Upper Salmon River Tributary Assessment Project (BOR002 16)

Multiple Reach Assessments Preliminary Summary Report

June 2019

Biomark
ABS
APPLIED BIOLOGICAL SERVICES

Table of Contents

Introduction **4**
Methods **5**
MRA Study Reaches 5
Fish Surveys 6
DASH 7
    On-The-Ground Habitat Sampling 8
    Drone Imagery 8
Fish-Habitat Data Integration 8
Depth and Velocity 8
Results **8**
MRA Study Reaches 8
Fish Surveys 9
DASH 9
    On-The-Ground Habitat Sampling 10
    Drone Imagery 11
Fish, Habitat, and Imagery Integration 12
    Upper Lemhi 16
    Lower Lemhi 17
    Pahsimeroi 18
    Upper Salmon 19
Discussion **20**
Next Steps 21
Conclusions 21
Literature Cited **22**

This document should be cited as:

Biomark ABS (Applied Biological Services). 2019. Upper Salmon River Tributary Assessment Project (BOR002 16), Multiple Reach Assessments Preliminary Summary Report. June 2019.

List of Tables

Table 1. MRA sites including description, river length, and location of site top and bottom where finer-resolution fish and habitat data were collected during summer 2018. Field efforts included channel unit delineation, fish mark-recapture surveys, and implementation of DASH protocol. 6

Table 2. Channel unit and site level habitat metrics currently generated from the DASH protocol including the method used to collect each metric. Methods include: Drone (D), Ground Crew (G)........... 7

Table 3. Frequency of channel unit types for each site including channel unit density (units/km). 9

Table 4. The number of individual fish captured summarized by site, species, and channel unit type. Abbreviated channel unit types include: OCA = Off Channel area, SSC = Small Side Channel. NA = Channel unit type did not exist in the given site. 9

Table 5. Summary of aerial surveys using a camera mounted to a drone including survey date, survey altitude, number of photos taken, and total areal coverage of survey. 11

Table 6. Estimates of average Chinook densities summarized by site and channel unit type. Abbreviated channel unit types include: OCA = Off Channel area, SSC = Small Site Channel. NA = Channel unit type did not exist in a given site. 12

List of Figures

Figure 1. Box and whisker plots showing the undercut length (m) of each channel unit for each individual site and the wood volume (m^3) for each qualifying piece in each channel unit. The ‘x’ in each plot represent the mean value and the horizontal bar illustrates the median value, the upper and lower bounding boxes show the 25th and 75th quantiles, while the dots illustrate the outliers outside of the 90th quantile... 10

Figure 2. Box and whisker plots illustrating the percent of gravel cover for each individual pool for all four unique MRA reaches and the maximum pool depth (m) for each channel unit in each reach. The ‘x’ represents the mean value and the horizontal bar represents the median value, while the dots show outliers falling outside of the 90th quantile and the upper and lower bounding boxes illustrate the 25th and 75th quantiles. 11

Figure 3. Box and whisker plots showing individual channel unit information. Left, the percent of each channel unit for each MRA reach with cover and the right, showing the percent of each channel unit covered by aquatic vegetation cover. The 'x' represents the mean value and the horizontal bar shows the median value for each site, the dots show outliers and the upper and lower bounding boxes illustrate the 25th and 75th quantiles. 12

Figure 4. A dot plot of juvenile chinook density (fish/m^2) for each unique channel unit type, where all four MRA reaches have been combined. 13

Figure 5. Dot and box and whisker plots showing juvenile Chinook density (fish/m^2) estimates available from fish and aerial surveys. The left plot shows density estimates for all mainstem channel units in each MRA reach. The right plot shows density estimates for channel units that do not fall within the main channel (e.g., off channel areas, small side channels, large side channels (riffle, run, pool) for each MRA reach. The horizontal line shows the median value, the upper and lower bounds of the box illustrate the 25th and 75th quantiles of the distribution. The black dots represent each individual channel unit density. 14

Figure 6. Histograms showing the distribution of juvenile Chinook salmon density (fish/m^2) estimates for all four MRA sites. The left histogram shows distributions for mainstem channel units. The right histogram shoes distributions for channel units present off of the mainstem for all four MRA sites......... 15

Figure 7. Map showing spatially distributed estimates of juvenile Chinook salmon densities (fish/m^2) in the Upper Lemhi MRA reach in which both DASH habitat protocol (drone and ground crews) and fish surveys were implemented in summer 2018. Channel unit area estimates were generated from drone imagery. The red rectangle indicates an area of interest zoomed closer in the map to the right. 16

Figure 8. A map showing estimated juvenile Chinook salmon densities (fish/m^2) in the lower Lemhi MRA reach in which both DASH habitat protocol (drone and ground crews) and fish surveys were implemented in summer 2018. Channel unit area estimates were generated from drone imagery. The red rectangle indicates an area of interest which as been zoomed into, shown by the map to the left. 17

Figure 9. Map showing estimated juvenile Chinook salmon densities (fish/m^2) in the Pahsimeroi MRA reach in which both DASH habitat protocol (drone and ground crews) and fish surveys were implemented in summer 2018. Channel unit area estimates were generated from drone imagery. The left map shows a zoomed in area of interest indicated by the red rectangle. 18

Figure 10. Map showing estimated juvenile Chinook salmon densities (fish/m^2) in the Upper Salmon MRA reach in which both DASH habitat protocol (drone and ground crews) and fish surveys were implemented in summer 2018. Channel unit area estimates were generated from drone imagery. The red rectangle indicates an area of interest shown in the left map. 19

Introduction

The Bureau of Reclamation (Reclamation), Idaho Governor's Office of Species Conservation (OSC), and an interdisciplinary team of partners assembled an Upper Salmon Assessment Team to complete biologic and geomorphic analyses to support future project identification, prioritization, and design in the Upper Salmon Sub-basin. Initial efforts from the Assessment Team resulted in a recently completed draft Upper Salmon Sub-basin Integrated Rehabilitation Assessment (IRA), a biologically based assessment of habitat conditions in the Upper Salmon River sub-basin in central Idaho for spring/summer run Chinook salmon (*Oncorhynchus tshawytscha*; hereafter Chinook salmon) and summer run steelhead (*O. mykiss*; hereafter steelhead) listed under the Endangered Species Act (ESA). The IRA framework was used to evaluate capacity limitations and associated geomorphic characteristics to facilitate habitat rehabilitation planning efforts for Chinook salmon and steelhead populations in the Upper Salmon River sub-basin. Recommended actions from the IRA include increasing juvenile rearing capacity during summer and winter months in target watersheds (Lemhi, Pahsimeroi, Upper Salmon above Redfish Lake Creek). The IRA was a watershed-scale assessment intended to identify the problem; future Multiple Reach Assessments (MRAs) will be developed to identify reach-scale, geomorphically appropriate target conditions and enhancement actions to inform the prioritization and development of specific enhancement projects. The MRAs are intended to refine analyses from the IRA by incorporating finer-resolution data, field work, and reach-specific rehabilitation targets, which will inform future habitat actions. Further, the MRAs include identifying appropriate and focused 'solutions' to particular capacity problems within four target areas (Upper Lemhi, Lower Lemhi, Upper Pahsimeroi, and Upper Salmon above its confluence with Redfish Lake Creek). To achieve this goal, the Assessment Team will collaboratively summarize existing and targeted physical habitat conditions relative to documented habitat needs for species and life stages, including discussion of high-quality habitat, its creation, and its maintenance to inform future rehabilitation actions.

Previously established habitat monitoring programs such as the Columbia Habitat Monitoring Program (CHaMP) were created to assess status and trends of stream habitat quality and quantity primarily in the Pacific Northwest (CHaMP 2016). CHaMP focused strictly on wadable, anadromous bearing streams which support Chinook salmon and steelhead. These types of programs collect a myriad of habitat data within very intensively monitored sites selected via a statistically rigorous study design known as generalized random tessellation stratified (GRTS). Limitations of previously established monitoring programs include personnel time required to complete the survey and limited spatial coverage. Typically, site lengths are a function of stream channel width, either wetted or bankfull, and ground crews must collect/complete all data collection. CHaMP leveraged surveying equipment such as total stations and prisms and older programs such as the USFS Pacfish/Infish Biological Opinion (PIBO) used a more traditional 'stick and tape' methodology of manually measuring channel cross sections to aide and accomplish data collection. These types of sampling procedures provide extremely detailed information on a small reach of stream but must be extrapolated to a larger watershed scale for larger scope assessments, relying on continuous remotely sensed information or other data sources that can be limiting. Further, these programs lacked extensive coordination to pair fish and habitat data collection at the channel unit scale, a scale thought to potentially be the most informative for habitat restoration design.

In an effort to address shortcomings of previous monitoring programs and leverage new technologies, we have developed the Drone Assisted Stream Habitat (DASH) protocol. This new methodology allows for an improved, rapid assessment of stream habitat, with data collected at both the channel unit and reach scales. Adaptation of CHaMP field methods, paired with high resolution drone survey, permits a crew of 1 to 2 ground personnel to sample kilometers of stream in 2 to 3 days as opposed to meters of stream in the same time frame. The new approach also lends itself well to informing restoration design and identification of limiting habitat factors and life stages due to the flexibility of channel unit scale information, which can be aggregated to any spatial scale desired (channel unit, reach scale, meso scale, watershed scale). Moreover, as technology, computational power, and methodologies improve, the need for extrapolation models to assess watershed scale status and trend may be minimized by the spatial extent that crews can sample in a single summer field season. In addition, paired fish and habitat data collected at multiple scales provide greater utility to engineers, geomorphologists, basin practitioners, biologists, and funding agencies.

During summer 2018, the Assessment Team initiated field efforts to provide finer-resolution data to be used to help define reach-specific rehabilitation targets. Field efforts included continuous juvenile fish surveys (e.g., electrofishing) and habitat surveys using the DASH protocol that leveraged remotely collected drone imagery and habitat information collected by ground crews. Field efforts were completed in four reaches: Upper Lemhi River, Lower Lemhi River, Pahsimeroi River, and the Upper Salmon River (above Redfish Lake Creek). The purpose of this report is to describe field efforts, data collected, and preliminary results from fish surveys and implementation of the DASH protocol. In particular, we address the following:

- Provide a summary of initial field efforts completed within MRA reaches (described below) in which fish surveys and the DASH protocol were implemented during summer 2018.
    - Briefly summarize results from juvenile fish surveys.
    - Briefly summarize on-the-ground habitat data collected using the DASH protocol.
    - Provide information on drone-collected orthomosaic imagery collected using the DASH protocol.
- Summarize depth and velocity information available to-date within the reaches.
- Provide a preliminary description of fish-habitat relationships gleaned from initial analysis of fish and habitat data available within the reaches from summer 2018 field efforts.
- Provide a summary of on-the-ground habitat data collected using the DASH protocol.
- Provide information on drone-collected orthomosaic imagery collected using the DASH protocol.

This report provides the remaining deliverables from Biomark, Inc. – Applied Biological Services to OSC for Project Number BOR002_16. This report also describes a portion of the finer-resolution fish and habitat (DASH) data that will be used to help define reach-specific rehabilitation targets, which will inform future habitat actions. Information presented here will be combined with geomorphic assessments and information on life-stage specific habitat preferences for juvenile Chinook salmon to identify target physical habitat conditions.

Methods

MRA Study Reaches

Four sites were selected for the 2018 MRA field season incorporating reaches from the three target watersheds: Upper Lemhi, Lower Lemhi, Pahsimeroi, Sawtooth Valley – Decker Flat. Sites were selected in an effort to incorporate a mix of habitat conditions and morphological characteristics ranging from simplified, mixed, to complex geomorphic character. Because the sites also included fish sampling, an attempt was made to use areas within the Lemhi River that had previously been slated for sampling. Further, areas within the Pahsimeroi River and upper Salmon River required accessibility considerations due to logistical constraints of fish sampling. Field efforts included channel unit delineation, juvenile fish mark-recapture surveys, on-the-ground habitat data collection, and drone imagery collection. The MRA reaches and spatial extents are listed in Table 1.

Table 1. MRA sites including description, river length, and location of site top and bottom where finer-resolution fish and habitat data were collected during summer 2018. Field efforts included channel unit delineation, fish mark-recapture surveys, and implementation of DASH protocol.

Site	Description	River Length (km)	Latitude/Longitude	
			TOS	BOS
Upper Lemhi	Upstream of L60 diversion	3.8	44.70532, -113.39184	44.71872, -113.41064
Lower Lemhi	Upstream of Screw Trap	3.1	45.14406, -113.81050	45.16018, -113.83237
Pahsimeroi	Dowton Ln	3.1	44.61235, -113.96316	44.62073, -113.98432
Sawtooth Valley	Decker Flat	3.6	44.06089, -114.85122	44.08425, -114.86743

Fish Surveys

Fish surveys were conducted using both backpack and raft electro-shocking units. Depending on stream width and depth, the raft electro-shocker was used in areas where it became necessary to create a larger electrical field to effectively capture juveniles. The shocker settings for both the backpack and raft remained similar in output where voltage typically did not exceed 300 peak voltage (VP), frequency remained around 30 hertz (Hz), and the duty cycle between 20-25%. The Upper Lemhi and Pahsimeroi sites were sampled in mid-June to early July using the raft electro-shocker moving in a downstream direction. The Upper Salmon was sampled in early July using both the raft and backpack electro-shockers, where the main channel was sampled using the raft moving in a downstream direction and the side channels were sampled using backpack shockers moving in an upstream direction. The Lower Lemhi was sampled in August using backpack shockers in an upstream direction. Due to insufficient flows (resulting from diverted water), we were unable to leverage the raft electro-shocker in the Lower Lemhi. The timing for sampling these areas occurred during periods where permitting and field schedules allowed, sampling before adult Chinook spawning, minimizing risk of encounter. All fish were collected, handled, and released at the location they were captured or recaptured. Chinook salmon and steelhead were PIT tagged to evaluate movement between channel units from the mark to recapture events.

All four sites were visited twice to generate data for a Chapman estimator. Rainbow trout/steelhead and Chinook salmon were marked using an upper caudal fin clip on the first visit which was then used as a visual for determining recaptures out of total captures from the second visit. The majority of channel units had little to no recaptures which made it impossible to estimate abundance at each individual channel unit. Therefore, the capture counts were combined to the site scale where we calculated a capture probability for each unique site, and for that sampling method (i.e. raft shocker sampling in the Upper Lemhi moving in a downstream direction). This allowed us to estimate total abundance and capture probability, by species, at the site scale. We then took the estimated capture probability for each site and species, applied that to the average fish capture found within each unique channel unit to estimate abundance at the channel unit scale by species. Lastly, we divided the abundance estimate by the area of the corresponding channel unit (estimated from drone imagery) and provided a spatially continuous, channel unit scale estimate of areal fish density (fish/m^2).

DASH

The DASH protocol and the MRAs are the first effort(s) within the region to incorporate channel unit scale fish sampling, habitat sampling, and drone-based sampling. We leveraged high resolution drone mounted cameras to populate juvenile Chinook density (fish/m^2) estimations and support on-the-ground habitat data collection. Further, the protocol was designed to support seamless fish-habitat integration at the channel unit scale, which allows for aggregation to larger scales beyond the channel unit. Table 2 shows habitat metrics generated by the DASH protocol and the methods to generate each metric.

Table 2. Channel unit and site level habitat metrics currently generated from the DASH protocol including the method used to collect each metric. Methods include: Drone (D), Ground Crew (G).

Category	Metric	Method
	Channel Unit Level Metrics	
Channel Unit Type	Channel Unit Type	G
	Adjacent Channel Unit Type	D, G
Channel Unit Area	Length	D
	Area	D
Depth	Max Depth	G
Side Channel	Count – Side Channels Entering	D
	Count – Side Channels Exiting	D
	Count – Adjacent Side Channels	D
Large Woody Debris	Jam Volume	G
	Wood Count	G
	Count – LWD Wetted	G
	Count – LWD Ballasted	G
Undercuts	Undercut Count	G
	Undercut Length	G
Substrate	% Fines	G
	% Gravel	G
	% Cobble	G
	D50	G
	D84	G
	Site Level Metrics	
Site Area	Total Site Area	D
Depth	Max Depth Average	G
Side Channel	Total Small Side Channel Area	D
	Total Small Side Channel Length	D
	Total Large Side Channel Area	D
	Total Large Side Channel Length	D
Undercuts	Site Undercut Count	G
	Site Undercut Length	D, G
	% Fines	G
	% Gravel	G
	% Cobble	G
	D50	G
	D84	G
Sinuosity	Sinuosity	D

On-The-Ground Habitat Sampling

The first step in DASH protocol sampling is to delineate channel units and collect their boundaries via a high resolution GNSS receiver (with horizontal error threshold set at 1m). This includes all mainstem channel units, channel units within large side channels (>25% of the flow, but <50%), and small side channels (<25% of the flow). Channel unit types included in the DASH protocol include pool, riffle, run, rapid+, off-channel area, and small side channel. These channel unit types are also delineated within large side channels. Next, ground crews collect habitat information within each individual channel unit throughout the entirety of the site. Lastly, the ground crew conducts the aerial survey using a drone mounted camera/sensor.

Drone Imagery

Four flights were conducted in total, one at each study reach. Flights were carried out at either 50m or 100m flying altitude with images captured at 70% front and 60% side overlap. Images were processed through Agisoft Photoscan to generate a continuous point cloud, orthomosaic, and digital elevation model for the entirety of each reach.

Fish-Habitat Data Integration

Fish data were merged to habitat information via a series of unique identification numbers related to the site, segment (differentiating main channel and all unique side channels), and channel unit sampled. The merged fish and habitat data were then joined to the spatially explicit channel unit polygons, through both a unique identification and spatial location, which tied all of the data back to the drone supported orthomosaic previously generated via Agisoft Photoscan.

Depth and Velocity

Depth and velocity results are available from a 2D-numerical model previously generated from bathymetric LiDAR in the Lemhi River (Tonina et al. 2018). Results are currently located on the OSC FTP site in three separate folders within a *LemhiLiDAR* directory split into *UpperLemhi*, *MidLemhi*, and *LowerLemhi*. Each results folder contains an accompanying spreadsheet within it, which outlines the discharge value for each modeled scenario. Available information includes depth, velocity, shear stress, and Chinook habitat suitability indices (HSI) for multiple life stages. This information will be leveraged in MRAs for the upper and lower Lemhi to help describe target habitat conditions.

At the time of writing of this report, 2D numerical model results were not available for the Pahsimeroi and Sawtooth Valley sites. However, model results are anticipated during spring/summer 2019 and will be leveraged in future MRAs at those sites. Depth, velocity, shear stress, and Chinook HSI results are not presented here, but will be communicated in reach assessments.

Results

MRA Study Reaches

Table 3 provides the number of channel units surveyed within each site including the channel unit density (units/km) and a breakdown by type. The Pahsimeroi site had the highest channel unit frequency followed by the Upper Lemhi site. The Upper Salmon site had the greatest number of small side channels and the Upper Lemhi site had the highest number of large side channel units. In total the Upper Lemhi had the greatest number of channel units sampled, conversely the Upper Salmon site had the lowest number of channel units sampled. In addition, the Upper Lemhi and Pahsimeroi had the greatest number of pool channel unit types encountered during surveying.

Table 3. Frequency of channel unit types for each site including channel unit density (units/km).

Site	Units /km	Main Channel				OCA	SSC	Large Side Channel			Total
		Pool	Riffle	Run	Rapid			Pool	Riffle	Run	
Upper Lemhi	3.46	66	40	18	0	5	14	4	4	0	151
Lower Lemhi	2.42	35	28	6	2	2	2	0	0	0	75
Pahsimeroi	4.10	50	23	9	0	2	5	3	1	1	94
Upper Salmon	1.90	19	17	3	0	4	17	3	0	3	66
Totals:	N/A	170	108	36	2	13	38	10	5	4	386

Fish Surveys

In total, we captured 1,209 unique juvenile Chinook salmon among the four sites (Table 4). The Upper Salmon site had the greatest number of captured juvenile Chinook salmon, followed by the Upper Lemhi, Lower Lemhi, and lastly the Pahsimeroi site. We captured 1,042 unique *O. mykiss*, where the Upper Lemhi had the greatest number captured, followed by the Pahsimeroi, Lower Lemhi, and Upper Salmon sites, respectively. The Upper Salmon site had a high number of Chinook salmon captured in small side channels. Disregarding rapids, in general, large side channel unit types had the lowest number of captured individual fish of all species.

The complete table of fish capture, and abundance by channel unit and site can be found on the OSC FTP site under *MRA/2018_Data/Fish.*

Table 4. The number of individual fish captured summarized by site, species, and channel unit type. Abbreviated channel unit types include: OCA = Off Channel area, SSC = Small Side Channel. NA = Channel unit type did not exist in the given site.

Site	Species	Main Channel				OCA	SSC	Large Side Channel			Total
		Pool	Riffle	Run	Rapid			Pool	Riffle	Run	
Upper Lemhi	Chinook	129	102	30	NA	4	2	0	7	NA	274
Upper Lemhi	O. Mykiss	286	202	123	NA	8	22	1	3	NA	645
Lower Lemhi	Chinook	30	71	3	0	0	1	NA	NA	NA	105
Lower Lemhi	O. Mykiss	36	97	17	1	0	8	NA	NA	NA	159
Pahsimeroi	Chinook	50	21	5	NA	1	12	0	0	0	89
Pahsimeroi	O. Mykiss	110	74	18	NA	1	8	2	4	0	217
Upper Salmon	Chinook	83	73	2	NA	3	577	2	1	NA	741
Upper Salmon	O. Mykiss	0	2	0	NA	0	10	0	9	NA	21

Below, we provide summaries of areal fish densities by site and channel unit type where individuals channel unit areas were estimated using drone supported orthomosaics.

DASH

Habitat metrics were collected from all 386 channel units using both ground crews and drone supported orthomosaic imagery applying methods outlined in the DASH protocol (Carmichael et al. 2019). Ground crew supported metrics include measurements describing channel unit type (boundaries refined using drone imagery), depth, large woody debris, undercut size and distribution, and substrate. Drone supported metrics include measurements describing channel unit configuration, channel unit area, side channel configuration and area, riparian and aquatic vegetation cover, and sinuosity (Table 2). In total, we estimate channel unit and reach scale habitat data were collected from 18.6 total wetted kilometers and 2.2 km^2 of stream and riparian.

On-The-Ground Habitat Sampling

Habitat measurements collected by ground crews were completed using methods described in the DASH protocol (Carmichael et al. 2019) and using the Survey123 application available by subscription from ESRI. We developed a custom survey template that aligns with measurements to be collected by DASH. We then developed an automated script to calculate habitat metrics from the habitat measurements at the channel unit, and site scale. Data has been exported, cleaned, and uploaded to the OSC FTP site and is available at *MRA/2018_Data/Habitat* and *MRA/2018_Data/Shapefiles* in both .csv and shapefile form.

Here we provide examples of habitat data collected from ground crews. Figure 1 shows estimates of undercut length and wood volume for individual channel units within each site collected using methods described in Carmichael et al. (2019). Further, Figure 2 shows estimates of % gravel and max depth estimates for pools within each site. Data like those presented in Figure 1 and Figure 2 can be used to make general comparisons among sites and can be used to describe fish-habitat relationships.

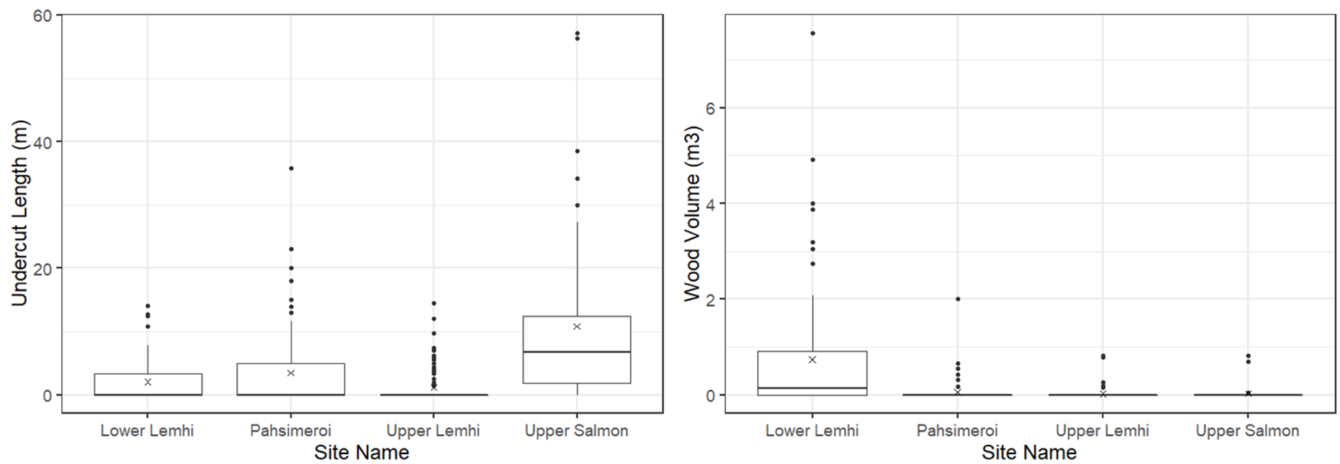


Figure 1. Box and whisker plots showing the undercut length (m) of each channel unit for each individual site and the wood volume (m^3) for each qualifying piece in each channel unit. The 'x' in each plot represent the mean value and the horizontal bar illustrates the median value, the upper and lower bounding boxes show the 25th and 75th quantiles, while the dots illustrate the outliers outside of the 90th quantile.

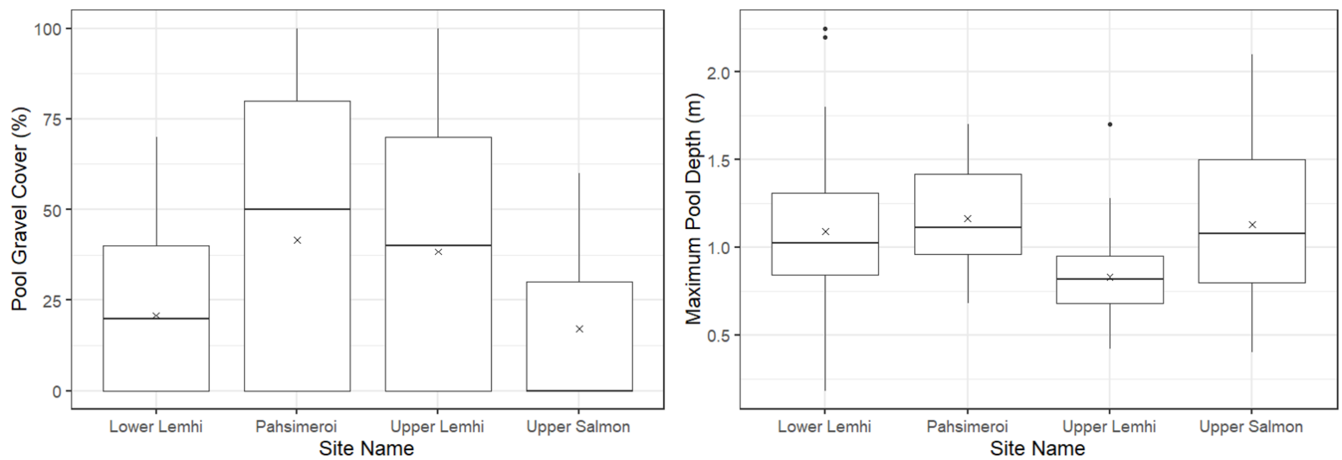


Figure 2. Box and whisker plots illustrating the percent of gravel cover for each individual pool for all four unique MRA reaches and the maximum pool depth (m) for each channel unit in each reach. The 'x' represents the mean value and the horizontal bar represents the median value, while the dots show outliers falling outside of the 90th quantile and the upper and lower bounding boxes illustrate the 25th and 75th quantiles.

Drone Imagery

Aerial surveys were completed using a 20-megapixel red, green, blue (RGB) camera/sensor mounted to a Phantom 4 Pro V2.0 drone during summer 2018. The camera/sensor was fixed with a polarized filter to limit water surface glare and captures visible light in the red, green, and blue spectrum to aide in generation of orthomosaic imagery. Table 5 summarizes aerial surveys including altitude, number of photos, and total and wetted areas. Orthomosaic images from aerial surveys have been uploaded to the OSC FTP site and are available at *MRA/2018_Data/Imagery*. Further, continuous point clouds and digital elevation models from aerial surveys are available upon request. Figure 3 provides estimates of total cover and cover from aquatic vegetation for individual channel units estimated from aerial surveys.

Table 5. Summary of aerial surveys using a camera mounted to a drone including survey date, survey altitude, number of photos taken, and total areal coverage of survey.

Site	Survey Altitude (m)	Number of Photos	Total Area (km^2)	Total Wetted Area (m^2)
Upper Lemhi	50	561	0.6	40,406
Lower Lemhi	50	568	0.37	38,431
Pahsimeroi	50	510	0.3	23,566
Upper Salmon	100	380	0.91	70,963

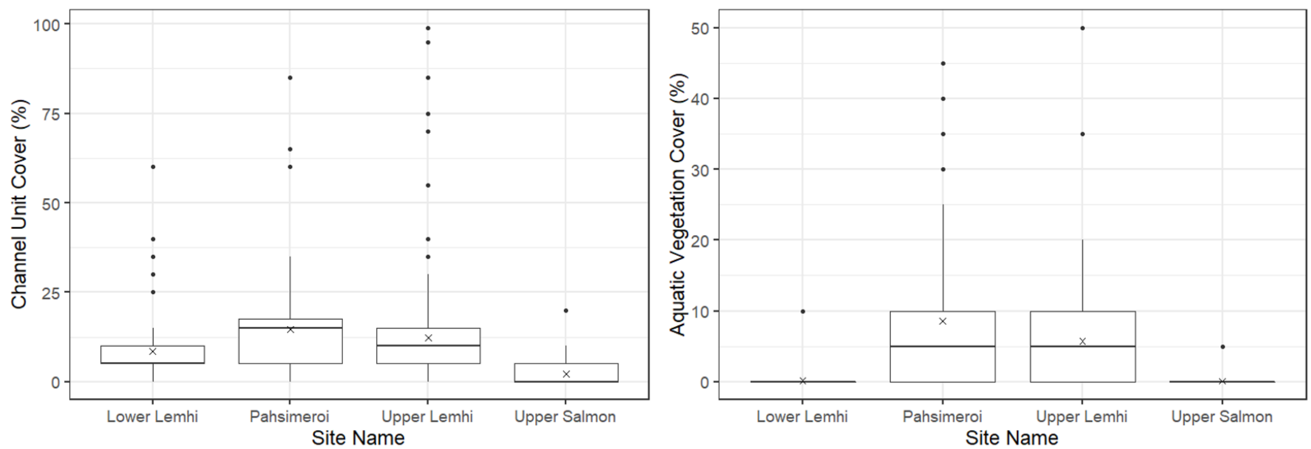


Figure 3. Box and whisker plots showing individual channel unit information. Left, the percent of each channel unit for each MRA reach with cover and the right, showing the percent of each channel unit covered by aquatic vegetation cover. The 'x' represents the mean value and the horizontal bar shows the median value for each site, the dots show outliers and the upper and lower bounding boxes illustrate the 25th and 75th quantiles.

Fish, Habitat, and Imagery Integration

Mark-recapture surveys of juvenile Chinook salmon and *O. mykiss* generated channel unit scale abundance estimates. Abundance estimates were merged with habitat information using unique identification numbers for each channel unit, and that dataset was spatially joined to channel unit polygons available from aerial surveys. The initial step was then to calculate the area (m^2) for each channel unit to convert abundance estimates to juvenile Chinook salmon and steelhead areal density (fish/m^2) estimates. Table 6 provides estimates of average juvenile Chinook densities by site, and channel unit type. Figure 4 shows estimates of juvenile Chinook salmon densities by channel unit type with the four MRA sites combined. In general, small side channels, pools, and off channel areas contained the highest observed fish densities. Conversely, riffles, runs, and large side channels supported lower densities of juvenile Chinook salmon. On average, the Upper Salmon site had the highest densities followed by the Pahsimeroi reach. The Lower Lemhi had the least number of captured juvenile Chinook at 0.0033 fish/m^2.

Table 6. Estimates of average Chinook densities summarized by site and channel unit type. Abbreviated channel unit types include: OCA = Off Channel area, SSC = Small Site Channel. NA = Channel unit type did not exist in a given site.

Site	Main Channel				OCA	SSC	Large Side Channel			Site Average
	Pool	Riffle	Run	Rapid			Pool	Riffle	Run	
Upper Lemhi	0.0651	0.0331	0.0330	NA	0.1065	0.0307	0.0000	0.0818	NA	0.0500
Lower Lemhi	0.0059	0.0069	0.0010	0.0000	0.0000	0.0058	NA	NA	NA	0.0033
Pahsimeroi	0.0778	0.0372	0.0443	NA	2.0151	0.0313	0.0000	0.0000	0.0000	0.2757
Upper Salmon	0.0782	0.0429	0.0155	NA	0.1404	3.8586	0.0278	0.0064	NA	0.5957

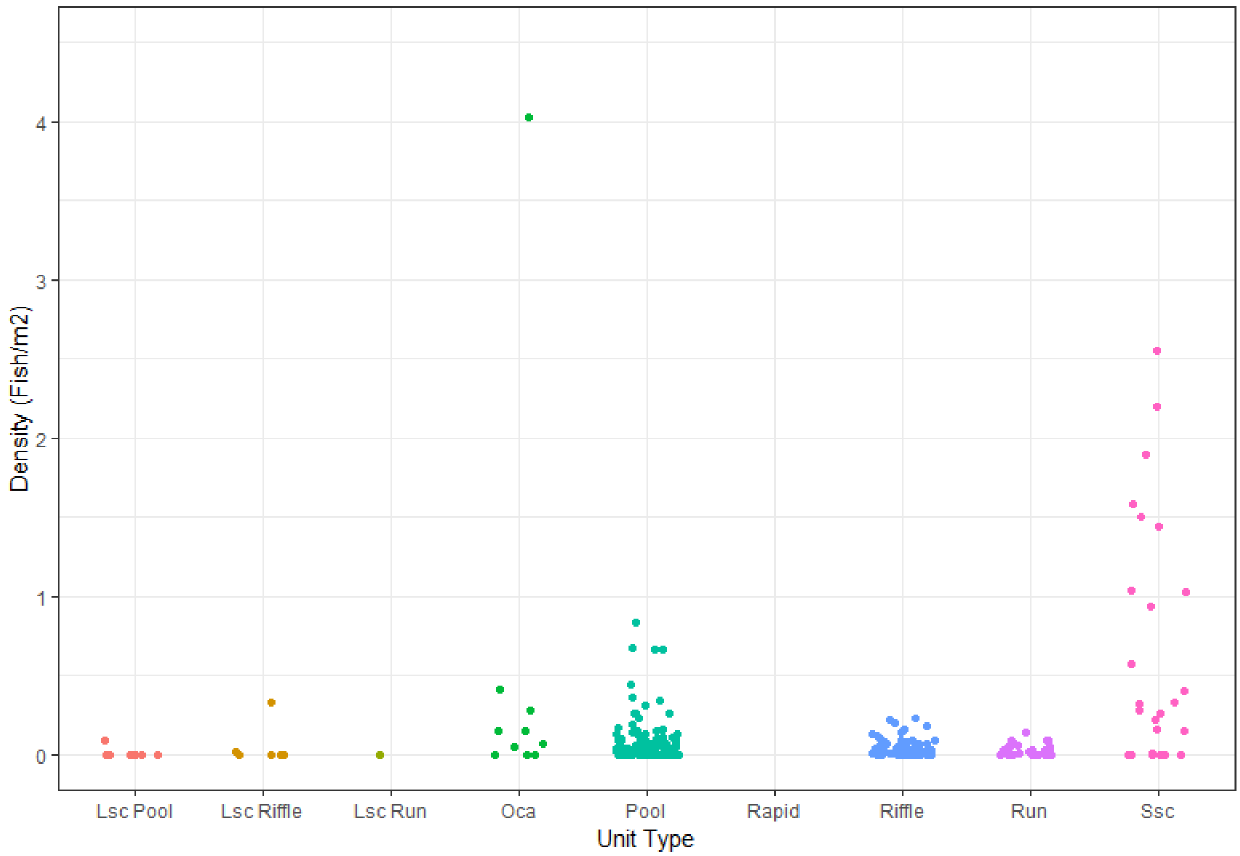


Figure 4. A dot plot of juvenile chinook density (fish/m^2) for each unique channel unit type, where all four MRA reaches have been combined.

Additionally, Figure 5 and Figure 6 show estimates of juvenile Chinook salmon densities by channel unit types both for the mainstem and for all non-mainstem channel unit types (off channel areas, small and large side channels). Overall, mainstem densities are lower than small side channels and off channel areas. Of the mainstem channel unit types only, the Upper Lemhi site had the highest average densities followed by the Upper Salmon MRA reach. However, the Upper Salmon site had the highest off channel densities then followed by the Upper Lemhi site. A single off channel area within the Pahsimeroi had the highest calculated densities, however the small side channel unit type had a greater number of densities above 0.5 fish/m^2 than any other channel unit type (Figure 6). Similarly, within the main channel, pools had the greatest number of units with densities greater than 0.3 fish/m^2.

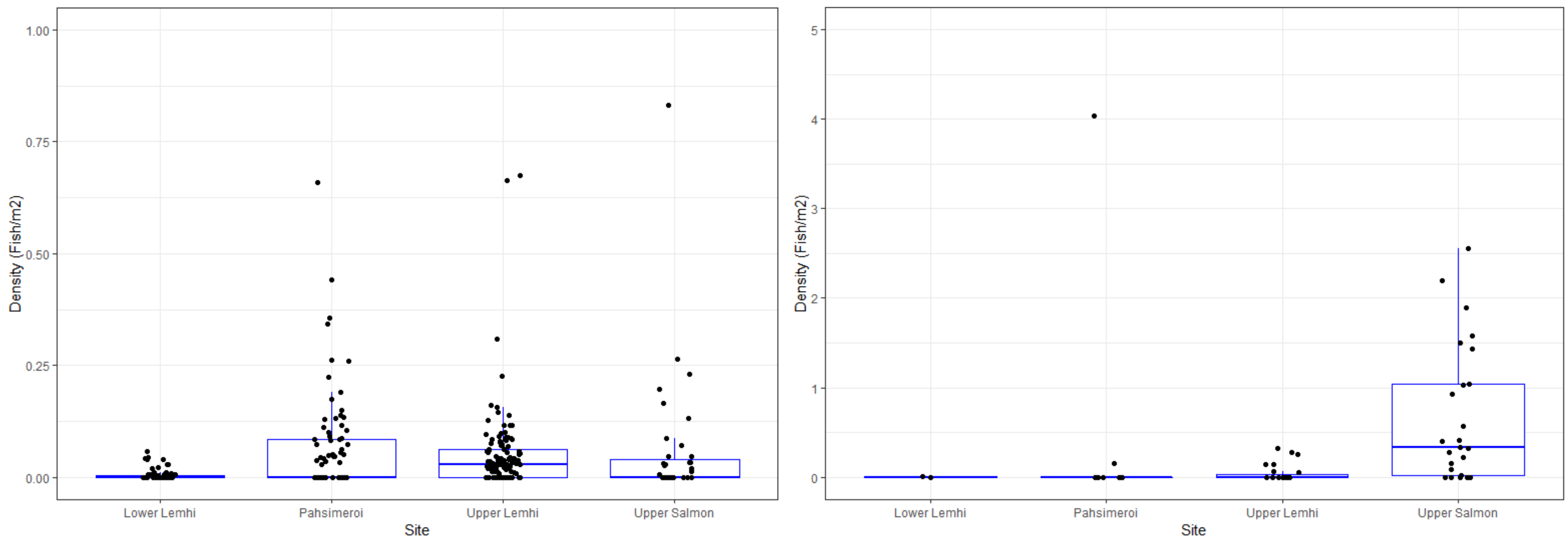
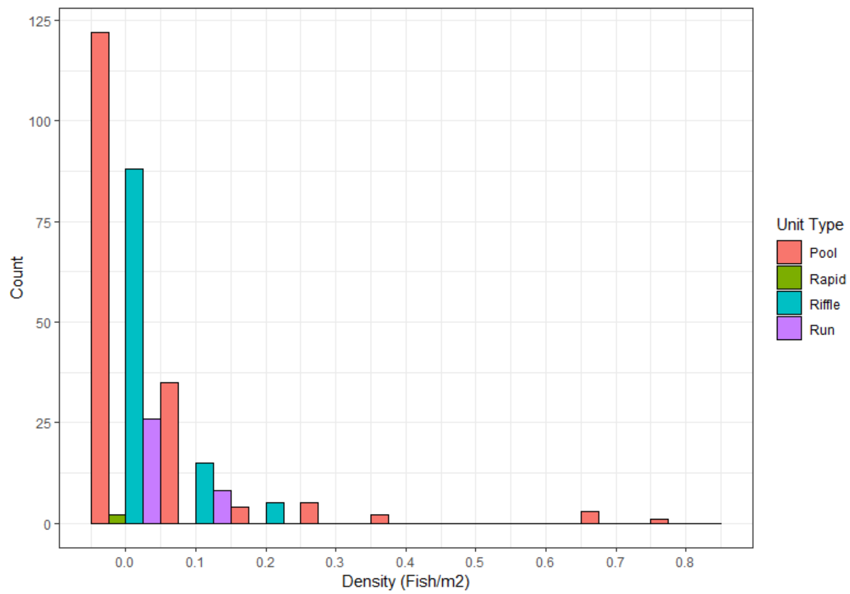


Figure 5. Dot and box and whisker plots showing juvenile Chinook density (fish/m^2) estimates available from fish and aerial surveys. The left plot shows density estimates for all mainstem channel units in each MRA reach. The right plot shows density estimates for channel units that do not fall within the main channel (e.g., off channel areas, small side channels, large side channels (riffle, run, pool) for each MRA reach. The horizontal line shows the median value, the upper and lower bounds of the box illustrate the 25th and 75th quantiles of the distribution. The black dots represent each individual channel unit density.



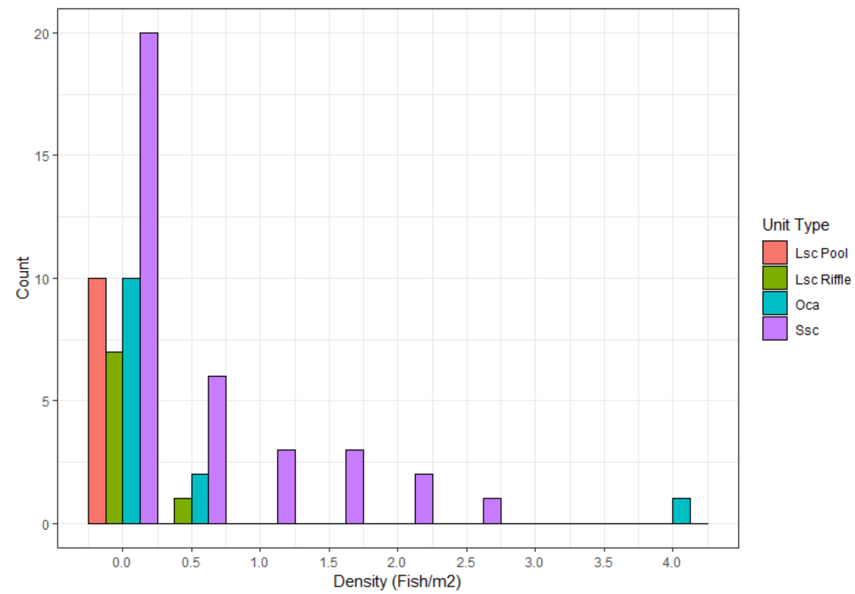


Figure 6. Histograms showing the distribution of juvenile Chinook salmon density (fish/m^2) estimates for all four MRA sites. The left histogram shows distributions for mainstem channel units. The right histogram shoes distributions for channel units present off of the mainstem for all four MRA sites.

Upper Lemhi

When analyzing the spatially distributed juvenile Chinook densities an area near the middle of the site shows that the higher mainstem densities occur in pools on the outside of meander bends. Near those higher pool densities, several small side channels are present where no target juvenile Chinook were captured. Interestingly, downstream, within the same site, several small side channels support up to 0.256 fish/m^2 (Figure 7).

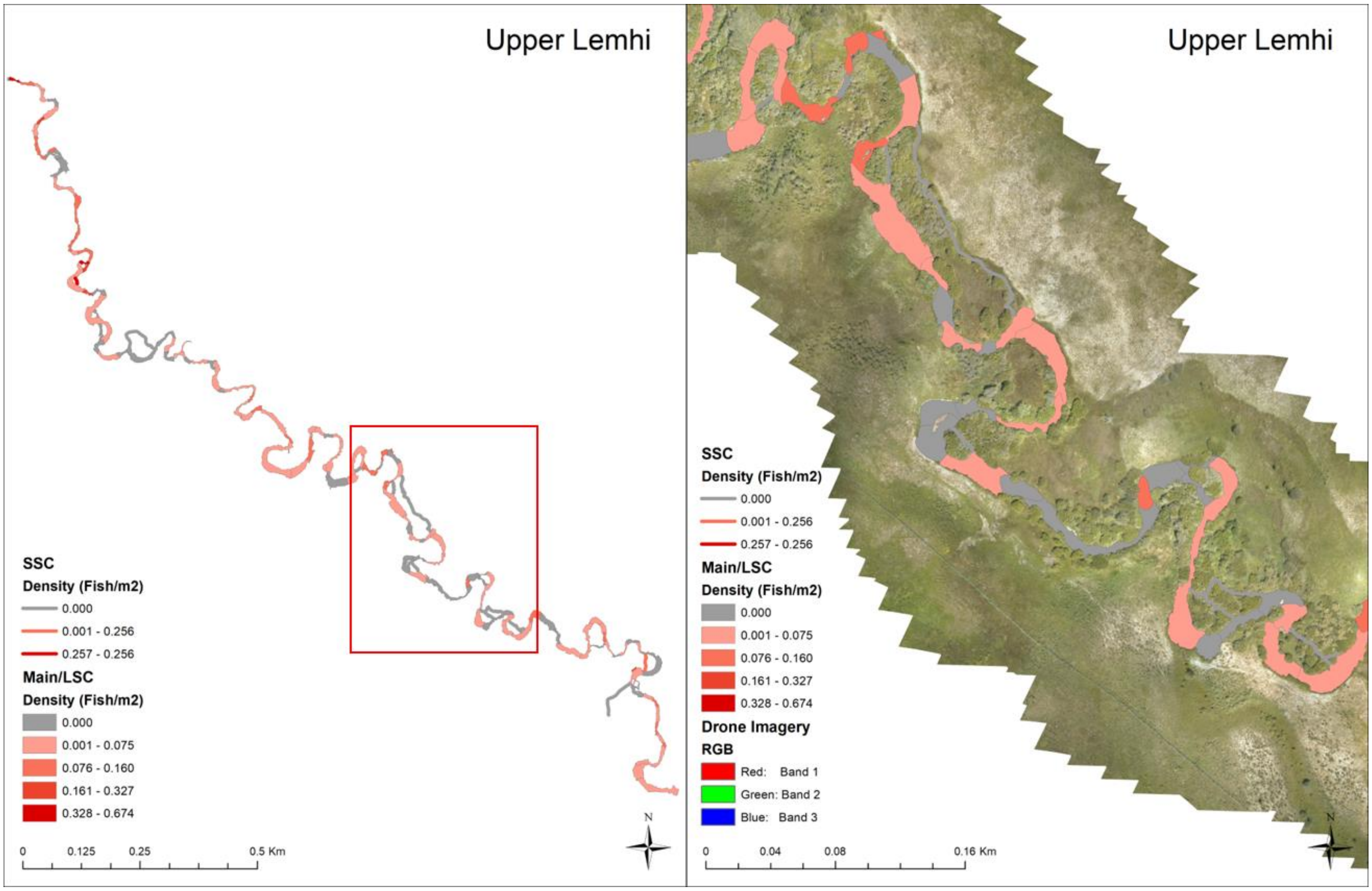


Figure 7. Map showing spatially distributed estimates of juvenile Chinook salmon densities (fish/m^2) in the Upper Lemhi MRA reach in which both DASH habitat protocol (drone and ground crews) and fish surveys were implemented in summer 2018. Channel unit area estimates were generated from drone imagery. The red rectangle indicates an area of interest zoomed closer in the map to the right.

Lower Lemhi

The Lower Lemhi site overall had the least number of targets captured during fish surveys. However, several channel units supported densities up to 0.050 fish/m^2, with the mainstem pool unit type showing the highest calculated densities. The Lower Lemhi site had a broad range of morphological characteristics, with the lower end illustrating unconfined meandering and multithreads. In that area, the small side channels had zero captured juvenile Chinook, but the small pool parallel to the small side channel had nearly the highest density of any unit in the site (Figure 8). Several long riffle unit types also supported moderate numbers of captured fish, where the site is confined near the highway.

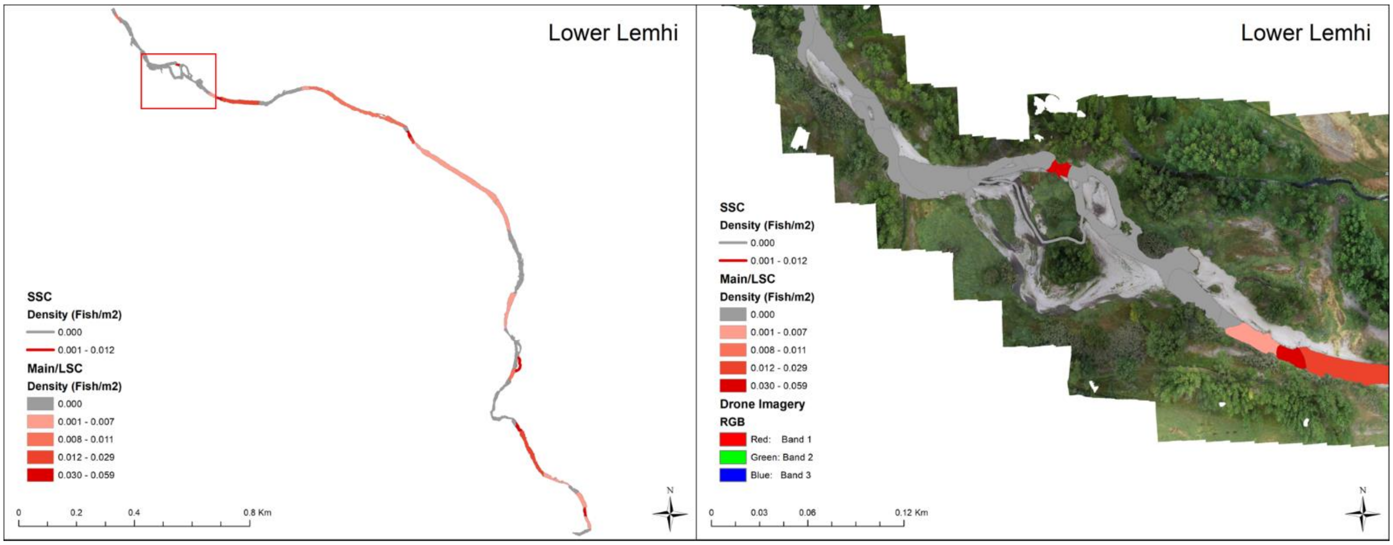


Figure 8. A map showing estimated juvenile Chinook salmon densities (fish/m^2) in the lower Lemhi MRA reach in which both DASH habitat protocol (drone and ground crews) and fish surveys were implemented in summer 2018. Channel unit area estimates were generated from drone imagery. The red rectangle indicates an area of interest which as been zoomed into, shown by the map to the left.

Pahsimeroi

Overall, non-mainstem channel units within the Pahsimeroi site illustrated the highest juvenile Chinook densities. An off channel area within the Pahsimeroi had the highest observed densities of any off channel area unit type throughout all four MRA reaches. In addition, the trend of preference toward small side channels as opposed to large side channels held true within this reach (Figure 9). Further, Chinook densities were highest within the mainstem in pool unit types, where pools are typically associated with a meander bend.

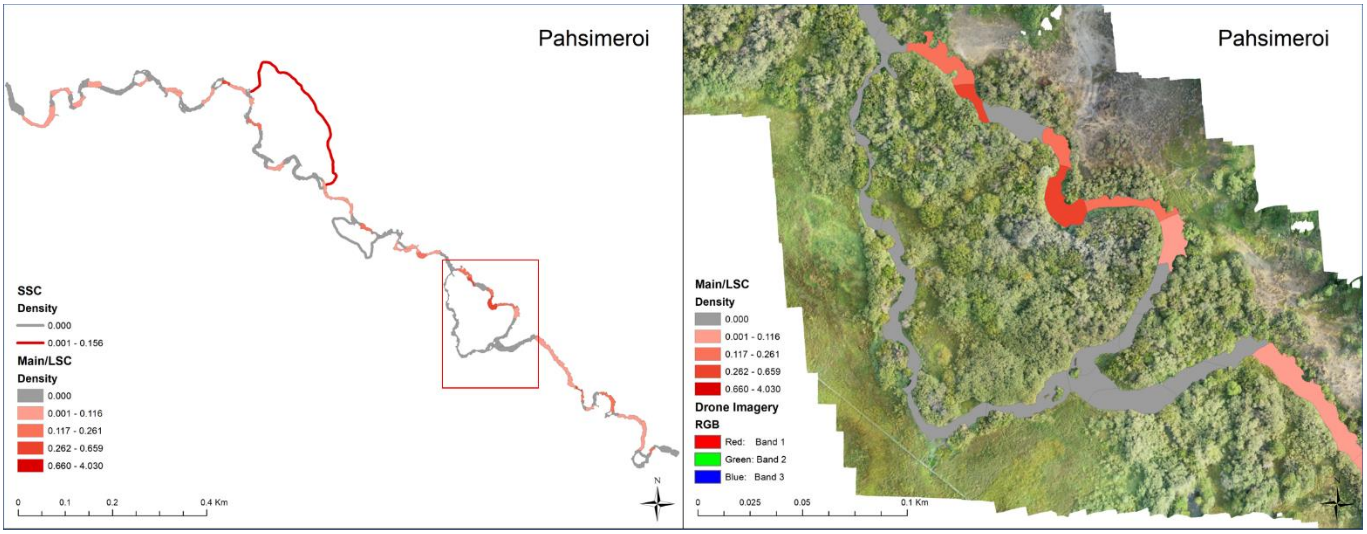


Figure 9. Map showing estimated juvenile Chinook salmon densities (fish/m^2) in the Pahsimeroi MRA reach in which both DASH habitat protocol (drone and ground crews) and fish surveys were implemented in summer 2018. Channel unit area estimates were generated from drone imagery. The left map shows a zoomed in area of interest indicated by the red rectangle.

Upper Salmon

The highest mainstem channel unit densities within the Upper Salmon site occurred in a pool where a multithread small side channel exits near the upper end of the channel unit (Figure 10). However, densities within the small side channels are consistently higher than any mainstem channel unit. The middle of the reach contained the largest number of small side channels within the four MRA sites and each small side channel supported juvenile Chinook production. The majority of small side channels within the Upper Salmon site supported densities greater 0.566 fish/m^2.

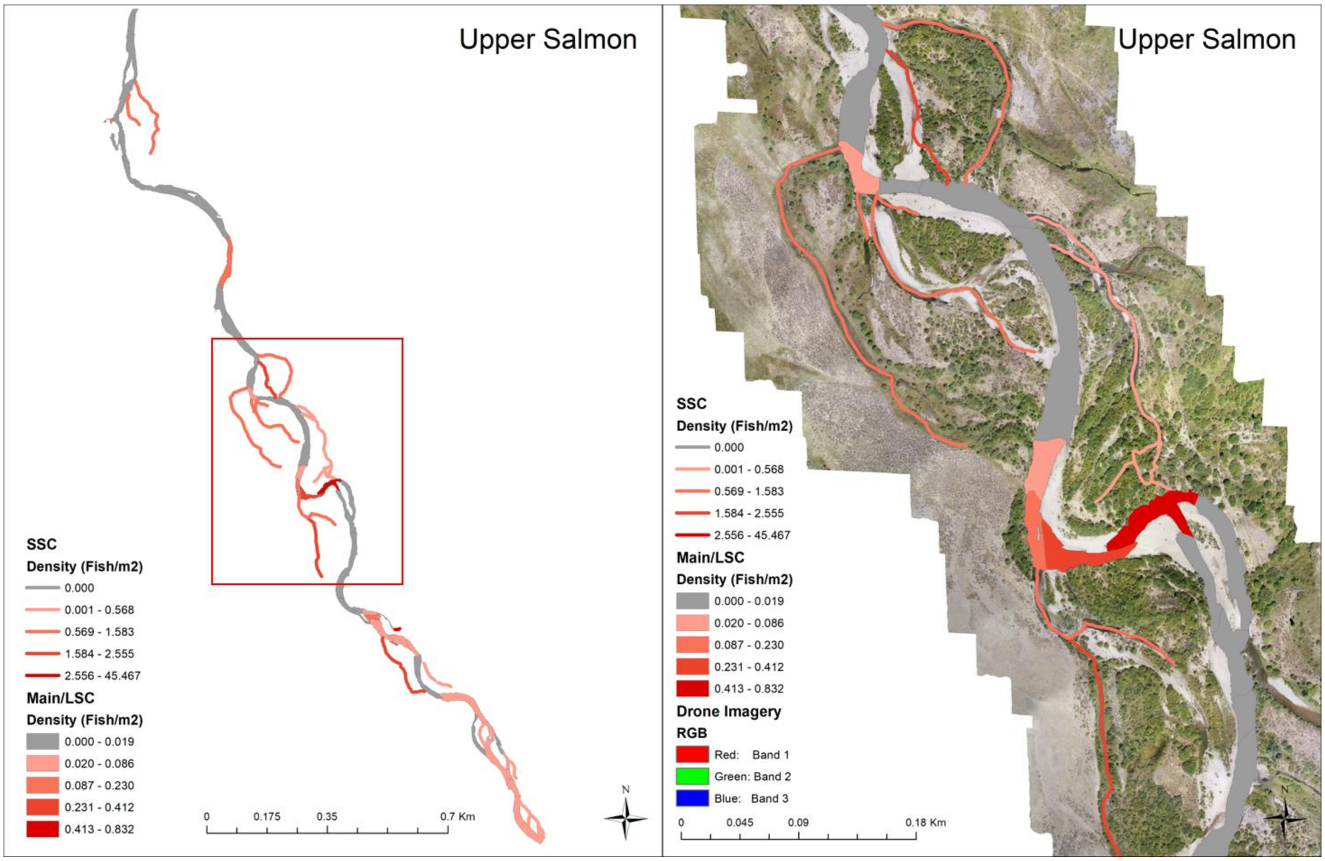


Figure 10. Map showing estimated juvenile Chinook salmon densities (fish/m^2) in the Upper Salmon MRA reach in which both DASH habitat protocol (drone and ground crews) and fish surveys were implemented in summer 2018. Channel unit area estimates were generated from drone imagery. The red rectangle indicates an area of interest shown in the left map.

Discussion

During summer 2018 field efforts, we collected fish abundance, habitat measurements, and aerial imagery for a total of 386 channel units in select tributaries (Lemhi, Pahsimeroi, Upper Salmon above Redfish Lake Creek) in the Upper Salmon Sub-basin. This finer-resolution data can be used in the future MRAs to describe existing and target physical habitat conditions relative to documented habitat needs for Chinook salmon and steelhead, particularly juveniles. For example, information can be used to describe channel unit types, mosaics (i.e., orientation and order of channel units), and characteristics (e.g., depth, velocity, cover, substrate) that create high-quality juvenile rearing habitat during summer and winter months. The MRAs will help characterize appropriate and focused 'solutions' to identified capacity problems in the Upper Salmon Sub-basin to inform the prioritization and development of specific enhancement projects.

In general, for the four MRA reaches, we found that areas off of the mainstem channel, such as off channel areas and small side channels supported the highest observed densities of juvenile Chinook salmon. Within the mainstem channel, pool unit types had the highest average calculated densities. Conversely, rapids, runs, and large side channels had the lowest densities of any unit types. These preliminary findings paired with the spatial orientation/distribution of channel units (the habitat mosaic) and associated habitat characteristics may help inform restoration design and implementation for future habitat enhancement projects. Although some of these results are telling, more data is needed to better inform and characterize habitat preference and uplift based on a given restoration. Further, juvenile fish did not utilize habitat consistently across all four reaches or within the same reach. Several locations of what appears to be high quality habitat had zero observed target species, whereas areas of similar habitat type and characteristics supported very high densities of juveniles. More data may be necessary to explain this finding and better understand habitat use and preference across very niche habitat types/characteristics where subtle differences may be explaining preferred habitat.

All four sites were selected because they illustrated variable habitat and morphological conditions. The Upper Salmon site had the greatest amount of off channel habitat, however is also had the least number of channel units in total. The Upper Lemhi and Pahsimeroi had the highest number of channel units and greatest channel unit frequency (units/100m), but they lacked the off channel habitat contained within the Upper Salmon site. Of all the sites, the Lower Lemhi reach was the most confined, and contained very small amounts of off channel and side channel habitat. An area near the bottom of the Lower Lemhi reach contained large amounts of cover and wood, however those locations supported very little to no target species, likely because of water temperature at time of fish sampling. This finding shows that many habitat characteristics must be considered when assessing habitat quality and more information may be necessary to explain preference within sites and between similar channel unit types (e.g. one pool compared to another pool or one side channel versus another side channel).

Beginning in summer 2019, the DASH protocol (ground crews and aerial imagery) is being implemented at all locations in the Lemhi River where mark-recapture fish-surveys are conducted within the Lemhi River basin, including a broad range of mainstem and tributary habitats. Doing so will significantly increase the amount of fish and habitat data available to describe fish-habitat relationships in the Lemhi and Upper Salmon River Sub-basin, thus improving our ability to describe existing and target habitat conditions. In addition, a radio telemetry study is currently underway in the Lemhi and Salmon rivers to better understand juvenile Chinook salmon movement, distribution, and habitat use during winter months. Field efforts beginning in 2019 under the radio telemetry project will be used to describe habitat availability and habitat use by juvenile Chinook salmon in the Lemhi River during winter months, which can be used to characterize habitat suitability and preference and provide another source of information to describe target habitat conditions moving forward in habitat enhancement projects and basin assessments.

As more data are incorporated into assessments and modeling, multiscale analysis (channel unit to watershed scale) of fish and habitat relations may allow for improved guidance and watershed recommendations to target certain life species and habitat characteristics. Targeted habitat enhancements and prioritization may allow for more efficient and cost-effective restoration, as well as a much-improved methodology for measuring ecological uplift from restoration activities. To our knowledge this is the first attempt at merging fish, habitat, and drone sampling at this spatial scale, and improvements to methodologies and fish-habitat understandings will continue to advance with more implementation. As techniques and understanding improve, it is imperative that all parties involved, from landowners and biologists, to funding agencies and engineers, work together to communicate the best science and findings and incorporate them into habitat enhancement projects prioritizations.

Next Steps

Moving forward, we hope to develop a new model to estimate carrying capacity for multiple species at multiple life stages and scales. By leveraging the recently developed and applied DASH protocol and paired fish sampling (abundance and density), the goal is to explain habitat capacity for current conditions, restored/improved habitat, and potential restoration designs. To do so, we must leverage sources of data from multiple projects and our hope is to incorporate previously collected fish-habitat information from the CHaMP program to build a robust and adaptive model. In addition, we will continue development of the DASH protocol and collect spatially continuous data across watershed scales to feed into our newly defined model. Leveraging machine learning and the latest fish-habitat relationships, a furthered understanding and improved guidance may be achieved for addressing limiting factors and refining engineered habitat conditions to maximize capacity within a watershed.

Conclusions

In general, we found that channel units off of the mainstem channel (off channel areas and small side channels) supported the highest densities in all of the 4 MRA reaches sampled. In addition, small side channels had a much greater density of target species than large side channels. This finding is important for consideration in restoration design and explaining target conditions. Although broad generalizations such as this can be drawn from the current work, more paired fish-habitat information may be needed to explain why densities within similar unit types vary within sites and across sites. By using these types of data to generate capacity estimates, we may alleviate some of the uncertainty and fluctuations associated with fish presence, abundance, density, and habitat characteristics and move to a currency that is more easily communicated and understandable. We feel that the merger of the newest technology (DASH protocol and drone supported imagery) and modeling techniques (Quantile Random Forest) provides a more informative, flexible approach to addressing limiting factors, assessing target habitat conditions, and communicating results to all interested parties.

Literature Cited

Carmichael, R.A., M.W. Ackerman, K. See, B. Lott, T. Mackay, and C. Beasley. 2019. Drone Assisted Stream Habitat (DASH) Protocol, DRAFT. May 2019.

CHaMP (Columbia Habitat Monitoring Program). 2016. Scientific protocol for salmonid habitat surveys within the Columbia Habitat Monitoring Program. Prepared by CHaMP for the Bonneville Power Administration.

Tonina, D., McKean, J.A., Benjankar, R.M., Wright, W., Goode, J.R., Chen, Q., Reeder, W.J., Carmichael, R.A., and Edmondson, M.R. 2018. Mapping river bathymetries: evaluating topobathymetric LiDAR survey. Earth Surf. Process. Landforms. doi:10.1002/esp.4513.