RPA Rollup Annual Report

Project 2003-007-00

Year: 2019

RPA 58.1 Evaluate smolt survival and/or fitness from Bonneville Dam through the estuary

Questions

1. What are the juvenile survival rates by tagged species/life history type from Bonneville Dam to the plume for various river segments and study-years?
2. What are the common themes in the survival data for tagged juvenile salmonids in the lower Columbia River and estuary?

Implementation

1. What are the trends or patterns in smolt fitness in the lower Columbia River and estuary? (As applicable: by habitat type, by fish size/genetic stock, by longitudinal position, etc)

Note: *Please specifiy what measurement of smolt fitness you use (lipid content, +/- tissue synthesis, etc) and why you selected that measurement for measuring smolt fitness.*

The Lower Columbia Estuary Partnership (Estuary Partnership) Ecosystem Monitoring Program (EMP; BPA Project 2003-007-00) is an integrated status and trends program for the lower Columbia River that includes a study area extending from the mouth of the river to Bonneville Dam. EMP trend sites include: Ilwaco Slough, rkm 6; Welch Island, rkm 53; Whites Island, rkm 72 Campbell Slough, rkm 149; and Franz Lake, rkm 221. The EMP aims to collect key information on ecological conditions for a range of habitats throughout the lower river characteristic of those used by migrating juvenile salmon and provide information toward the recovery of threatened and endangered salmonids. The program provides an inventory of the different types of habitats within the lower river, track trends in the overall condition of these habitats, provide a suite of reference sites for use as end points in regional habitat restoration actions, and places findings from management actions into context with the larger ecosystem.

The EMP collects data on condition factor and lipid content in juvenile Chinook salmon. Lipid content can be a useful indicator of salmon health since it affects contaminant uptake and toxicity. In addition, Fulton's condition factor (K) was calculated as an indicator of salmon health and fitness. Monthly lipid analyses for fish collected in 2019 are currently under analysis and results are not available at this time; however, we present lipid data collected between 2007 and 2018. Fulton's condition factor (K) is available for 2019, specifically for fish collected at Welch, Whites and Campbell and was calculated using the following formula:

$$K = [\text{weight (g)}/\text{fork length (cm)}^3] \times 100$$

Results

1. What are the trends or patterns in smolt fitness in the lower Columbia River and estuary? (As applicable: by habitat type, by fish size/genetic stock, by longitudinal position, etc)

Note: *1. As applicable, please call-out results for interior, ESA-listed salmonids.*

Lipid Content of Juvenile Chinook Salmon

Lipid content and Fulton's condition factor are useful indicators of salmon health and fitness. Lipid data for 2019 are still under analysis, data from 2007 and 2018 are reported below. Lipid data were collected at Welch Island, Whites Island, and Campbell Slough. At Welch, average lipid percentages for fish collected in 2018 were significantly lower relative to those from 2015. Average percent triglycerides were significantly lower for fish collected in 2018 relative to those collected in 2013 and 2015. At Whites Island, percent triglycerides for fish collected in 2018 were significantly lower than those collected in 2013. In contrast, fish from Campbell Slough in 2018 had significantly higher percent triglycerides compared to the fish collected in 2007. Some of the lowest percent lipid and triglyceride values were found in 2009-2013, which might indicate reductions in health during these years. In addition, median percent triglycerides in 2018 increased with respect to river kilometer, yet this pattern was not present in previous years.

Condition Factor of Juvenile Chinook Salmon

The condition of unmarked Chinook salmon increased over the course of the migration period, with the lowest values observed in February (mean K=0.75) and the highest values observed in July (mean K=1.23). Limited data indicated that after July, condition starts to decline, likely due to high water temperature. Condition factor of marked Chinook salmon (0.99 – 1.14) was slightly greater than that for unmarked Chinook salmon (0.93 – 1.05) but still trended upward during the migration season. Similar to unmarked fish, the condition factor appeared to decrease in late summer.

In 2019, the condition factor (K), average length and weight for unmarked Chinook captured at the following sampled sites were: Welch Island (± SD): 0.93 ± 0.02 (K); 54.67 ± 2.19 mm; and 2.69 ± 0.65 g, Whites Island (± SD): 1.01 ± 0.11 (K); 61.67 ± 4.44 mm; and 3.46 ± 0.69 g, and Campbell Slough (± SD): 1.05 ± 0.03 (K); 63.13 ± 2.64 mm; and 3.46 ± 0.43 g respectively. No average length, weight, and condition factor was calculated for Ilwaco due to no Chinook being sampled and no effective sampling was conducted at Franz Lake in 2019, which is similar pattern seen over a number of years at both sites. Unmarked Chinook sampled at Whites Island in 2019 appeared to have a slightly larger average weight than seen in 2018 and 2017. However, Fulton's condition factor appears to follow the overall general trend on Whites Island over the past 5 years. Unmarked Chinook sampled at Welch Island in 2019 had a larger average fork length, weight and condition than previously observed in the 2018 sample. However, this is likely due to no June sampling at Welch Island in 2018, which would have likely contributed to the decreased averages of all measured indices. In 2019, marked Chinook salmon were caught at three of the five sampled locations. Specifically, Welch Island, Whites Island, and Campbell Slough experienced significant enough catches to examine marked Chinook size and condition. In 2019, the condition factor (K), average length and weight for marked Chinook captured at the following sampled sites were: Welch Island (± SD): 1.04 ± 0.02 (K); 80.15 ± 4.27 mm; and 6.20 ± 5.12 g, Whites Island (± SD): 1.14 ± 0.03 (K); 82.14 ± 3.81 mm; and 6.65 ± 0.89 g and Campbell Slough (± SD): 0.99 ± 0.01(K); 85.0 ± 5.27 mm; and 7.65 ± 1.77g, respectively. Campbell Slough shows little variation in length, weight, and condition across the past three sampled years. Similar to unmarked Chinook sampled at Welch Island in 2019, marked Chinook size, weight, and condition were all greater than previously seen in the 2018 sampling season.

For additional detail on the evaluation of juvenile salmon fitness in the lower Columbia River, refer to Rao et al. (2020) Lower Columbia River Ecosystem Monitoring Program Annual Report for Year 15 (October 1, 2018 to September 30, 2019).

Adaptive Management

Comparison of this year's study to previous monitoring years across sites indicates that smolt fitness in the Estuary has generally stayed consistent over time. In 2019, condition index for unmarked Chinook were only slightly lower than that for marked Chinook. Similar to previous monitoring years, condition factor in 2019 was highest in unmarked juvenile salmon from Campbell Slough (Reach F). Historically, the lowest condition factor is observed in salmon captured at Franz Lake, however, no average length, weight and condition factor was calculated for Ilwaco and Franz Lake in 2019 due to inadequate sampling conditions. Continued sampling efforts at the trends sites during the peak migration period and potentially into the late summer and fall will contribute to a better understanding of how fish condition varies temporally and spatially across the lower river and under a range of environmental conditions.

RPA 58.3 Evaluate juvenile salmonid growth rates & prey resources

Questions

1. What are growth rates and prey resources for juvenile salmonids based on sampling in the LCRE and plume?

Implementation

1. What are growth rates and prey resources for juvenile salmonids based on sampling in the LCRE and plume?

Note: *Please include the method used for measuring growth rate and the time period for the growth you inferred.*

The Lower Columbia Estuary Partnership (Estuary Partnership) Ecosystem Monitoring Program (EMP; BPA Project 2003-007-00) is an integrated status and trends program for the lower Columbia River that includes a study area extending from the mouth of the river to Bonneville Dam. EMP trend sites include: Ilwaco Slough, rkm 6; Welch Island, rkm 53; Whites Island, rkm 72 Campbell Slough, rkm 149; and Franz Lake, rkm 221. The EMP aims to collect key information on ecological conditions for a range of habitats throughout the lower river characteristic of those used by migrating juvenile salmon and provide information toward the recovery of threatened and endangered salmonids. The program provides an inventory of the different types of habitats within the lower river, track trends in the overall condition of these habitats, provide a suite of reference sites for use as end points in regional habitat restoration actions, and places findings from management actions into context with the larger ecosystem.

Patterns in somatic growth rate can represent variations in growth in response to genetic stocks or environmental conditions. Otoliths were extracted from juvenile Chinook salmon collected at EMP status and trends sampling sites as well as Action Effectiveness Monitoring sites in 2005 and 2007-2018 (n = 28 sites).

In 2019, macroinvertebrate samples (neuston tows and benthic cores) were also collected at the trends sites for salmon prey availability analysis. Neuston tows were performed in open water (i.e., mid-channel) and in emergent vegetation along the edge of the channel using a 250 μm mesh Neuston net. The 2019 macroinvertebrate data is still under analysis. This report presents the data collected in 2018.

Results

1. What are growth rates and prey resources for juvenile salmonids based on sampling in the LCRE and plume?

Note: *As appropriate, please call-out results specific to interior, ESA-listed salmonids.*

Fish Somatic Growth

Otoliths are used to estimate somatic growth rates in fish. Patterns in somatic growth rate can represent variations in growth in response to genetic stocks or environmental conditions. Somatic growth rate in Chinook salmon ranged from 0.31 to 0.87 mm/day with an average of 0.54 mm/day. Of these otoliths, 65% were classified as unmarked and 35% as marked. On average, marked fish were 10 mm larger than unmarked fish; however, the range of growth rates overlapped between these two groups. Growth rates between stocks differed, but our results showed that growth rates of marked fish varied more among stocks than that of unmarked fish. Growth rates have a consistently positive relationship to fork lengths at trend sites. Generally, somatic growth rate indicated an increasing trend with river kilometer and a decreasing trend with discharge, of approximately 6%, over the nine years of this study.

Somatic growth analyses from otoliths indicate that fish collected in this study (2005-2018) are growing at rates similar to or greater than what other studies in the Columbia River estuary have observed (this study: 0.54 mm/d, Chittaro et al. 2018; 0.41 mm/d, Campbell 2010; 0.23 mm/d, Goertler et al. 2016; 0.53 mm/d, McNatt et al. 2016). These findings highlight that subyearling Chinook salmon that reside in tidal wetlands can achieve substantial growth. McNatt et al. (2016) measured increases of 20 mm for individuals that resided in a tidal wetland in Reach B for 15 days or more.

Measures of performance such as condition factor and growth, coupled with residence time, indicate that tidal wetlands are productive and beneficial habitats for juvenile salmon. The abundance of prey items and refuge from piscine predators and high flows creates beneficial rearing habitat to allow juvenile salmon to grow and adjust to an increasingly marine environment as they migrate seaward.

Prey Availability

Macroinvertebrate and zooplankton abundance and community structure within a wetland channel and within the emergent vegetation are important for determining the quantity and quality of prey available to juvenile salmon. The average density and biomass of all invertebrate taxa are typically greater in emergent vegetation habitats than in open water habitats. Neuston samples were composed of a diverse array of benthic/epibenthic, terrestrial riparian, and planktonic taxa.

Between sampling years 2015 to 2018, results from monitoring salmon diet in the lower Columbia river have consistently shown the importance of chironomids and amphipods as prey items for juvenile Chinook salmon. Amphipods occurred regularly in monthly benthic core samples taken at Ilwaco Slough between April and July; however, amphipod abundance declined upstream from Ilwaco Slough, with low densities at Welch Island and White Island and almost none at Campbell Slough and Franz Lake. The highest densities of Amphipoda were observed from the emergent vegetation at Welch Island in May 2016 and 2017.

Between 2015 to 2018, Diptera, including Chironomidae, were collected from the emergent vegetation and open water at all sites sampled between April and July. The highest dipteran densities were observed at Whites Island, Campbell Slough, and Franz Lake in the emergent vegetation. The average density of dipterans was relatively low at all sites sampled in 2017 and 2018, except for emergent vegetation densities at Campbell Slough in 2017.

For additional detail on the evaluation of juvenile salmon growth rates in the lower Columbia River, refer to Rao et al. (2020) Lower Columbia River Ecosystem Monitoring Program Annual Report for Year 15 (October 1, 2018 to September 30, 2019).

Adaptive Management

Growth rates overlapped for stocks and were not related to ESU, suggesting environmental factors may be a critical driver of growth for juvenile salmon in the lower river. Spatial patterns also show growth rate was reduced in the lower reaches of the study area, which may have been due to physiological costs associated with environmental conditions such as increasing salinity levels and tidal action. Marked and unmarked Chinook salmon appear to utilize tidal freshwater and estuarine habitats in similar ways given that these two groups co-occur in the study area and generally have comparable growth rates. It may be possible for juvenile Chinook salmon to exhibit higher physiological performance in lower river habitats, and that the quantification of such physiological improvements could be used to measure the effectiveness of restoration efforts. Growth rate results from 2015 – 2018 as well as continued collection and analysis of otolith samples from EMP sites in future monitoring years and could help discern how juvenile salmon growth patterns relate to environmental conditions (e.g., warm water, low flow years).

Beginning in 2015, macroinvertebrates collected at the EMP sites were identified to a lower taxonomic level than in previous years. As finer-scale identification methods continue into the coming monitoring years, additional data will become available about the types of salmon prey available to fish and the habitats in which the prey live. The EMP may also benefit from a more rigorous prey sampling regime that could better identify patterns in abundance and help explain differences in habitat capacity between sites. Currently, macroinvertebrate sampling in at the EMP trends sites includes benthic core sampling and neuston tows. Amphipods (i.e., *Americorophium* spp.) often occur within the sediment and in a patchy distribution, thus conducting an *Americorophium* spp. distributional study at the EMP sites could help determine the sub-habitats they are using and help refine the sample locations for benthic core sampling.

RPA 59.4 Understand habitat use & importance to juvenile salmonids

Questions

1. What are the results for
- salmonid density,
- fish community species composition,
- salmonid age-size structure,
- genetic stock identity,
- spatial and temporal distribution,
- residence time,
- migration rates,
- growth rates,
- migration pathways,and
- habitat characteristics to support characterizing the relative importance of various habitat types to juvenile salmonid performance and the ecological benefits of estuarine habitats?

Implementation

1. As applicable, please comment on how your project contributed to better understanding juvenile salmonid habitat use & the importance of LCRE habitats for juvenile salmonids (stream-/ocean-type)

2. Which for the following did you measure?
- salmonid density,
- fish community species composition,
- salmonid age-size structure,
- genetic stock identity,
- spatial and temporal distribution,
- residence time,
- migration rates,
- growth rates,
- migration pathways, and
- habitat characteristics to support characterizing the relative importance of various habitat types to juvenile salmonid performance and the ecological benefits of estuarine habitats?

The Lower Columbia Estuary Partnership (Estuary Partnership) Ecosystem Monitoring Program (EMP; BPA Project 2003-007-00) is an integrated status and trends program for the lower Columbia River that includes a study area extending from the mouth of the river to Bonneville Dam. EMP trend sites include: Ilwaco Slough, rkm 6; Welch Island, rkm 53; Whites Island, rkm 72 Campbell Slough, rkm 149; and Franz Lake, rkm 221. The EMP aims to collect key information on ecological conditions for a range of habitats throughout the lower river characteristic of those used by migrating juvenile salmon and provide information toward the recovery of threatened and endangered salmonids. The program provides an inventory of the different types of habitats within the lower river, track trends in the overall condition of these habitats, provide a suite of reference sites for use as endpoints in regional habitat restoration actions, and places findings from management actions into context with the larger ecosystem.

The EMP considers the spatial and temporal distribution of juvenile salmonid density, fish community species composition, salmonid size-structure, genetic stock, residence time, growth rate, and their associations with shallow-water wetland habitats over time in the LCRE. This information is used to evaluate the relative importance and benefits of shallow-water emergent wetland habitat types to juvenile salmonids.

Results

1. What are your results relevant to juvenile salmonid use of LCRE habitats and their importance to juvenile salmonids?

As applicable, what are the results for
- salmonid density
- fish community species composition
- salmonid age-size structure
- genetic stock identity
- spatial and temporal distribution
- residence time
- migration rates
- growth rates
- migration pathways
- habitat characteristics to support characterizing the relative importance of various habitat types to juvenile salmonid performance and the ecological benefits of estuarine habitats?

<u>Salmonid Density</u>
The density of juvenile salmonids at trends monitoring sites indicates the timing of wetland habitat use across the lower river for different salmonid species.

Chinook salmon. In 2019, unmarked Chinook salmon were captured at the EMP trend sites from March (Welch only) through June and again in October. The highest average densities of unmarked juvenile Chinook salmon were 69.5 per 1000 m^2 in May. Marked Chinook salmon were captured from March through June and again in October as well, with the highest average densities of 17 fish per 1000 m^2 in May. In 2019 the density of unmarked Chinook salmon was highest at Welch Island (54.60 fish per 1000 m^2) and Whites Island (35.89 fish per 1000 m^2) and lowest at Campbell Slough (19.26 fish per 1000 m^2). No Chinook captured at Ilwaco Slough and Franz Lake was not sampled due to inadequate sampling conditions in 2019. Densities of marked Chinook salmon in 2019 were greatest at Campbell Slough and similar to catches in the past three previous years. The densities of marked Chinook salmon in 2019 were generally within the same ranges as 2008-2018 at all sites.

Coho salmon. In 2019, only one unmarked Coho salmon was collected at Whites Island in May. This marks only the third time in the past eleven years in which Coho salmon have been sampled at

Whites Island. Coho salmon have been captured only sporadically at Ilwaco Slough, Campbell Slough and Welch Island, so their absence in 2019 was not unusual compared to previous years. No sampling was conducted at Franz Lake in 2019 due to high water and warm summer water conditions. Franz Lake is traditionally the only site where coho salmon have been consistently collected, although, Franz lake was not sampled in 2019, due to inadequate sampling conditions. Coho salmon density at Franz Lake was at its lowest reported level in 2016 and has shown a consistent decline since 2011. However, low sampling efforts in 2017, 2018 and no sampling in 2019 have made it difficult to determine any recent trends in coho abundance levels at Franz Lake. Marked coho salmon, which were common at Franz Lake in 2008 and 2009, have not been observed since 2012.

Chum salmon. In 2019, chum salmon were found at 4 of 5 trends sites in March, April, and May with the highest average monthly density across all sites in May (11.14 fish per 1000 m^2). Chum salmon were present at Ilwaco Slough, Welch Island, and Whites Island in 2019. The density of chum salmon was highest at Ilwaco Slough (11.08 fish per 1000 m^2) and lowest at White Island (1.50 fish per 1000 m^2). However, no chum were captured at Campbell Slough and Franz Lake was not sampled in 2019. Chum salmon have been found at all the sampling sites at varying densities, although not consistently. Chum salmon have not been observed at Franz Lake since 2009.

Sockeye salmon and trout species. In 2019, as in the past 4 years, Sockeye salmon and trout were not caught.

<u>Fish Community Composition</u>

Fish community composition is an important metric because it shows the presence of predator species and invasive species that could compete with juvenile salmon for resources. In 2019, Chinook salmon were caught at three of the four sampled sites and were the dominant salmon species at Welch Island in Reach B, Whites Island in Reach C and Campbell Slough in Reach F. At these sites, Chinook salmon comprised 90 to 100% of salmonid catches. In 2019, unmarked (presumably wild) Chinook were more abundant at all three sites where Chinook were sampled than marked hatchery Chinook. In addition to Chinook salmon, small numbers of chum salmon were found at Welch Island and Whites Island. This pattern is typical for Welch and Whites Islands and has been evident since 2012. Chum salmon were the most abundant and only salmon species captured at Ilwaco Slough in Reach A. Only one unmarked Coho salmon was collected at Whites Island. No trout or sockeye salmon were caught in 2019.

Non-native fish species occur at all five trend sample sites over all sampling years; their presence is highly variable and likely very dependent on water levels and temperature. The highest number of non-native fishes occur at Campbell Slough where the catch rates have exceeded 50% for seven out of the last eleven years. At Campbell Slough, banded killifish, yellow perch, and unidentified juvenile carp comprise the majority of the non-native species. Franz Lake has the second highest numbers of non-native species exceeding 20% for six out of the last nine years of sampling and ranging from 6-54%. At Franz Lake, banded killifish, unidentified juvenile carp, and yellow bullhead are the predominant non-native species.

There are five non-native (small and largemouth bass, walleye, warmouth, and yellow perch) and one native (northern pikeminnow) fish species that produce mature stages that can prey on juvenile salmon. These fish are freshwater species that primarily occur at Campbell Slough and Franz Lake and minimally occur at Welch and Whites Islands. Yellow perch are the most common species followed by northern pikeminnow and are found at the four sites. Smallmouth bass is the third most common species and has been captured at Campbell Slough and Franz Lake exclusively. In 2019, yellow perch comprised 81% of the total number of predatory fish captured across the four sampled trend sites.

<u>Salmon size class distribution</u>

Size class distribution indicates at which age juvenile salmon are more likely to use off-channel habitats in the lower river. At the trend sites in 2019, the majority of unmarked Chinook salmon were fry, 64%, 32% were fingerlings, and 4 % were yearlings. Only at Welch Island did fry dominate catches, making up 77% of unmarked Chinook salmon. Campbell Slough and Whites Island showed a more even distribution of fry and fingerling of unmarked Chinook salmon. In comparison to previous years, the percentage of fry at all of the trend sites was slightly lower than in recent years.

A total of 37 (67 %) marked Chinook salmon caught at the trends sites in 2019 were fingerlings (Figure 124b). In comparison to previous sampling years, the proportion of yearlings encountered in 2019 was greater (18%). This does appear to differ from the overall trend; however, sample size is relatively low. Similar to all previous years, no fry marked Chinook were observed in 2019 at any of the sampled locations.

<u>Genetic Stock Identity</u>

Data on genetics indicate how juvenile salmon from various ESUs and life history types use off-channel habitats in the lower Columbia River. In 2019, genetics data were collected from Chinook salmon at Welch Island, Whites Island, and Campbell Slough. To maintain the highest level of confidence in stock assignments, we only reported stock assignments for fish that had an assignment probability greater than or equal to 0.90. We applied this criterion across all reporting years. On average, 86% of genetic samples assigned at 0.90 or greater.

Among unmarked fish in 2019, West Cascade fall Chinook were the predominant stock at sites in Reaches B and C: Welch Island and Whites Island. The percentages of upper Columbia summer/fall stocks at both Welch and Whites Islands, 21 and 17%, respectively, were the highest yet reported at those sites. Similar to previous years, the unmarked stock composition at Campbell Slough were more diverse than the lower river sites; with West Cascade fall stocks comprising only 16%. These 2019 levels are the lowest observed contribution of West Cascade fall stock at Campbell Slough except for 2011 and 2015 when no West Cascade fall stocks were collected. In contrast, upper Columbia summer/fall stocks comprised 66% of the sample at Campbell Slough in 2019, the highest percentage observed at that site. Overall, Spring Creek fall stock represented 12.5% and West Cascade spring stock comprised 6.3%.

Substantially fewer marked fish were collected and subsequently analyzed for genetics at trend sites in 2019 due to generally lower catch numbers compared to previous years. Changes in stock composition occurred at Welch and Whites Islands in 2019, and spring stocks represented a larger percentage of the sample than had been observed in previous years. 2019 was the first year that West Cascade spring stocks were observed at Welch and Whites, and the percentage of Willamette River spring stock increased at both sites, as well. At Campbell Slough, 85% of marked Chinook were assigned to the Spring Creek Group, while 15% were assigned to the mid and upper Columbia spring reporting group. 2019 is the first year the mid and upper Columbia spring reporting group, which includes ESUs listed as endangered, has been observed at any of the trend sites.

The seasonal distribution of stocks in 2019 reveals that West Cascade fall Chinook are present throughout the lower Columbia River and estuary during spring and summer. Willamette River spring fish were present in the early spring and in June. Interior stocks occurred earlier at upper reaches and were not present in lower reaches until June. The increase in upper Columbia summer/fall stock in 2019 is evident in May and June. May and June are also the months when the greatest diversity of stocks is observed with the mid and upper Columbia spring present at Campbell Slough in May and Snake River fall stocks present in June. The seasonal trend of stocks in 2019 varied from previous years due to higher percentages of upper Columbia summer/fall stocks and at all sites and mid and upper Columbia spring stock at Campbell Slough.

For additional detail on the evaluation of genetic stock identity in the lower Columbia River, refer to Rao et al. (2020) Lower Columbia River Ecosystem Monitoring Program Annual Report for Year 15 (October 1, 2018 to September 30, 2019).

<u>Residence Time</u>

Detections on a PIT tag array show how much time tagged juvenile salmon spend in a specific habitat, potentially indicating the suitability of that habitat for rearing and refuge. Two PIT tag detection systems are used to determine salmonid presence and residence time at Campbell Slough (EMP trends site) and Horsetail Creek/Oneonta Creek (AEM site). In 2019, the PIT tag detection system at Campbell Slough began operating on March 20 and was continuously collecting data until August 30. Forty-nine individual fish were detected from April 10–August 4; 80% of the fish (N=39) detected were hatchery fall Chinook salmon with all but one originating from Spring Creek NFH located above Bonneville Dam. Hatchery spring Chinook and northern pikeminnow were almost equally represented at 3 and 2 individuals, respectively. Overall, salmon residence times at Campbell Slough were short with median residence times of 2 seconds for both spring and fall Chinook. Only three of 39 fall Chinook resided in Campbell Slough for greater than a day, but all three had residence times of greater than two weeks (16, 18, and 20 days). Northern Pikeminnow individuals demonstrated the longest residence times, with 46 days and 91 days, respectively.

The Horsetail Creek PIT detection array was operational from March 20–October 13, 2019. Although not all 10 antennas were operating, we had coverage of three antennas on the downstream side and two antennas on the upstream side of the culvert. Fifteen individual fish were detected from April 26–August 14; 47% of fish (N=7) detected were hatchery fall Chinook, one of which originated from the Snake River. All other fall Chinook salmon originated from the middle

Columbia Basin. The second most prevalent category was hatchery spring Chinook at 27% (N=4). One hatchery coho released in the Umatilla River was also detected. Additionally, two northern pikeminnows were detected. Residence times at Horsetail Creek were relatively short in 2019. Spring Chinook salmon had the longest median residence time of 11.7 hours; however, the longest maximum residence time was observed in fall Chinook at 5.4 days. The single coho detected at Horsetail Creek resided for 1.7 days. Two northern pikeminnow were detected at Horsetail Creek over a short period of time in early June.

Adaptive Management

The fish community at the trends sites were most diverse in the upper reaches (Reach F and H); however, non-native and salmon predator species were more common at these sites compared to sites in the lower reaches. Salmon species composition varies by site, typically showing distinct patterns associated with hydrogeomorphic reach. Chinook densities typically peak in May, with the majority of the fish being in either the fry or fingerling size classes. West Cascade Fall Chinook are commonly observed in the lower reaches, Spring Creek Group are often found at sites in the upper reaches. 2019 varied from previous monitoring years due to higher percentages of upper Columbia summer/fall stock at all sites. Given the variability in environmental conditions over recent years a synthesis of the genetic, lipid, and growth data would assist in drawing parallels between fish metrics and environmental conditions. Understanding such connections will be useful when planning and designing habitat restoration projects that will withstand year-to-year variation and potential environmental changes that may occur in the future.

In 2019, juvenile Chinook salmon were detected at both Campbell Slough and Horsetail/Oneonta Creek PIT arrays, although majority of these fish spent only a few minutes at both these locations. Northern pikeminnow were also detected at both locations, however, they had higher residence time at Campbell Slough. Continued data collection with these PIT arrays is necessary to determine the variability of salmon with site-specific environmental conditions. Additionally, Pikeminnow occurrences have shown an increase with much logger residence times at both Campbell Slough and Horsetail Creek; further research is needed to understand how these predatory non-native fish may be impacting salmonid utilization and survival at these sites.

RPA 59.5 Monitor habitat conditions periodically

Questions

1. What are the time series results for habitat condition data (vegetation, water surface elevation, substrate, accretion, water quality)?
2. Are there trends in habitat conditions that might affect juvenile salmonids using these habitats?

Implementation

1. Please provide a brief description of metrics and sites you monitor (a map would be helpful if sampling design is complex)

2. How were those sites selected?

The Lower Columbia Estuary Partnership (Estuary Partnership) Ecosystem Monitoring Program (EMP; BPA Project 2003-007-00) is an integrated status and trends program for the lower Columbia River that includes a study area extending from the mouth of the river to Bonneville Dam. EMP trend sites include: Ilwaco Slough, rkm 6; Welch Island, rkm 53; Whites Island, rkm 72 Campbell Slough, rkm149; and Franz Lake, rkm 221. The EMP aims to collect key information on ecological conditions for a range of habitats throughout the lower river characteristic of those used by migrating juvenile salmon and provide information toward the recovery of threatened and endangered salmonids. The program provides an inventory of the different types of habitats within the lower river, track trends in the overall condition of these habitats, provide a suite of reference sites for use as end points in regional habitat restoration actions, and places findings from management actions into context with the larger ecosystem.

The EMP monitors a suite of indicators at six fixed sites to monitor trends in lower river habitat conditions. A full suite of fish measurements at the trend sites includes genetic stock identification (covered in depth in RPA 59.4), life history type (covered in depth in RPA 59.4), growth (covered in depth in RPA 58.3), and condition (covered in depth in RPA 58.1), and fish community composition (covered in depth in RPA 59.8). Other measurements are used to develop a better understanding of conditions favorable to juvenile salmon production and survival: habitat (vegetation community composition, cover, macroinvertebrate composition, fish diet, sediment accretion, hydrology, water quality conditions that affect the salmon food web).

Results

1. Do you see trends in your habitat conditions over time at the site scale, or other scales? (vegetation, water surface elevation, substrate, accretion, water quality)

2. Are there activities in the vicinity that may be causing those changes? (Please be as specific as possible)

Water Surface Elevation

Water surface elevation data are used to identify the times throughout the year and duration of time that fish can access sites. Hydrologic patterns vary from year to year at all but the most tidal sites. The frequency of inundation at each site is dependent on the elevation, the position along the tidal and riverine gradient, and the seasonal and annual hydrologic conditions.

Although water surface elevation at Ilwaco Slough is minimally affected by the spring freshet, it is elevated due to winter storm events and extreme high tides. Additionally, low water elevations are truncated at the site due to the elevation of the tidal channel above extreme low water. Welch Island (rkm 53) is predominantly tidal, however slightly elevated water surface elevation are detectable during prolonged spring freshet conditions observed in past years and also during winter storms. Tidal range is greatest at this site at 2.22 m due to the depth of the channel below the extreme low water level. The hydrologic patterns at Whites Island (rkm 72) exemplify the mix of hydrologic drivers in the lower river (tidally influenced and elevated water levels during winter storm events and the spring freshet).

The Cunningham Lake and Campbell Slough sites (rkm 145 and 149, respectively) have similar hydrologic patterns except the Cunningham Lake site has a slightly greater tidal range and slightly lower water surface elevation during flood events. Campbell Slough water surface elevation does not get as low as the Cunningham Lake site due to a weir located at the mouth of Campbell Slough, which limits drainage. In most years, the primary hydrologic driver at both sites is usually the spring freshet. Franz Lake does not exhibit a discernable tidal signal and is often indistinguishable from daily dam operation variation. In addition, water levels are typically maintained at the site by a beaver dam located near the mouth of the slough.

Sediment Accretion Rates

Sediment accretion rate is important for understanding the evolution of the site. For example, the site may be losing or gaining in elevation, which subsequently affects inundation rates, access for fish, and vegetation communities. Sediment accretion data collected in 2019 are currently under analysis and not available at the time of the writing of this report. The following is a summary of general patterns observed at the trends sites over multiple years. Welch Island tends to show the least amount of variability in sediment accretion, while the greatest variation between years has been observed at the Campbell Slough and Franz Lake sites. Data from 2016 indicated that erosion occurred at Franz Lake; however, at both sets of stakes, the erosion is potentially caused by beaver activity. Long-term data indicate increased accretion occurs at lower elevations (Cunningham Lake and Campbell Slough) and in proximity to channels (Welch Island).

Water quality

Water quality metrics, such as dissolved oxygen, temperature, pH and salinity are important in determining whether the site offers good quality habitat for juvenile salmon, and the seasonal timing and duration of those conditions. The following is summary of observed trends in 2019.

Illwaco Slough. In 2019, maximum summer temperatures reached nearly 21^0C in August. Ilwaco is strongly influenced by tidal exchange with marine waters from the coastal ocean. Salinity is the clearest indicator of this influence: between March and September, waters went from mesohaline (~0.5–5 practical salinity units, PSU) to polyhaline (~5–18 PSU). Dissolved oxygen percent saturation relative to the atmosphere was as low as 45% at Ilwaco during the warm months of June and July. Between March and July pH fluctuated between 7.3 to 7.9, which falls within the recommended range (6.5–8.5; Washington State Water Quality Standards).

Welch Island. In 2019, maximum summer temperatures at Welch Island reached ~23^0C in August, which was slightly higher than observed at Ilwaco. Dissolved oxygen saturation levels were much higher at Welch Island than at Ilwaco, ranging from ~80% to close to 120%. Conductivity increased during the summer months as river discharge declined and water levels fell. Between March and late September, pH ranged from ~7.5 to 8.2, which falls within the recommended range (6.5–8.5; Washington State Water Quality Standards).

Whites Island. Temporal patterns in water quality parameters at Whites Island were very similar to those observed at Welch Island. In 2019, dissolved oxygen saturation levels were similar between Welch Island and Whites Island prior to the freshet; however, after the freshet subsided, dissolved oxygen saturation was higher at Whites Island, never dipping below 95%.

Campbell Slough. Of the five off-channel trends sites, Campbell Slough had the highest summer water temperatures, with values exceeding 25 ^{o}C in August. All biogeochemical properties reflect the influence of the freshet, with high elevation values, a reduction in chlorophyll, dissolved oxygen saturation, conductivity, temperature, and pH. In 2019, pH increased to values close to 10 by mid-July, which exceeds water quality benchmarks (Washington State Water Quality Standards). There were dramatic fluctuations in the percent saturation of dissolved oxygen throughout the year at Campbell Slough, indicating high biological activity at this site. Values dropped to as low as 40% relative to atmospheric values during the spring freshet. Chlorophyll concentrations observed at Campbell Slough were below the recommended benchmark of 15 µg L-1 (based on three samples collected over three consecutive months; Washington State Water Quality Standards).

Franz Lake. Similar to Campbell Slough, in 2019, summer temperatures at Franz exceeded 25^0C from late-July through mid-August. Peaks in chlorophyll and phycocyanin fluorescence were large from April through August, with a decline accompanying the spring freshet. Spring primary production—as inferred from chlorophyll fluorescence—occurred in a large, long-lived peak lasting from mid-April to mid-May. In contrast, although levels of phytoplankton biomass were high during the post-freshet period, the peaks were shorter lived and punctuated by low values. Conductivity values fluctuated more widely at Franz Lake Slough compared to Campbell Slough, as did pH. Dissolved oxygen saturation values were generally higher than at Campbell Slough; however, short-lived low values were observed in the daily averages, driven by periodic low values occurring during some part of the day.

For additional detail, refer to Rao et al. (2020) Lower Columbia River Ecosystem Monitoring Program Annual Report for Year 15 (October 1, 2018 to September 30, 2019).

Adaptive Management

Results from long-term monitoring identified important habitat condition trends in data gathered from the trends sites. Sediment accretion rates are variable in time and space. Accretion is generally greater at lower elevations and along channels. Inundation magnitude and frequency vary spatially in the lower Columbia River, generally increasing with distance from the Columbia River mouth, while elevation of emergent wetlands in the lower reaches covers a very narrow range. Emergent wetland vegetation cover and composition in the lower river are related to hydrologic patterns, with some species (such as wapato and spikerush) thriving under low marsh conditions exposed to greater durations and frequencies of flooding. Reed canarygrass cover peaks at moderate inundation levels, but cover remains relatively high at low inundation levels. The plant species composition in a wetland is important for determining the quality and quantity of macrodetritus available to salmon prey, thus understanding the hydrology of a wetland and the plants that grow there are important information when assessing the function of the food web. Some water level loggers and sediment accretion stakes were lost or damaged in recent years; thus replacement equipment was deployed at some of the sites to allow for continued data collection and to minimize gaps in the long-term dataset. To reduce the variability in the accretion data greater numbers of sediment accretion stakes should be installed across each site's elevation and inundation gradient.

Water temperatures in recent years at some trends sites (Campbell Slough and Franz Lake) were higher than long-term averages, likely due to the warmer air temperatures, increased solar radiation, and differences in freshet size and timing. By June, temperatures at trend sites in the upper reaches (Campbell Slough and Franz Lake) are often above optimal levels for juvenile salmon, increasing the potential for lethal and sub-lethal effects. These elevated water temperatures have also been accompanied by increases in cyanobacteria abundance. Cyanobacteria blooms have been regularly observed in off-channel habitats during the mid to late summer months throughout the duration of the Ecosystem Monitoring Program. The ecological and health implications of these blooms are not well known for the lower Columbia; it is interesting to note that although cyanobacteria blooms tend to be associated with high temperatures, the blooms observed during the warmest of recent years (2015) was associated with species that were not toxin-producing. This highlights the interplay between species composition and environmental conditions that influence the development of blooms, especially nutrient supply, temperature, and transport and colonization of organisms. Since nutrient supply to the lower Columbia River appear to come from different sources, including particulate matter (phosphorus), direct inputs from tributaries (nitrogen; especially from the Willamette), and the ocean (nitrogen or phosphorus, depending on the season; especially at Ilwaco), it is important to better understand how temporal patterns in nutrient supply influence the timing and magnitude of phytoplankton blooms, especially when they are dominated by noxious species such as toxin-producing cyanobacteria.

RPA 60.1 Develop limited number of ref. sites for typical habitats

Questions

1. *What is the status of the reference site characterization?*
2. What are the results from reference site characterization in terms of invasive species (composition, abundance, spatial distribution), sediment accretion rate(s), surface water elevation, bathymetry, floodplain topography, dissolved oxygen, salinity, temperature, ecosystem structures map, and percent cover by plant species?
3. How have the reference sites been used or planned to be used in action effectiveness research?

Implementation

1. *What is the status of the reference site characterization?*
2. *As applicable, which reference sites have been, or will be, used in action effectiveness research?*

The Ecosystem Monitoring Program (BPA Project 2003-007-00) assesses annual trends and reference sites throughout the lower river. Previously, another project – the Columbia River Estuary Habitat Restoration (BPA Project 2003-011-00) – developed a suite of reference sites in the wetland habitats following the estuarine tidal freshwater gradient to provide "targets" or comparison for habitat action effectiveness monitoring at restoration sites. Currently, the Estuary Partnership has data on the structure, function, and condition of over 50 reference sites in its database that can be paired with habitat restoration actions to identify where sites are located on the trajectory towards recovery.

The Columbia River and Estuary Restoration Reference Site Study (LCRE Ecosystem Monitoring, BPA Project 2003-007-00) synthesized information for factors that structure shallow water vegetated habitats along the entire longitudinal gradient of the lower Columbia. This project evaluated plant community composition at 52 tidal wetlands (marshes, shrub, and forested) in the lower Columbia for the purpose of providing specific reference and habitat restoration design elevations. Marshes, shrub wetlands, and forested wetlands were examined respective to their location and landforms (i.e., tributaries, islands, and bays). Three distinct wetland origins were considered: historically present, historically breached, and created. Four sites, Reed Island, Franz Lake, Illwaco Slough, and Cunningham Lake, were used as reference sites for nearby restoration projects. Franz Lake, Illwaco Slough, and Cunningham Lake are sites sampled for long-term trends under the Ecosystem Monitoring Program, and Reed Island is a wetland site identified in the 2011 PNNL reference site study, these sites were all selected as Action Effectiveness (Level 2) reference sites in 2019.

Results

1. What is the status of the reference site characterization?
2. Are there trends or patterns in reference sites in terms of juvenile salmonids, invasive species

(composition, abundance, spatial distribution), sediment accretion rate(s), surface water elevation, bathymetry, floodplain topography, dissolved oxygen, salinity, temperature, ecosystem structures map, and percent cover by plant species?

<u>Note:</u> *as applicable, please call-out results specific to interior, ESA-listed salmonids.*

<u>Juvenile Salmonids</u>
Salmonid data collected under the Ecosystem Monitoring Program (EMP) indicate that a variety of salmon stocks utilize rearing habitats throughout the lower Columbia River. Juvenile salmon originating from interior Columbia River stocks comprise a larger percent of the catches in the upper, freshwater reaches of the lower river, whereas the lower reaches are typically dominated by West Cascade fall Chinook salmon.

<u>Habitat Structure</u>
Habitat structure is important because the percent vegetation cover and vegetation community composition not only provide habitat for juvenile salmon but also affect the quality and quantity of macrodetritus available to juvenile salmon prey. Overall patterns and variability in habitat structure are observed temporally and spatially at sites monitored as part of the EMP. In general, vegetation cover is higher and more consistent between years at sites in the lower reaches than at sites in the upper reaches where cover tended to be lower and more variable between years depending on the magnitude and timing of the freshet. Species composition varies in the estuary, shifting from sites dominated by Lyngby's sedge (Carex lyngbyei) at and below rkm 53 to sites dominated by reed canarygrass (Phalaris arundinacea) at and above rkm 72. The number of species also changes longitudinally, with the greatest diversity of plant species observed at the sites located at rkm 53 and 72 (Welch Island and Whites Island, respectively). In 2018, the % cover of reed canarygrass stayed relatively similar to 2017 levels at Welch Island, Campbell Slough, and Franz Lake, but showed continued declines at Cunningham Lake and Whites Island. 2019 data is still under analysis, however, we have consistently observed annual shifts in reed canarygrass across reference sites corresponding directly with the annual magnitude and timing of the freshet, especially at mid and upper river sites such as Franz Lake, Cunningham Lake, and Campbell Slough. Higher freshet years such as 2011 and 2012 resulting in as much as a 20% decline in reed canarygrass cover across these sites.

<u>Water Quality</u>
Water quality metrics, such as dissolved oxygen, temperature, pH and salinity are important for determining whether the site offers good quality habitat for juvenile salmon and the seasonal timing and duration of those conditions. The following are results of the 5 trend sites.

Illwaco Slough. In 2019, maximum summer temperatures reached nearly 21^{0}C in August. Ilwaco is strongly influenced by tidal exchange with marine waters from the coastal ocean. Salinity is the clearest indicator of this influence: between March and September, waters went from mesohaline (~0.5–5 practical salinity units, PSU) to polyhaline (~5–18 PSU). Dissolved oxygen percent saturation relative to the atmosphere was as low as 45% at Ilwaco during the warm months of June and July. Between March and July pH fluctuated between 7.3 to 7.9, which falls within the recommended range (6.5–8.5; Washington State Water Quality Standards).

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Whites Island. Temporal patterns in water quality parameters at Whites Island were very similar to those observed at Welch Island. In 2019, dissolved oxygen saturation levels were similar between Welch Island and Whites Island prior to the freshet; however, after the freshet subsided, dissolved oxygen saturation was higher at Whites Island, never dipping below 95%.

Campbell Slough. Of the five off-channel trends sites, Campbell Slough had the highest summer water temperatures, with values exceeding 25 ^{o}C in August. All biogeochemical properties reflect the influence of the freshet, with high elevation values, a reduction in chlorophyll, dissolved oxygen saturation, conductivity, temperature, and pH. In 2019, pH increased to values close to 10 by mid-July, which exceeds water quality benchmarks (Washington State Water Quality Standards). There were dramatic fluctuations in the percent saturation of dissolved oxygen throughout the year at Campbell Slough, indicating high biological activity at this site. Values dropped to as low as 40% relative to atmospheric values during the spring freshet. Chlorophyll concentrations observed at Campbell Slough were below the recommended benchmark of 15 µg L-1 (based on three samples collected over three consecutive months; Washington State Water Quality Standards).

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For additional detail, refer to Rao et al. (2020) Lower Columbia River Ecosystem Monitoring Program Annual Report for Year 15 (October 1, 2018 to September 30, 2019).

Adaptive Management

Trends sites sampled under the EMP, as well as the Reference Site Study sites, have been included as paired reference sites with restoration sites for Action Effectiveness Monitoring. Data collected at the trend and reference sites (vegetation, hydrology, water quality) can provide context to the success of restoration actions in terms of site recovery and benefits for ESA-listed salmonids. Our long-term trend data demonstrate that juvenile Chinook salmon from multiple interior Columbia River ESUs use off channel slough habitats in the lower river for periods of hours to weeks, to feed and grow before moving downstream.

RPA 61.1 Define importance of tidal freshwater/estuary/plume/nearshore

Questions

1. What were the results from investigating the extent of limiting ecological functions for juvenile salmon in the estuary and plume? (Table 3 metrics.)
2. What are some of the main research findings indicating the ecological importance or not of LCRE and plume ecosystems?

Implementation

1. Please describe (briefly, succinctly) the study design you used to investigate the importance of the LCRE, plume, and/or nearshore ocean for juvenile salmonids.

2. What specific questions were you investigating?

3. What is the geographic scope of this study? (Please feel free to include a map, if complex sampling design)

The Lower Columbia Estuary Partnership (Estuary Partnership) Ecosystem Monitoring Program (EMP; BPA Project 2003-007-00) is an integrated status and trends program for the lower Columbia River that includes a study area extending from the mouth of the river to Bonneville Dam. EMP trend sites include: Ilwaco Slough, rkm 6; Welch Island, rkm 53; Whites Island, rkm 72 Campbell Slough, rkm149; and Franz Lake, rkm 221. The EMP aims to collect key information on ecological conditions for a range of habitats throughout the lower river characteristic of those used by migrating juvenile salmon and provide information toward the recovery of threatened and endangered salmonids. The program provides an inventory of the different types of habitats within the lower river, track trends in the overall condition of these habitats, provide a suite of reference sites for use as end points in regional habitat restoration actions, and places findings from management actions into context with the larger ecosystem.

The EMP monitored juvenile salmon use of shallow-water habitats in Reaches A-H. The project analyzed salmonid densities, fish community composition (covered in depth in RPA 59.4), salmonid age-size structure (covered in depth in RPA 58.3), genetic stock identity (covered in depth in RPA 59.4), prey availability/salmon diet (covered in depth in RPA 58.3), residence times (covered in depth in RPA 59.4), spatial and temporal distribution, growth rates and habitat characteristics (covered in depth in RPA 60.1). In addition, the EMP collects data on salmon food web metrics at trend sites and in the river mainstem to better understand the interactions of different food web components (primary and secondary production, nutrient inputs, water quality) can benefit juvenile salmon.

Results

1. What are your most salient research findings on the ecological importance of LCRE and plume ecosystems for juvenile salmonids?

2. Please comment on temporal variability (e.g. seasonality) and juvenile salmonid ESU benefiting, if data is available.

Note: As applicable, please call-out results for interior, ESA-listed salmonids.

Food Web

Phytoplankton forms the base of the juvenile salmon food web that feeds zooplankton and macroinvertebrates, which are important juvenile salmon prey items. Different types of phytoplankton are more nutritious (e.g., diatoms) than others and it is important for the timing of quality phytoplankton blooms to overlap with the presence of juvenile salmon and salmon prey. In addition, the presence and abundance of some primary producers, such as cyanobacteria, often indicate reductions in water quality and presence of potentially harmful toxins. Chlorophyll *a* concentration is an indicator of phytoplankton abundance and primary production.

Chlorophyll *a* concentration is determined at six trend sites (Ilwaco Slough, Welch Island, Whites Island, Campbell Slough, and Franz Lake Slough) from March to September. Similar to previous years, in 2019, the lowest chlorophyll *a* value were observed at Ilwaco Slough. Aside from the very high value observed in May at Franz Lake Slough, primary production was highest in March at the lower river sites (Welch Island and Whites Island) and in August at the more upriver sites (Campbell Slough and Franz Lake Slough). Spring chlorophyll *a* concentration is typically higher than in the summer months. As flows begin to recede in the summer months, phytoplankton populations also begin to increase. In the lower reaches, phytoplankton species composition is typically dominated by colonial diatoms; however, the loss of connectivity to the mainstem at Campbell Slough and Franz Lake Slough result in the development of distinct phytoplankton assemblages characterized by higher proportions of flagellate taxa, including chlorophyte, cryptophyte, and chrysophyte algae. These algal groups are less nutritious than diatoms, potentially resulting in lower quality organic matter available to support consumers. In addition, at these two upriver sites, cyanobacteria populations increase as temperatures rise, often resulting in noxious blooms.

In 2019, the zooplankton assemblages were dominated by a variety of rotifers in the spring (March through May) at all sites. Similar to previous years, zooplankton assemblages at Ilwaco were dominated by copepods, with spring samples heavily dominated by nauplii. The zooplankton assemblages at both Campbell Slough and Franz Lake Slough were dominated by copepod nauplii and rotifers in March. Zooplankton assemblages at Welch and Whites Island differed from those at Campbell Slough and Franz Lake Slough but were similar to each other. Zooplankton abundance typically increases throughout the lower estuary following spring growth of phytoplankton. During the spring freshet, zooplankton abundance is diluted but increases again once water levels recede.

This is particularly evident at sites such as Campbell Slough were connectivity to the mainstem is relatively low.

<u>Spatial and temporal genetic stock distribution</u>

Data on genetics indicate how juvenile salmon from various ESUs and life history types use off channel habitats in the lower Columbia River. In 2019, genetics data were collected from Chinook salmon at Welch Island, Whites Island, Campbell Slough, and Franz Lake. To maintain the highest level of confidence in stock assignments, we only reported stock assignments for fish that had an assignment probability greater than or equal to 0.90. We applied this criterion across all reporting years. On average, 86% of genetic samples assigned at 0.90 or greater.

Among unmarked fish in 2019, West Cascade fall Chinook were the predominant stock at sites in Reaches B and C: Welch Island and Whites Island. The percentages of upper Columbia summer/fall stocks at both Welch and Whites Islands, 21 and 17%, respectively, were the highest yet reported at those sites. Similar to previous years, the unmarked stock composition at Campbell Slough were more diverse than the lower river sites; with West Cascade fall stocks comprising only 16%. These 2019 levels are the lowest observed contribution of West Cascade fall stock at Campbell Slough except for 2011 and 2015 when no West Cascade fall stocks were collected. In contrast, upper Columbia summer/fall stocks comprised 66% of the sample at Campbell Slough in 2019, the highest percentage observed at that site. Overall, Spring Creek fall stock represented 12.5% and West Cascade spring stock comprised 6.3%.

For additional detail, refer to Rao et al. (2020) Lower Columbia River Ecosystem Monitoring Program Annual Report for Year 15 (October 1, 2018 to September 30, 2019).

Adaptive Management

Phytoplankton plays a key role in river food webs since other sources of organic matter (i.e., detrital material) that traditionally fueled the food web has been reduced. Monitoring the seasonality and species composition of phytoplankton and understanding their pathways in the salmon food web (for example through grazing by zooplankton and consumption of detritus by macroinvertebrates) is a critical component of ecosystem monitoring in salmon food webs. Species composition matters at all levels of the food web; the composition of algal taxa reflects water conditions and quality, the amount of carbon and nutrient transformations that occur, and the suitability of food for zooplankton or benthic species. Salmon exhibit clear preferences for different food sources, which are found under specific conditions, both biotic (i.e., food availability) and abiotic (water quality, substrate). Continued long-term monitoring of phytoplankton and zooplankton dynamics, with a focus on environmental variables such as temperature and water depths, provides contextual information to pinpoint critical time periods that can be targeted for management of water quality and salmonid food resources.

Juvenile salmon data collection at the EMP trends sites has, in recent years, been expanded to include year-round sampling, which can provide additional data on stock-specific use of lower river habitats. Continued collection of Chinook salmon genetics data will provide information on how interior Chinook salmonid use habitats spatially and temporally in the lower Columbia River.

RPA 61.3 LCR-investigate early life history of salmon populations

Questions

1. What were the research results relating to the importance of early life history (growth, survival, and timing of ocean entry) of salmon populations in tidal fresh water of the lower Columbia River?
2. Do juvenile salmon over-winter in tidal freshwater?
3. If so, what are the biological features of this behavior? (Federal Columbia River RME Program Table 3 metrics.)

Implementation

1. What size class(es) did you use to determine life histories? Were there threshold sizes used?

2. Please briefly, concisely describe your methods.

The Lower Columbia Estuary Partnership (Estuary Partnership) Ecosystem Monitoring Program (EMP; BPA Project 2003-007-00) is an integrated status and trends program for the lower Columbia River that includes a study area extending from the mouth of the river to Bonneville Dam. EMP trend sites include: Ilwaco Slough, rkm 6; Welch Island, rkm 53; Whites Island, rkm 72 Campbell Slough, rkm149; and Franz Lake, rkm 221. The EMP aims to collect key information on ecological conditions for a range of habitats throughout the lower river characteristic of those used by migrating juvenile salmon and provide information toward the recovery of threatened and endangered salmonids. The program provides an inventory of the different types of habitats within the lower river, track trends in the overall condition of these habitats, provide a suite of reference sites for use as end points in regional habitat restoration actions, and places findings from management actions into context with the larger ecosystem.

The EMP monitored salmonid density, fish community composition (covered in depth in RPA 59.4), salmonid age-size structure (covered in depth in RPA 58.3), genetic stock identity (covered in depth in RPAs 59.4 and 61.1), prey availability (covered in depth in RPA 58.3), residence times (covered in depth in 59.4), spatial and temporal distribution (covered in depth in RPA 59.4) , growth rates (covered in depth in RPA 58.3), and habitat characteristics (covered in RPA 59.5) throughout the LCRE to further investigate the importance of early life history diversity. Life history types were determined by noting whether salmon were marked or unmarked (indicating hatchery or wild origin), genetic stock identification, and by using length to determine size classes of captured salmonids.

Results

1. What were your results?

2. Which ESU(s) and life history type(s) did you find? Were they associated with any measurements? (e.g. depth)

3. Did you investigate, or is there information available on, the contribution of those life histories to adult returns or their estuary/plume/ocean survival?

Data on genetics, size, and whether a salmon is marked or unmarked may reveal how juvenile salmon from various ESUs and life history types use off-channel habitats in the lower Columbia River. In 2019, genetics data were collected from Chinook salmon at Welch Island, Whites Island, and Campbell Slough. To maintain the highest level of confidence in stock assignments, we only reported stock assignments for fish that had an assignment probability greater than or equal to 0.90. We applied this criterion across all reporting years. On average, 86% of genetic samples assigned at 0.90 or greater.

Among unmarked fish in 2019, West Cascade fall Chinook were the predominant stock at sites in Reaches B and C: Welch Island and Whites Island. The percentages of upper Columbia summer/fall stocks at both Welch and Whites Islands, 21 and 17%, respectively, were the highest yet reported at those sites. Similar to previous years, the unmarked stock composition at Campbell Slough were more diverse than the lower river sites; with West Cascade fall stocks comprising only 16%. These 2019 levels are the lowest observed contribution of West Cascade fall stock at Campbell Slough except for 2011 and 2015 when no West Cascade fall stocks were collected. In contrast, upper Columbia summer/fall stocks comprised 66% of the sample at Campbell Slough in 2019, the highest percentage observed at that site. Overall, Spring Creek fall stock represented 12.5% and West Cascade spring stock comprised 6.3%.

Substantially fewer marked fish were collected and subsequently analyzed for genetics at trend sites in 2019. Changes in stock composition occurred at Welch and Whites Islands in 2019, and spring stocks represented a larger percentage of the sample than had been observed in previous years. 2019 was the first year that West Cascade spring stocks were observed at Welch and Whites, and the percentage of Willamette River spring stock increased at both sites, as well. At Campbell Slough, 85% of marked Chinook were assigned to the Spring Creek Group, while 15% were assigned to the mid and upper Columbia spring reporting group. 2019 is the first year the mid and upper Columbia spring reporting group, which includes ESUs listed as endangered, has been observed at any of the trend sites.

The seasonal distribution of stocks in 2019 reveals that West Cascade fall Chinook are present throughout the lower Columbia River and estuary during spring and summer. Willamette River spring fish were present in the early spring and in June. Interior stocks occurred earlier at upper reaches and were not present in lower reaches until June. The increase in upper Columbia summer/fall stock in 2019 is evident in May and June. May and June are also the months when the greatest diversity of stocks is observed with the mid and upper Columbia spring present at

Campbell Slough in May and Snake River fall stocks present in June. The seasonal trend of stocks in 2019 varied from previous years due to higher percentages of upper Columbia summer/fall stocks and at all sites and mid and upper Columbia spring stock at Campbell Slough.

At the trend sites in 2019, the majority of unmarked Chinook salmon were fry, 64%, 32% were fingerlings, and 4 % were yearlings. Only at Welch Island did fry dominate catches, making up 77% of unmarked Chinook salmon. Campbell Slough and Whites Island showed a more even distribution of fry and fingerling of unmarked Chinook salmon. In comparison to previous years, the percentage of fry at all of the trend sites was slightly lower than in recent years.

A total of 37 (67 %) marked Chinook salmon caught at the trends sites in 2019 were fingerlings. In comparison to previous sampling years, the proportion of yearlings encountered in 2019 was greater (18%). This does appear to differ from the overall trend; however, sample size is relatively low. Similar to all previous years, no fry marked Chinook were observed in 2019 at any of the sampled locations.

For additional detail on ESUs and life history in the lower Columbia River, refer to Rao et al. (2020) Lower Columbia River Ecosystem Monitoring Program Annual Report for Year 14 (October 1, 2018 to September 30, 2019).

Adaptive Management

At the EMP trend sites in 2019, the unmarked Chinook salmon captured were mostly fry or fingerlings, with only a few yearlings, whereas the marked Chinook salmon caught at the trends sites were either fingerlings or yearlings. A greater percentage of interior Chinook salmon stocks are typically observed in the upper reaches and lower Columbia River Chinook salmon stocks are more common in the lower reaches. 2019 varied from previous monitoring years with higher percentages of upper Columbia summer/fall stock at all sites. Genetic origin should be considered when assessing the influence of habitat condition and opportunity in areas of restored or enhanced habitat on early life history of salmonids. Fish data collected under the EMP have shown differences among genetic stocks in factors such as size and presence at the trends sites. EMP fish collection data show that marked and unmarked juvenile Chinook salmon from West Cascade, Willamette River, and Interior Columbia River stocks use off-channel habitat in the lower river during migration. Thus, habitat management decisions should consider a variety of salmon life-history types.

RPA 71.4 Implement std metrics, biz practices, & info collection

Questions

1. How has your project worked with regional monitoring agencies to track and report on the status of regional fish improvement and fish monitoring projects?

Implementation

The Estuary Partnership (BPA Project 2003-007-00) convenes the Science Work Group, a forum to exchange regional scientific information about the estuary and provides technical and scientific support to the Estuary Partnership, it's partners and regional agencies. Additionally, every two years we co-host a Columbia River Estuary Conference with several regional partners. The Estuary Partnership regularly works with the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) to support efforts for the standardization of restoration action effectiveness monitoring. Using monitoringmethods.org, we manage the "Protocols for Monitoring Habitat Restoration Projects in the Lower Columbia River and Estuary" (Roegner et al. 2009), to ensure project sponsors and other entities can access the methods for measuring applicable indicators.

Results

Through the Science Work Group and the Columbia River Estuary Conference, the Estuary Partnership presents results from the Ecosystem Monitoring Program and the Action Effectiveness Monitoring Program to regional monitoring agencies. Annual monitoring reports are available to the Science Work Group upon completion. The Estuary Partnership created and distributed a "best" practices document related to the collection of Level 3 Standard Monitoring Indicators. The Estuary Partnership also presents new techniques in vegetation community monitoring at Level 3 sites using UAVs.

The creation of a standard protocol and methods allows for the comparison of data collected from multiple restoration action effectiveness monitoring sites. The Estuary Partnership manages the Level 3 Standard Monitoring indicators protocol and Level 2 Extensive Monitoring indicators. Currently, the protocol "Lower Columbia River Estuary Habitat Action Effectiveness" (https://www.monitoringmethods.org/Protocol/Details/460), "Columbia Estuary Ecosystem Restoration Program (CEERP) Level 3 Standard Monitoring Indicators" (https://www.monitoringmethods.org/Protocol/Details/1894), and "Lower Columbia River Habitat Status and Trends" (https://www.monitoringmethods.org/Protocol/Details/85) are currently awaiting review for publication on Monitoringmethods.org.

Adaptive Management

The Estuary Partnership continues to collaborate with other regional monitoring agencies to find avenues to integrate monitoring data. Additionally, the Estuary Partnership continues to refine collection and data management practices for Level 3 metrics. The nature of the data collected in the lower River and Estuary is different from monitoring data collected in the tributaries. The Estuary Partnership is working with other regional entities to better illustrate improvements in fish and fish habitat projects throughout the watershed.

RPA 72.1 Participate & jointly fund support in reg coordination forums

Questions

1. How did your project contribute to the coordination and standardization of information to support the RME program and related performance assessments?

Implementation

The Lower Columbia River Estuary Ecosystem Monitoring Program (BPA Project 2003-007-00) facilitated completion, collection, and quality assurance/quality checks (QA/QC) of data exchange templates for core monitoring metrics at restoration sites. The estuary monitoring data is collected for eventual input into LCRE regional monitoring database currently under developed (RPA 70.2). The Estuary Partnership maintains online maps related to the Columbia River Estuary Ecosystem Classification and other GIS-based data.

Results

To manage the data, the Estuary Partnership completed and collected core monitoring metric data exchange templates (DET) created for a regional monitoring database. The Estuary Partnership QA/QCs submitted data and work with project sponsors to ensure data quality. The data is housed on Estuary Partnership servers until the completion of the regional monitoring database. Additionally, we evaluated potential regional monitoring databases and provided feedback and recommendations to action agencies.

All elements of the Columbia River Estuary Ecosystem Classification can be found on the Estuary Partnership's website (*http://www.estuarypartnership.org/columbia-river-estuary-ecosystem-classification*). Hydrogeomorphic Reaches, Ecosystem Complexes, Geomorphic Catenae, Primary Cover Class, and Anthropogenic features are available through web mapping services, and the raw GIS data is available for download Topography, bathymetry, land cover and other data are available from the website or by request from the Estuary Partnership.

Adaptive Management

Promoting and using existing DETs improves the standardization, capture, and usability of monitoring data. We successfully collected monitoring data DETs to ensure data is centralized and not lost. We coordinated with database managers to evaluate existing DETs and the transfer of data to a regional database. We continue to work with regional project sponsors to capture DETs, address user issues, and provide QA/QC for submitted data. The lack of an upload protocol and database hinders efforts to make the data readily available in a format that can be analyzed efficiently by outside entities. The Estuary Partnership analyzed all submitted monitoring data and reported the information in the CEERP 2018 Synthesis Memorandum. The completion of a regional database for monitoring information will facilitate data analysis and will become an important tool for answering management questions in the future.

RPA 72.3 Develop a reg mgmt strategy for water, fish & habitat data

Questions

1. How did your project participate in Northwest regional coordination and collaboration efforts for data management?

Implementation

The Estuary Partnership continues to coordinate with the BPA and the US Army Corps in the development of an online database to store habitat, fish, and water quality data collected at restoration, status, and trend sites. This work includes implementing data reduction protocols and quality assurance practices for pre- and post-restoration habitat monitoring. The result is an increase in the amount and quality of monitoring data.

Results

The Estuary Partnership coordinated the collection of monitoring data DETs from restoration project sponsors. The DETs contain data related to water surface elevation and temperature, sediment accretion, and photo points. The data collected by the Estuary Partnership is available to project sponsors upon request.

Adaptive Management

The Estuary Partnership continues to coordinate the collection and storage of DETs until a regional database is completed. The completed database will greatly ease filling requests for data. In the interim, data requests are filled upon request and results of annual data analyses are available in BPA annual reports.