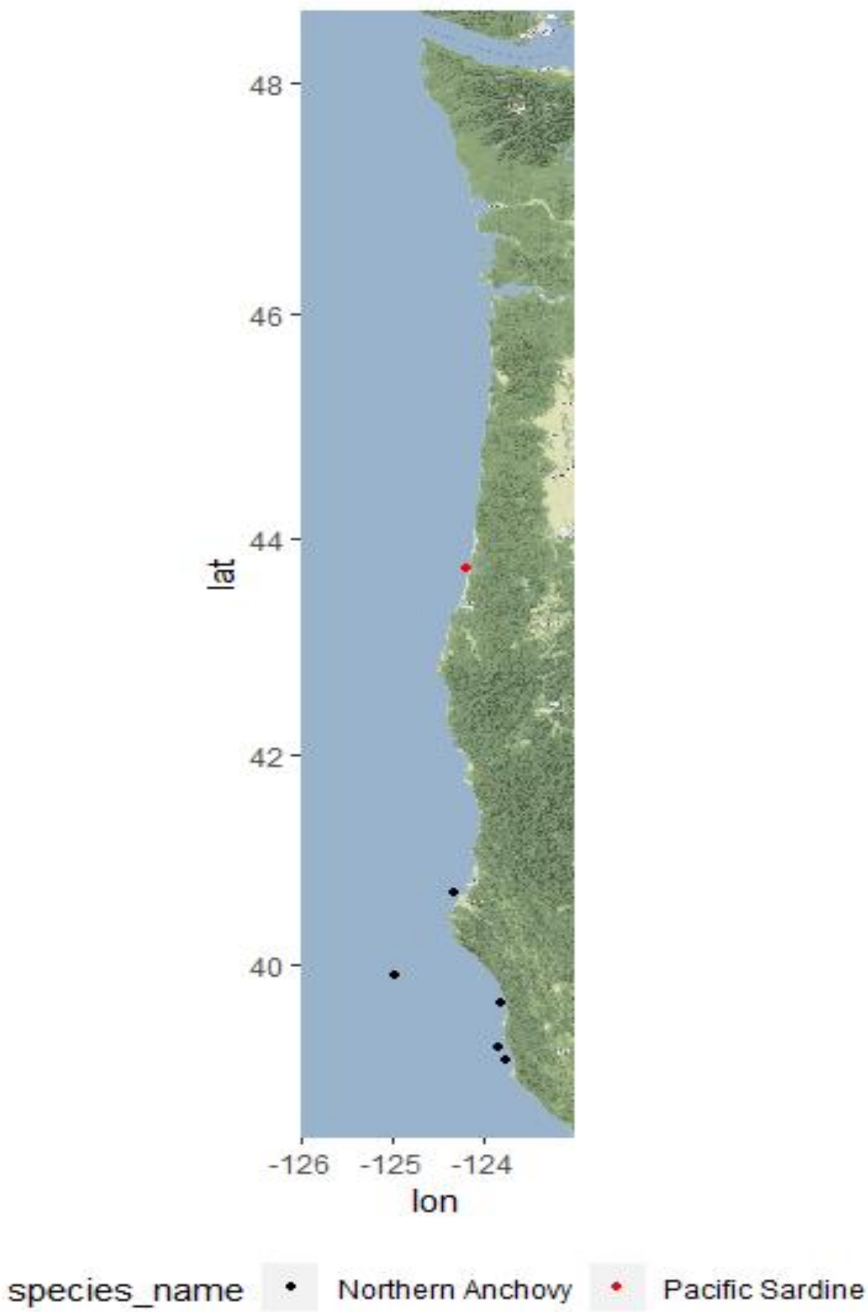

Figure 13. Set locations of sampled Northern anchovy and Pacific sardine, 2021.

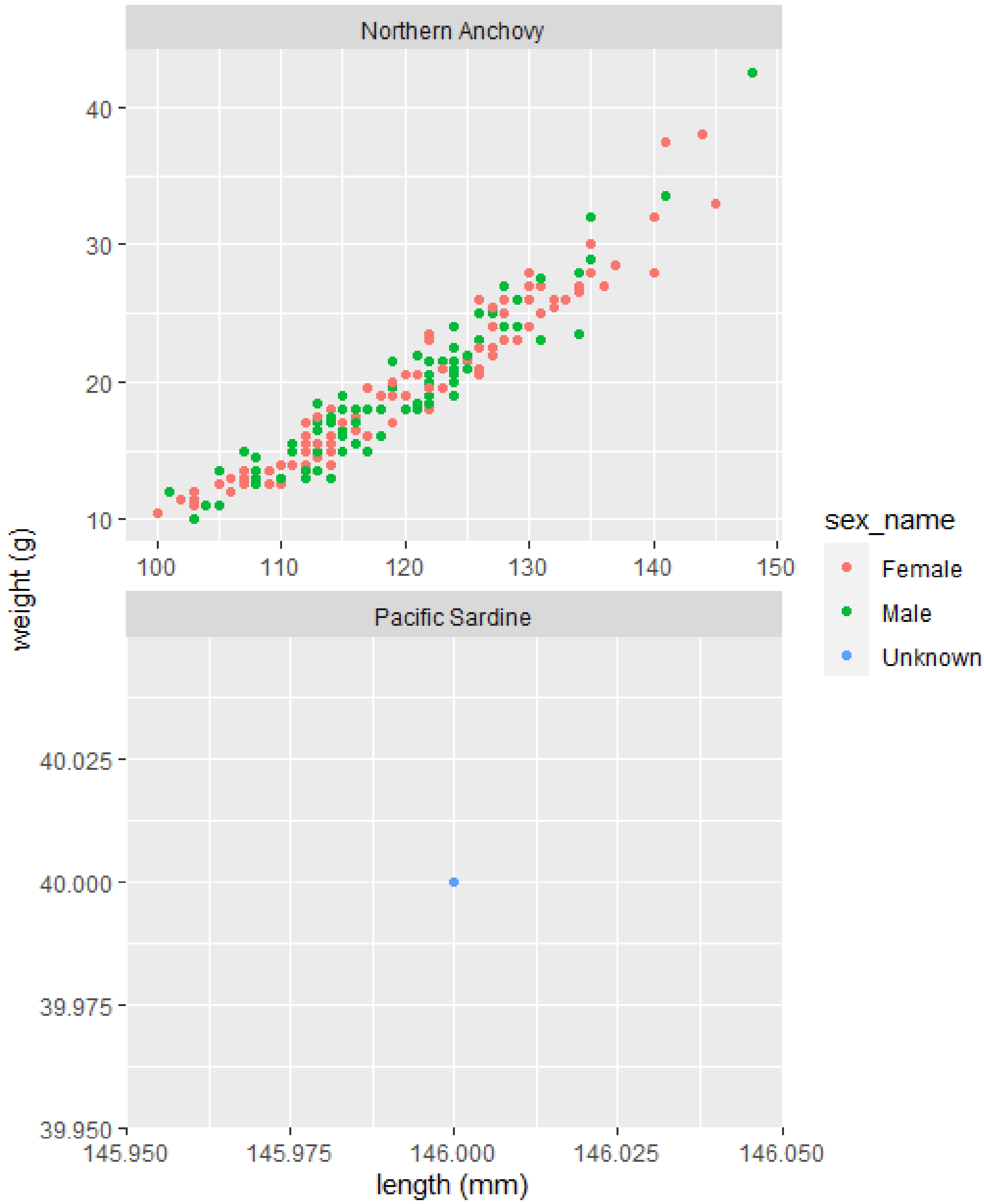

Figure 14. Length weight plots for Northern anchovy (top) and the single Pacific sardine (bottom).

Table 3. Species composition of sampled sets, weight (g) and count, all sets combined, ranked by weight (g), Part 1.

Species	Count	Weight (g)
Northern Anchovy	2063	38390
Herring	1111	37626
Whitebait Smelt	1062	5781
Pacific Tomcod	740	3845
unidentified juvenile smelt	621	3494
Surf Smelt	590	10362
Water Jellies	420	35280
Market Squid	408	15774
Jacksmelt	272	34554
Ctenophores	250	5355
Small Bell Jelly	145	671
Gadidae unidentified	65	400
Chinook Salmon	55	1175
Salp	29	987
Sea Nettle	21	26587
Moon Jelly	10	11368
unidentified Jellyfish	3	499
English Sole	2	3
Lingcod	2	8
Starry Flounder	1	432
Medusafish	1	3.5
Shiner Perch	1	16
Isopod	1	0.5
unidentified juvenile rockfish	1	

Sea Elephant	1	4
Sanddab	1	2.5
Cabezon	1	657
Black Rockfish	1	1594
Pacific Sardine	1	41
unidentified eel larvae	0	1
Total	7879	234907

Appendix B.

Transect and Set Locations, F/V *Lisa Marie*, Part 2, 2021.

App B. Table 1. 2021 CPS Survey Transect Locations, F/V *Lisa Marie*, Part 2. Line 327 corresponds to the approximately the Washington-Oregon border. Line 351 corresponds to Cape Flattery, Washington. Lines are presented here south to north but were surveyed from north to south.

SWFSC Transect Number	Waypoint	Latitude	Longitude	Type	Region
327	327.1N	46.33641	-124.077414	Nearshore	WA/OR
327	327.2N	46.335727	-124.168858	Nearshore	WA/OR
328	328.1N	46.420128	-124.070273	Nearshore	WA/OR
328	328.2N	46.41944	-124.161358	Nearshore	WA/OR
329	329.1N	46.503803	-124.071837	Nearshore	WA/OR
329	329.2N	46.503119	-124.161574	Nearshore	WA/OR
330	330.1N	46.587442	-124.080992	Nearshore	WA/OR
330	330.2N	46.586811	-124.162904	Nearshore	WA/OR
331	331.1N	46.670485	-124.101442	Nearshore	WA/OR
331	331.2N	46.669721	-124.206255	Nearshore	WA/OR
332	332.1N	46.754593	-124.123971	Nearshore	WA/OR
332	332.2N	46.753993	-124.200301	Nearshore	WA/OR
333	333.1N	46.838368	-124.124185	Nearshore	WA/OR
333	333.2N	46.837559	-124.22605	Nearshore	WA/OR
334	334.1N	46.921686	-124.184418	Nearshore	WA/OR
334	334.2N	46.920932	-124.278337	Nearshore	WA/OR
335	335.1N	47.005495	-124.185776	Nearshore	WA/OR
335	335.2N	47.004795	-124.272136	Nearshore	WA/OR
336	336.1N	47.089259	-124.195772	Nearshore	WA/OR
336	336.2N	47.088587	-124.277807	Nearshore	WA/OR
337	337.1N	47.172975	-124.214299	Nearshore	WA/OR
337	337.2N	47.172269	-124.299718	Nearshore	WA/OR
338	338.1N	47.256629	-124.243024	Nearshore	WA/OR
338	338.2N	47.255617	-124.364218	Nearshore	WA/OR
339	339.1N	47.339954	-124.3132	Nearshore	WA/OR
339	339.2N	47.339087	-124.416172	Nearshore	WA/OR
340	340.1N	47.423594	-124.348134	Nearshore	WA/OR
340	340.2N	47.422861	-124.434343	Nearshore	WA/OR

341	341.1N	47.507425	-124.363321	Nearshore	WA/OR
341	341.2N	47.506688	-124.449111	Nearshore	WA/OR
342	342.1N	47.591207	-124.386839	Nearshore	WA/OR
342	342.2N	47.59045	-124.474211	Nearshore	WA/OR
343	343.1N	47.674926	-124.420301	Nearshore	WA/OR
343	343.2N	47.674129	-124.511408	Nearshore	WA/OR
344	344.1N	47.758471	-124.475953	Nearshore	WA/OR
344	344.2N	47.757328	-124.605361	Nearshore	WA/OR
345	345.1N	47.841793	-124.558723	Nearshore	WA/OR
345	345.2N	47.840427	-124.712013	Nearshore	WA/OR
346	346.1N	47.925022	-124.65344	Nearshore	WA/OR
346	346.2N	47.924134	-124.752178	Nearshore	WA/OR
347	347.1N	48.008748	-124.694755	Nearshore	WA/OR
347	347.2N	48.007964	-124.781255	Nearshore	WA/OR
348	348.1N	48.092793	-124.703629	Nearshore	WA/OR
348	348.2N	48.091872	-124.80433	Nearshore	WA/OR
349	349.1N	48.176669	-124.733852	Nearshore	WA/OR
349	349.2N	48.17574	-124.834461	Nearshore	WA/OR
350	350.1N	48.261231	-124.692959	Nearshore	WA/OR
350	350.2N	48.260192	-124.8045	Nearshore	WA/OR
351	351.1N	48.345249	-124.713761	Nearshore	WA/OR
351	351.2N	48.344192	-124.826404	Nearshore	WA/OR

App B. Table 2. Cumulative study set number, set date, set number per date, time, and location, F/V *Lisa Marie*, 2021; Part 2.

Study Cumulative Set Number	Date	Set Number Per Date	Local Time	State	Latitude	Longitude
1	8/18	1	1309	WA	48° 12.4332	124° 43.8623
2	8/20	1	1141	WA	47° 47.2434	124° 33.5982
3	8/21	1	955	WA	47° 30.7043	124° 37.1607
4	8/21	2	1612	WA	47° 19.6771	124° 33.3675
5	8/21	3	2009	WA	47° 15.1003	124° 30.5491
6	8/22	1	854	WA	47° 12.7456	124° 15.7547

7	8/23	1	932	WA	46° 56.8328	124° 13.2900
8	8/23	2	1127	WA	46° 55.1554	124° 24.5996
9	8/23	3	1529	WA	46° 50.0877	124° 21.8672
10	8/23	4	1642	WA	46° 48.7452	124° 21.4739
11	8/24	1	1030	WA	46° 35.7277	124° 7.9805
12	8/25	1	859	WA	46° 22.0610	124° 6.5993
13	8/25	2	123	WA	46° 20.4801	124° 11.0302
14	8/25	3	1239	WA	46° 17.7290	124° 7.6377
15	8/25	4	1451	WA	46° 17.7503	124° 9.0275
16	8/25	5	1549	WA	46° 19.2482	124° 7.4475
17	8/25	6	1652	WA	46° 20.1334	124° 7.4564
18	8/25	7	1735	WA	46° 21.0339	124° 6.5672
19	8/25	8	1902	WA	46° 27.1701	124° 7.1577
20	8/26	1	932	WA	46° 57.3645	124° 22.4833
21	8/26	2	1034	WA	46° 58.5336	124° 25.6360
22	8/26	3	1115	WA	46° 59.2684	124° 25.5925
23	8/26	4	1154	WA	46° 59.7630	124° 25.6528
24	8/26	5	1304	WA	47° 0.2760	124° 25.5717
25	8/26	6	1342	WA	47° 0.2537	124° 25.3228