Technical Report No. 17-08

Duck Creek Realignment Monitoring, 2012-2016 Final Report

by

Greg Albrecht

August 2017

Alaska Department of Fish and Game **Division of Habitat**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in reports by the Divisions of Habitat, Sport Fish, and of Commercial Fisheries. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figures or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
no data	ND
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

TECHNICAL REPORT NO. 17-08

DUCK CREEK REALIGNMENT MONITORING, 2012-2016

FINAL REPORT

By

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August 2017

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Cover: Realigned Duck Creek, 2012.

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ACKNOWLEDGEMENTS

The Alaska Department of Fish and Game thanks Engineers Tom Carson of Carson Dorn Inc. and JoAnn Quigg of Wilson Engineering for their assistance during Juneau International Airport Runway Safety Expansion monitoring. We appreciate the Juneau International Airport for funding this study.

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EXECUTIVE SUMMARY

The Juneau International Airport (JNU) proposed to realign Duck Creek to accommodate airport expansion and improve public safety. After considerable input from an interagency review team, JNU designed and constructed a meandering channel draining to the Mendenhall River that included streambank revetments[a] and instream structures.[b] JNU constructed a sloping floodplain and steep streambanks to flush spawned salmon carcasses downstream, stabilized the floodplain with native grasses and wetland plants, and lined the channel upstream of the pedestrian bridge with bentonite to retain water.

At project completion, JNU contracted the Alaska Department of Fish and Game (ADF&G) Division of Habitat to monitor the performance of the relocated water body for five years. While we originally planned to sample biotic components in the relocated reach and compare them to upper Duck Creek and upper and lower Jordan Creek reaches, we determined during sampling it was more informative to assess realigned channel stability and design function.[c] We also compared realigned Duck Creek and realigned Jordan Creek biotic components in similarly tidally influenced reaches.

Our monitoring confirms JNU constructed the project as designed and it remains stable. The channel and floodplain are inundated by saltwater when tides exceed 15 ft. When surface water was flowing, the constructed realignment provided riffles, pools, and runs in the sinuous channel within a developing riparian community, and we observed spawning chum and pink salmon, juvenile coho and chum salmon, Dolly Varden char, sculpin, and threespine stickleback using the water body. Though we observed salmon carcasses in the channel during the spawning season, we did not observe bald eagles, ravens or seagulls in the incised channel upstream of the pedestrian bridge.

During spring, summer and fall, however, Duck Creek flow was absent up to 78% of the time and the embryos and rearing fish we observed died as the surface water remaining in the bentonite lined pools became shallow, warm and anoxic. In winter, any surface water remaining in the pools froze solid. Duck Creek water quality was poor and we did not find sensitive benthic macroinvertebrates in the substrate. Gravels and cobbles prescribed for spawning were too large for Duck Creek species and the proportion of fine sediment transported into the reach increased. The lush riparian community now includes reed canary grass and orange hawkweed recruited from upstream and the adjacent wetlands.

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[a] Cabled spruce trees, root wads, and willow plantings.
[b] Boulders and crossed log weirs.
[c] Historic Duck Creek degradation is well documented, and the lack of flow in the impaired water body has limited fish use for decades. We did not want these factors influencing monitoring outcomes if JNU constructed the project to interagency review team specification.

INTRODUCTION

In 2010, JNU realigned Duck Creek about 100 m to the north to increase airport capacity and efficiency and to reduce risks posed to aviation from wildlife (Figure 1).

Figure 1.–Duck Creek before (top) and after (bottom) channel realignment.

PURPOSE

The purpose of this technical report is to summarize monitoring conducted to evaluate the stability and function of the Duck Creek realignment between 2012–2016.

AQUATIC STUDIES

We monitored the realigned Duck Creek physical, chemical, and biological parameters listed in Table 1 at the locations shown in Figure 2 from 2012–2016. We monitored the biological parameters listed in Table 1 in a previously realigned reach of Jordan Creek with comparable tidal influence at the locations shown in Figure 3.

Table 1.–Monitoring parameters and schedule.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Data logger (operated during ice free conditions in Duck Creek)											
Spawning substrate (once annually in Duck Creek)											
Minnow trapping (monthly following at least 7 days of continuous flow in Duck and Jordan Creek)											
Adult spawning index (weekly July 15–September 15 in Duck Creek)											
Egg viability (once annually in Duck Creek)											
Benthic macroinvertebrates (once annually in Duck and Jordan Creek)											
Photo points (Duck Creek)											
Reed canary grass survey (once annually in Duck Creek)											

Note: Target timeframes in gray.

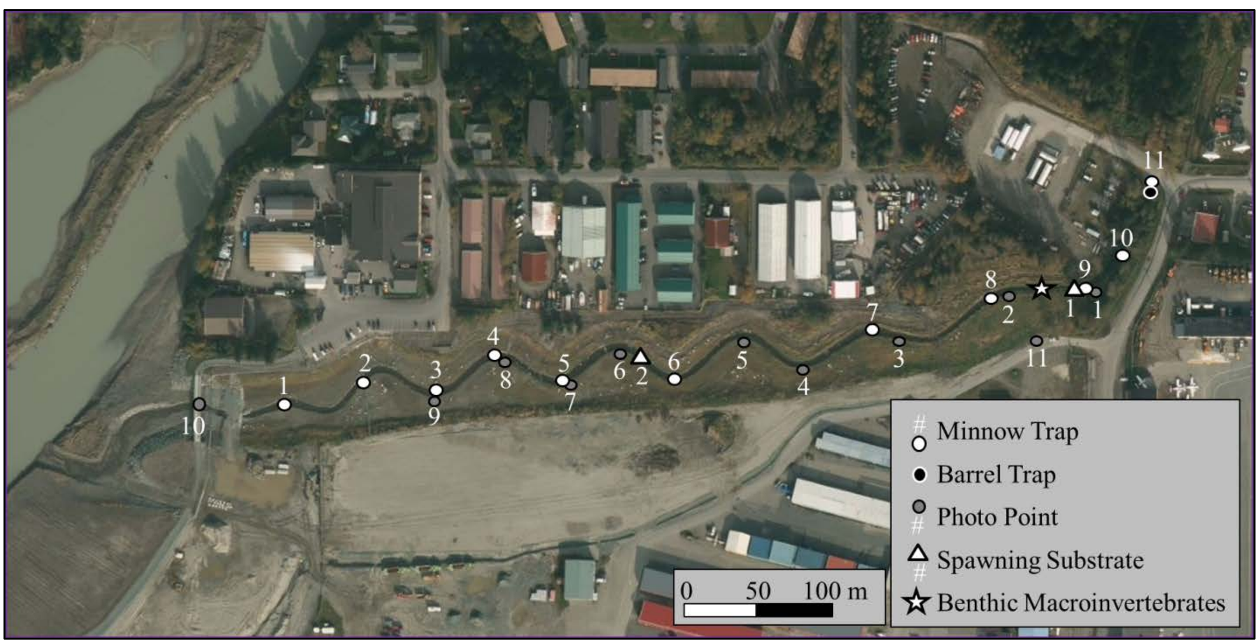

Figure 2.–Duck Creek sampling locations.

Figure 3.–Jordan Creek sampling locations.

STUDY AREA AND REALIGNMENT DESIGN

Duck Creek drains about 4 km^2 of the urbanized Mendenhall Valley into the Mendenhall River just above its confluence with Gastineau Channel and is listed in the ADF&G *Catalog of Waters Important for the Spawning, Rearing, or Migration of Anadromous Fishes* as providing habitat for chum *Oncorhynchus keta*, coho *O. kisutch*, and pink salmon *O. gorbuscha*, Dolly Varden char *Salvelinus malma*, and cutthroat trout *O. clarkia* (Johnson and Blossom 2017). Modification to Duck Creek as a result of urbanization include channel relocation, gravel mining, streambank encroachment, and road crossings. Natural processes affecting the stream include isostatic rebound as a result of relatively recent deglaciation and decreased availability of groundwater recharge. Over time the combination of urbanized and natural events has degraded the water quality of and fish habitat in this stream and caused pollutant levels to exceed State standards (JWP 2007). Duck Creek is now on the State of Alaska's 303 (d) Impaired Waters List due to low dissolved gas, iron, residues, toxic and other deleterious organic and inorganic substances, fecal coliform bacteria, and turbidity (ADEC 2010).

JNU realigned Duck Creek into a sinuous channel in 2010 and incorporated bioengineered bank treatments and instream structures (Figure 4). The floodplain was sloped to encourage salmon carcass flushing and was sown with native grass and wetland plant seed mixes. Upstream of the pedestrian bridge, the creek was lined with a bentonite clay layer and 60 cm of silt and sand to exclude groundwater and retain pools of surface water for fish passage and egg survival during low flows. A 30 cm layer of gravel and cobble substrate was placed on top of the silt and sand layer. The realigned channel and floodplain are subject to tidal influences above about 15 ft (Figure 5).

Figure 4.–Realigned channel and instream structures, July 2012.

Figure 5.–Map showing tidal inundation.

METHODS

Stream Stage and Temperature

We mounted a *YSI 600LS* water quality sonde on a rebar stake driven into the streambed under the Cessna Drive Culvert to record hourly water temperature and depth measurements during the ice free season each year. We used a framing level and tape measure to check sonde height against a benchmark on a nearby concrete wall and calibrated stage data among years. We noted the time and date when discontinuous flow impeded fish passage in the realignment and correlated these events with sonde depth measurements to better understand how often low flow limits fish movement (Figure 6). We present graphed water level and temperature data along with the annual proportion of the recording period when fish passage was obstructed by low flow in a table.

Figure 6.–Water quality sonde (left) and discontinuous flow in the realignment (right).

Spawning Substrate

We measured spawning substrate size annually to assess spawning habitat quality and changes at two sites over time. Site 1 is located at the top of the realignment above the influence of tides less than 19.5 ft and site 2 is about 300 m downstream and is inundated with a mixture of brackish sea water and fresh water from the Mendenhall River at tides greater than 18 ft (Figures 2, 7). We used a McNeil sampler to take three replicate samples from sites directly downstream of pool tails in the thalweg of riffles where the water begins to accelerate (Valentine 1995). We worked the McNeil sampler into the substrate and excavated substrate in the basal core (15 cm diameter x 25 cm depth) for measurement, unless the compacted sand and silt layer was encountered, in which case we only excavated to that point. We recovered water containing suspended fines from the basal core with four rapid scoops of a 500 mL beaker and transferred the entire sample to a clean five gallon bucket. We then washed the sample through sieve sizes 101.6, 50.8, 31.75, 19, 2.36, and 0.063 mm and retained the rinse water. We allowed the rinse water to settle in Imhoff cones for 10 minutes before recording the displacement volume. We measured displacement of substrate from the larger sieve sizes by placing each sample into a beaker with a known quantity of water and recording the water level increase to the nearest 25 mL. Substrate retained by the 101.6 mm sieve is larger than that targeted by pink and chum salmon and therefore not included in the analysis (Lotspeich and Everest 1981; Kondolf and Wolman 1993).

Figure 7.–Spawning substrate sampling sites 1 (left) and 2 (right).

To account for water that adheres to substrate particles between sieving and measurement, we assumed a gravel density of 2.6 g/cm^3 and used conversions from Shirazi et al. (1979) and Zollinger[d] (1981) to correct for sediments measured in graduated cylinders and Imhoff cones.

Following methods from Lotspeich and Everest (1981), we calculated the geometric mean particle size (d_g) by raising the size midpoint between consecutive sieve sizes (d) to its percent by volume of the entire sample (w) and obtained the final product,

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[d] For Imhoff cone readings greater than 70 mL, the Table A maximum value, we assumed a sediment weight to volume correction factor of 0.68.

$$d^g = d_1^{w1} \times d_2^{w2} \times d_3^{w3} \dots d_n^{wn}$$

We present mean values by site for d_g and percent fines in line graphs and tables to show trends over time and present data in Appendix A.

MINNOW TRAPPING AND JUVENILE FISH PRESENCE

We placed 11 minnow traps with 3 mm mesh and 22 mm diameter entrance, and one barrel trap with 3 mm mesh and 55 mm diameter entrance, at established locations between the Cessna Drive Culvert and the security fence[e] (Figure 2). In 2013 we began trapping the reach of Jordan Creek that is subject to similar tidal influence as a reference site (Figure 3). We baited the traps with freshly punctured Whirl-packs® containing disinfected salmon eggs and allowed them to soak for at least six hours before recording species caught. We measure dissolved oxygen (DO), stream temperature, and salinity with a *YSI Pro 2030* handheld unit during sampling events in the middle of the sampling reaches[f]. If established trapping sites were dewatered or frozen, we set traps as close as possible or delayed trapping until at least seven days of consecutive streamflow had occurred. We also recorded fish visually observed in the creek during trapping. We present our findings as CPUE in relation to drainage, trap location, and seasonality and provide data in Appendix B.

ADULT SALMON COUNTS AND EGG VIABILITY

We walked Duck Creek from its confluence with the Mendenhall River up to the Cessna Drive Culvert to count adult salmon on a weekly basis from mid-July to mid-September each year. We recorded numbers of live fish to serve as an index of variation in adult salmon returns among years and realignment habitat use. We counted carcasses during the survey as a qualitative measure and noted where spawning activity was observed for future investigation during winter egg viability assessments. We opportunistically sampled fresh carcasses in 2013 and 2015 to better understand the level of pre-spawn mortality by cutting open the abdominal cavity and assessing the gametes. We present weekly observations in a table where temporal trends can be seen, but do not attempt to estimate adult salmon returns due to uncertainty of residence time and the survey being limited to the realignment area.

We excavated 15–20 suitable chum salmon spawning locations in the realignment during November and December of 2012, 2013, and 2014 to better understand salmon egg survival. We targeted the thalweg of the stream and areas where active spawning was recorded during adult surveys. Excavation typically required breaking through ice up to 10 cm thick and sifting through gravels by hand with a 3 mm mesh net to capture eggs and alevins. We measured DO, temperature and salinity in sample locations before disturbing the sediments and recorded the number of live and dead eggs and alevins. For the 2015 brood year we tried a new approach of waiting until early March, 2016, and using a Smith and Root backpack electrofishing unit to draw salmon fry out from the gravel. We did not conduct egg viability investigations for the 2016 brood year in which little spawning activity was recorded. We present our findings in a table and narrative.

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[e] We originally performed trapping at only six locations on Duck Creek in the top 100 m of the realignment in accordance with the 2012 Duck Creek Monitoring Plan before determining it would be more relevant to trap a greater length of the realignment in July, 2012. Data is in Appendix B

[f] We incorporated DO and temperature measurements starting July, 2012.

BENTHIC MACROINVERTEBRATES

We used a 0.093 m^2 Surber stream bottom sampler with a 300 µm mesh net to collect three replicate samples of benthic macroinvertebrates from one site on Duck and Jordan Creeks (Figures 2, 3). We placed the sampler on the stream bottom in riffle or run habitat and disturbed sediments by hand to a depth of 10 cm, using a scrub brush to free invertebrates from larger rocks. We then transferred the sample from the cod end of the net into 500 mL bottles filled with 70% ethanol preservative.

In the laboratory, we used an elutriator with a 300 µm sieve to sort macroinvertebrates from debris[g] then identify individuals to genus, or the lowest possible level, with Merritt and Cummins (1996) and Stewart and Oswood (2006) taxonomic keys using a 100x magnification stereoscope. We estimated the mean macroinvertebrate density (per m^2) by dividing the number of macroinvertebrates in each sample by 0.093 m^2, the Surber sampler area. We calculated Shannon Diversity (*H*) and Evenness (*E*) (Magurran 1988) indices according to the following equations:

$$H = -\sum_{i=1}^{S} (p_i \log_{10} p_i)$$

and

$$E = \frac{H}{\log_{10} S},$$

where P_i equals the number of invertebrates per taxonomic group divided by the total number of invertebrates in the sample and *S* is the number of taxonomic groups in the sample. In addition, we calculated percent Ephemeroptera, Plecoptera, and Trichoptera (% EPT) and report environmental tolerance values for invertebrates according to Barbour et al. (1999). We did not make comparisons to upstream sites due to the presence of tidal influence in the realignment. We present a figure of macroinvertebrate community composition and abundance across all years and a table showing Shannon Diversity and Evenness index results. Data are in Appendix C.

RIPARIAN VEGETATION AND STREAM CHANNEL MORPHOLOGY

We took photos quarterly, preferably when snow did not significantly cover the stream and banks, at 11 points established shortly after construction throughout the realignment to document change in riparian vegetation and stream revetments[h] (Figure 2). We began mapping the invasive reed canary grass *Phalaris arundinacea* extent in the fall of 2013 in the realignment and floodplain. We discuss our observations in narrative and present a selection of photos that best illustrate changes in vegetation and stream morphology over the five year timeframe in Appendix D. We present a reed canary grass survey graphic to show changes over time.

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[g] Gordon Willson-Naranjo and Greg Albrecht, Habitat Biologists, ADF&G Habitat Division, to Jackie Timothy, Southeast Regional Supervisor, ADF&G Habitat Division. Memorandum: Benthic Macroinvertebrate Elutriation Trials Amendment; dated 12/17/2013.

[h] The panoramic photo point (11) was added in 2014.

RESULTS

STREAM STAGE AND TEMPERATURE

We recorded hourly stream temperature and stage measurements at the Cessna Drive Culvert from spring to early winter each year and correlated stream stage measurements with field observations when the channel was dry (Table 2; Figure 8). We did not report data from 2014 and 2015 when periodic beaver dam construction near the sonde and a battery failure affected stage recordings. Rainfall during the 2014 and 2015 recording periods exceeded all other years and field observations during weekly spawning season indicated there were no days when the streambed was dry (Table 2).

Stream temperatures ranged from 0–18.5°C during the recording periods with the highest events occuring during prolonged dry and sunny weather and the coldest at the onset freeze up and dry weather (Figure 9).

Table 2.–Duck Creek flow and precipitation data, 2012–2016.

	2012	2013	2014	2015	2016
Percentage of days without flow during recording period	20%	31%	ND	ND	78%
Percentage of days without flow during spawning season	6%	67%	0%[a]	0%[a]	67%
Precipitation during recording period (cm)[b]	87.6	91.2	106.9	127.8	51.8
Precipitation during spawning period (cm)[b]	29.0	21.1	35.1	43.7	24.3

[a] Based on weekly field observations and precipitation data sourced from the National Oceanic and Atmospheric Administration, Juneau International Airport, accessed from wunderground.com, December 9, 2016.

[b] Data sourced from the National Oceanic and Atmospheric Administration, Juneau International Airport, accessed from wunderground.com, December 9, 2016.

Note: a battery failure occurred between 6/12/2013 and 6/27/2013 and we estimated stream stage using local precipitation data.

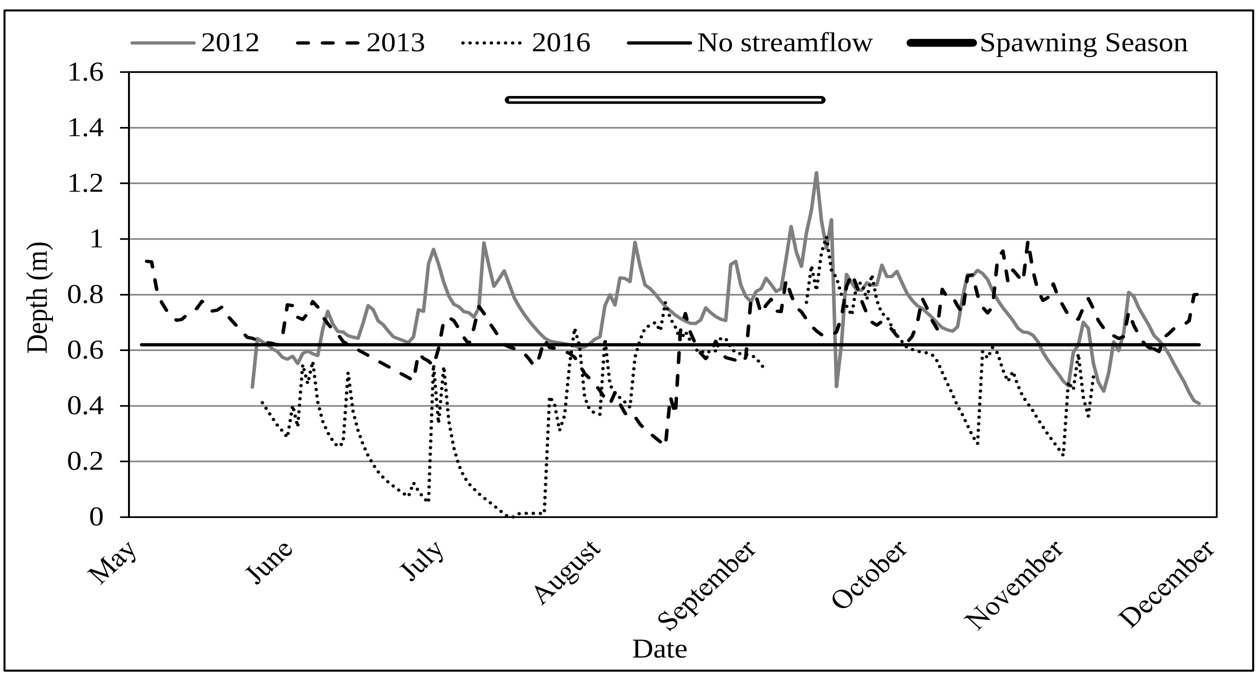

Figure 8.–Mean daily stream stage, 2012, 2013, and 2016.

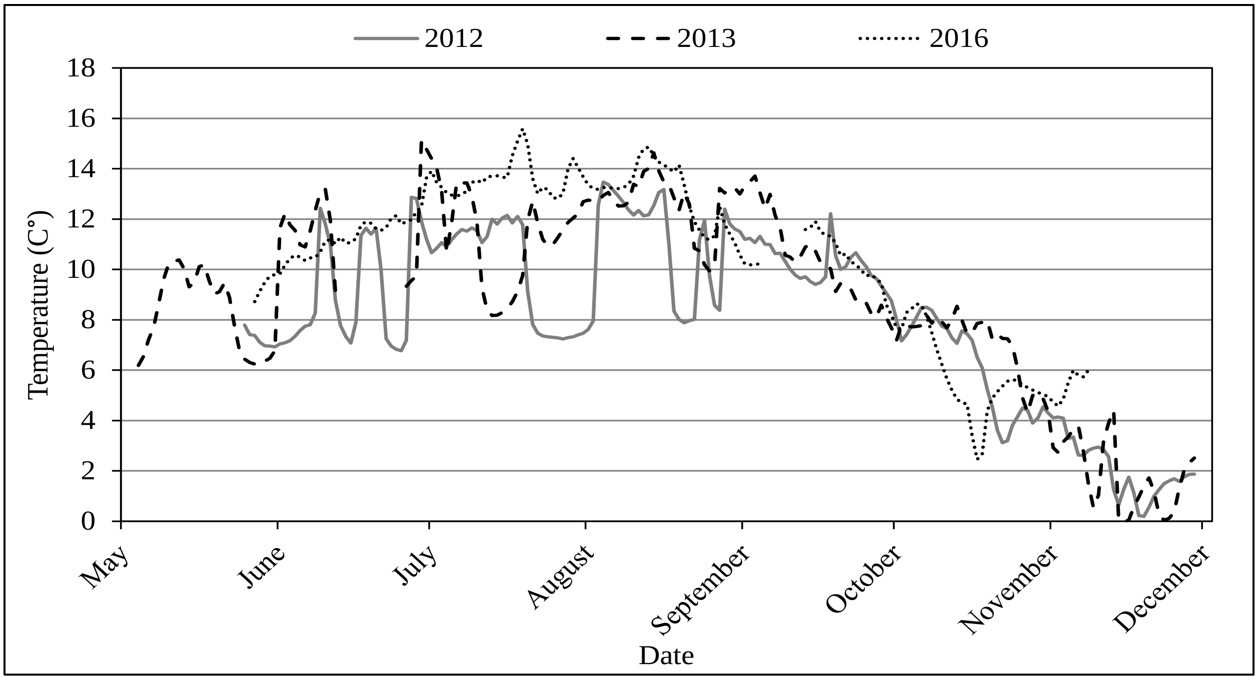

Figure 9.–Mean daily stream temperature, 2012, 2013, and 2016.

Spawning Substrate

Mean values from three replicates sampled at Sites 1 and 2 showed trends of increasing percent fines (<2.36 mm) and decreasing mean particle diameter (Table 3; Figures 10, 11). We observed spawning substrate in the realignment lacked medium, fine, and very fine gravel size classes (2–18 mm diameter). Based on visual observations, substrate downstream of the security fence, which was not from the same source as upstream, appeared to contain all size classes and was imbedded in fine sediments about 5 cm below the surface making it difficult to excavate.

Table 3.–Mean geographic mean particle diameter (*dg*) and percent fines, 2012–2016.

	Site 1					Site 2				
Parameter	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
dg (mm)	35.6	23.8	28.2	9.4	13.9	38.6	30.7	23.5	30.7	21.5
% fines	7.4%	13.5%	9.8%	27.4%	17.4%	4.3%	9.9%	16.2%	9.4%	17.3%

Figure 10.–Sites 1 and 2 mean percent fines, 2012–2016.

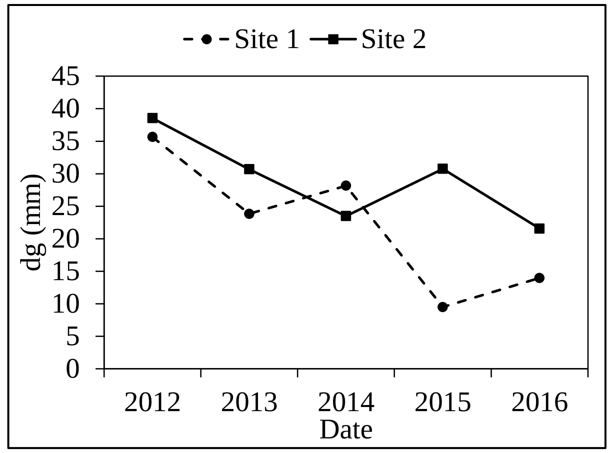

Figure 11.–Sites 1 and 2 mean geographic mean particle diameter (d_g), 2012–2016.

MINNOW TRAPPING AND JUVENILE FISH PRESENCE

We captured juvenile coho and chum salmon, Dolly Varden char, sculpin, and threespine stickleback during trapping in Duck and Jordan Creek (Table 4; Figures 12–15; Appendix B). DO and temperature measurements ranged from 3.4 mg/L to 15.0 mg/L and -0.9°C to 18.1°C during trapping events (Appendix B). We were unable to minnow trap monthly due to dry spells lasting 2–4 months. We captured only two Dolly Varden char greater than 160 mm in the large opening barrel traps during all events and these two traps consistently captured fewer juvenile fish than the minnow traps at the same sites in both streams (Figures 12, 13; Appendix B). On August 1, 2012, we observed 198 juvenile coho salmon mortalities distributed throughout the realignment following a nine day low flow period.

We observed rapid growth of green filamentous algae (*Spirogyra* sp.) during prolonged periods of sunshine in the summer and winter months. The algae would persist until senescing and dislodging during higher flows. Minnow traps placed in dense algae caught noticeably fewer fish than surrounding traps. We observed local DO values >14 mg/L during these blooms due to photosynthesis.

Table 4.–Mean CPUE by creek and species, 2012–2016.

	Coho Salmon	Dolly Varden Char	Sculpin	Stickleback	Chum Salmon
Duck Creek	0.7	0.1	0.6	10.1	0.0
Jordan Creek	4.6	0.4	0.6	0.2	0.0

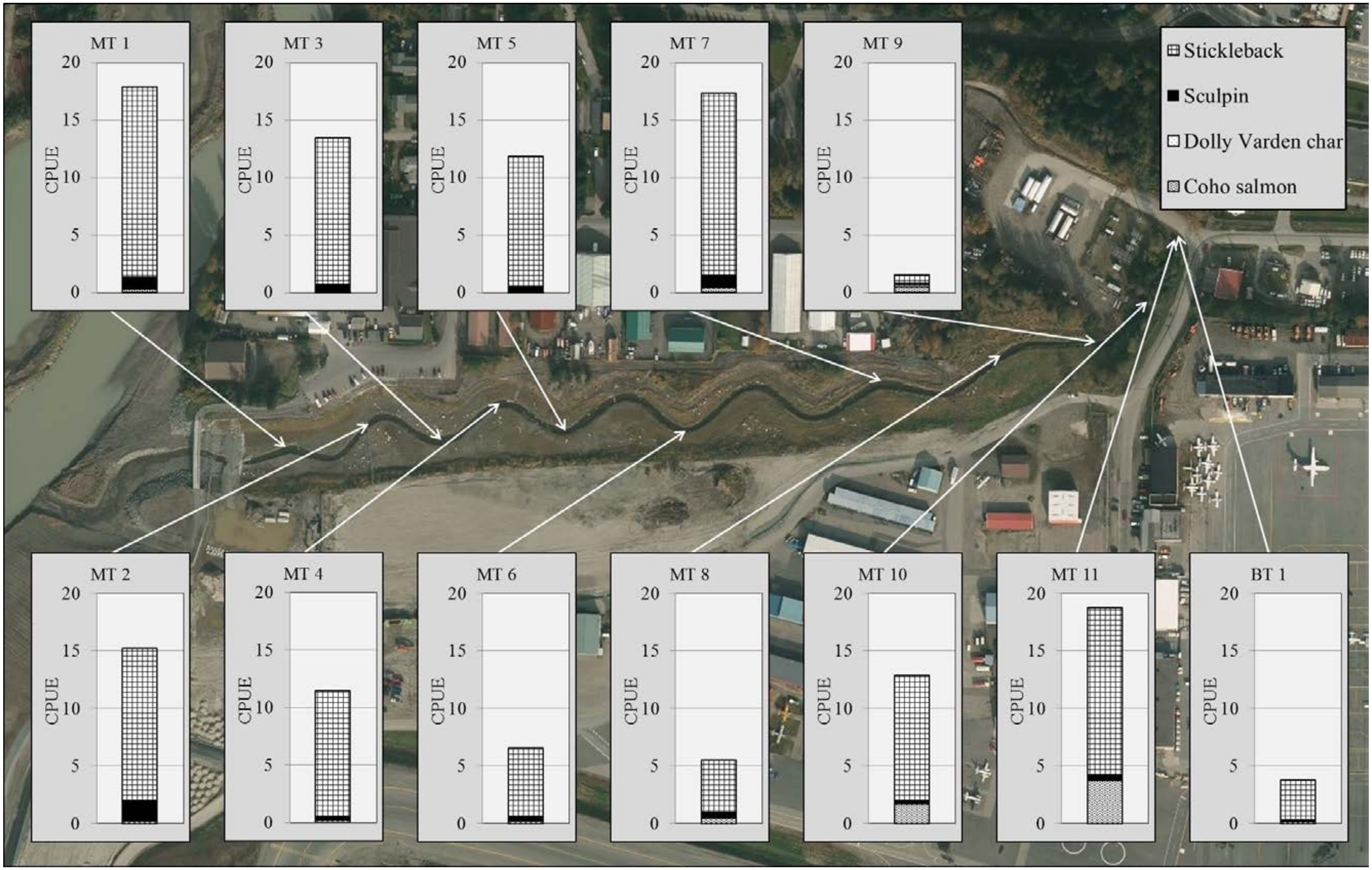

Figure 12.–Mean CPUE by species in Duck Creek, 2012–2016.

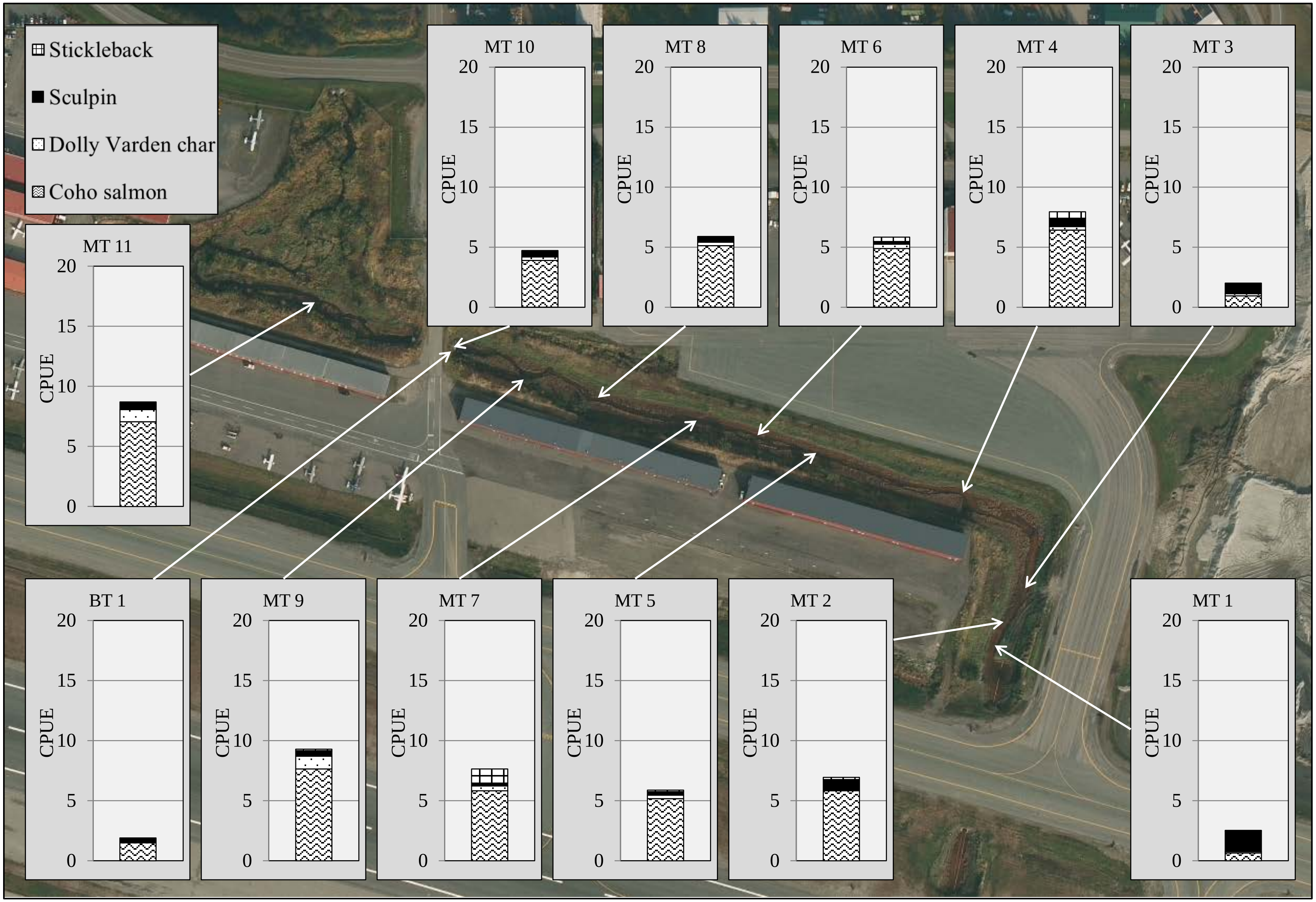

Figure 13.–Mean CPUE by species in Jordan Creek, 2012–2016.

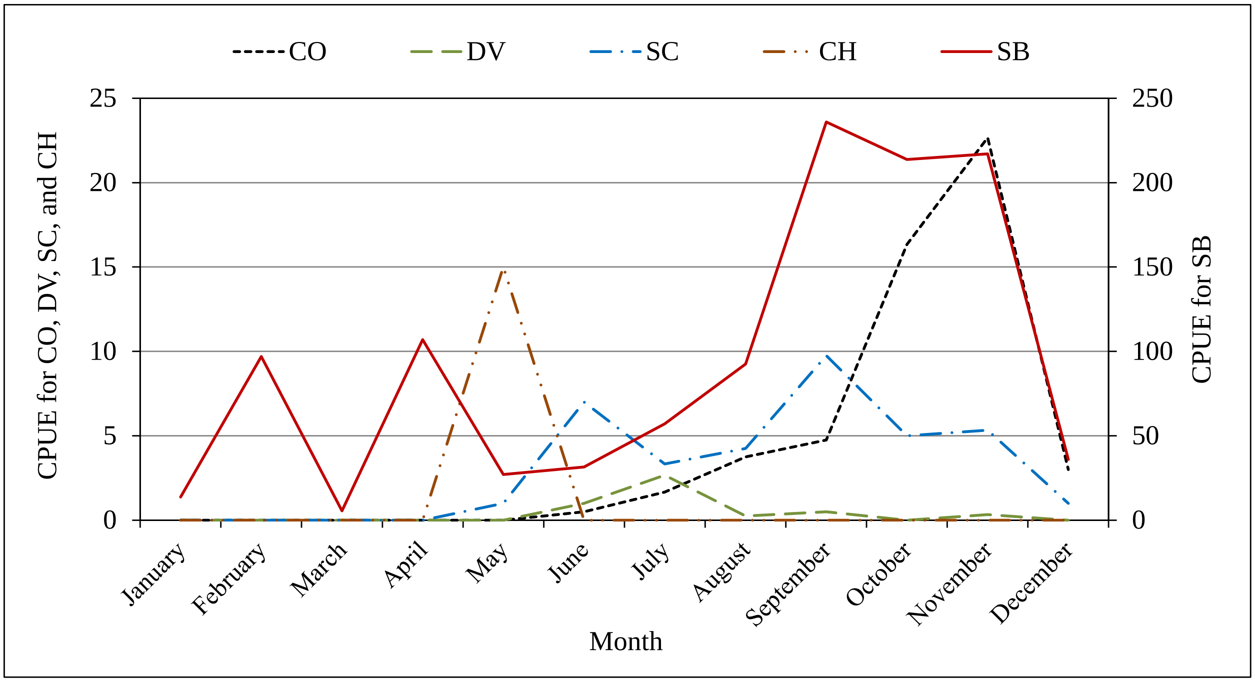

Figure 14.–Monthly mean CPUE in Duck Creek by species (coho salmon CO, Dolly Varden char DV, sculpin SC, chum salmon fry CH, threespine stickleback SB).

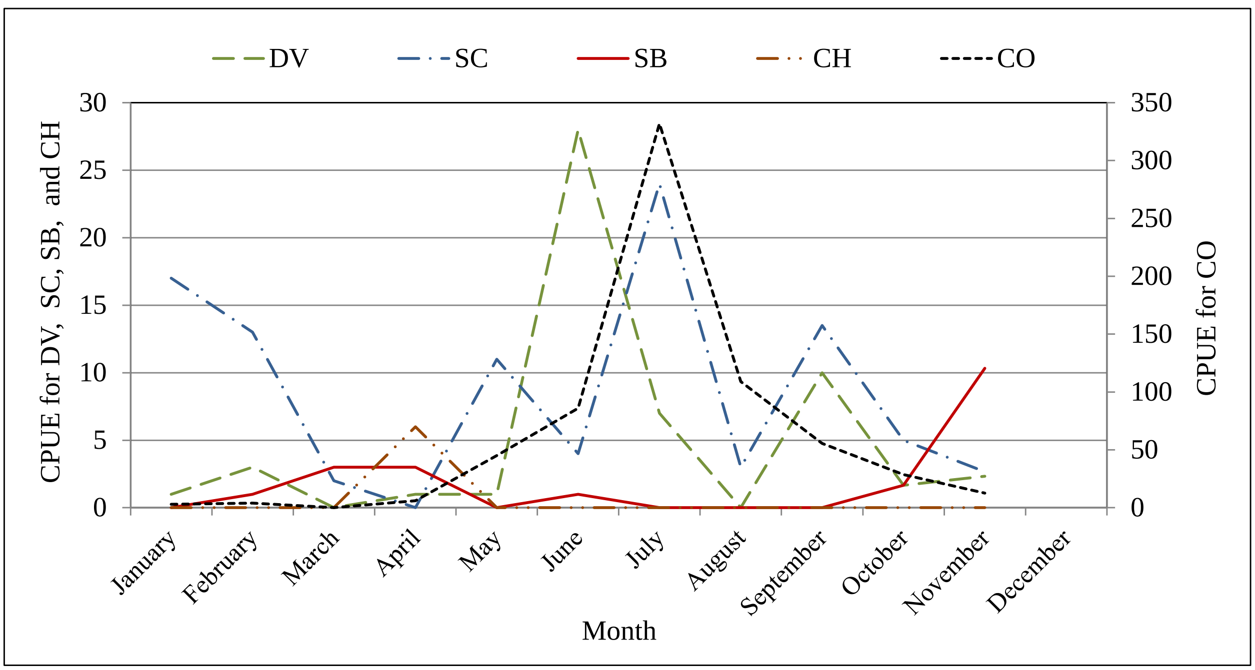

Figure 15.–Monthly mean CPUE in Jordan Creek by species (coho salmon CO, Dolly Varden char DV, sculpin SC, chum salmon fry CH, threespine stickleback SB).

Juvenile Coho Salmon

Average coho salmon capture in Duck Creek was the highest at minnow trap sites 10 and 11, which are upstream of the realignment where there is no tidal inundation and deeper pools provide low water refugia (Figure 12). We observed higher coho salmon captures during spring smolt outmigration and fall immigration of juveniles seeking overwintering habitat upstream (Figure 14; Appendix B). We consistently captured more coho salmon in Jordan Creek than Duck Creek and saw a more even distribution of individuals throughout Jordan Creek trapping sites (Table 4; Figure 13).

Chum Fry

We captured 15 chum salmon fry on one occasion in April, 2013, between minnow traps 5 and 9 in Duck Creek and 6 chum salmon fry across two trap events in March, 2016, in Jordan Creek. Chum fry are not easily captured in minnow traps due to their life history and prompt emigration to salt water.

Threespine Stickleback

Threespine stickleback captures in Duck Creek exceeded all other captures with a maximum capture of 576 individuals during one trapping event and a mean CPUE ranging from 1–17 fish among 12 trapping sites. In Jordan Creek, threespine stickleback were the least captured fish, next to chum salmon fry, with a maximum capture of 26 and mean CPUE ranging from 0–1 fish among 12 trap sites. We observed threespine stickleback were able to proliferate during even the driest conditions when Duck Creek was limited to isolated pools for weeks at a time, though their highest trap abundance occurred in the fall months when flows were most consistently present in Duck Creek.

Dolly Varden Char

We did not capture Dolly Varden char downstream of minnow trap 5 in Duck Creek where there is reduced overhead cover and more regular tidal inundation, though we visually observed individuals too large for minnow traps to capture in the area during salmon spawning. We captured Dolly Varden char at relatively even rates throughout Jordan Creek. Dolly Varden char seasonal presence in both streams was highest during the summer and fall months (Figures 14, 15).

Sculpin

Sculpin captures were the highest in both creeks at lower intertidal sites where brackish water is present more often.

ADULT SALMON COUNTS AND EGG VIABILITY

We recorded live and dead adult chum and pink salmon in Duck Creek during weekly spawning surveys between July 15 and September 19, annually (Table 5). We observed redd construction by spawning pairs, adult fish trapped in pools during dry conditions, and loose eggs littering the creek bottom from pre-spawn mortalities (Figures 16, 17). Checks of fresh chum carcasses in 2013 and 2015 showed 21/24 and 19/32 fish died before spawning. Pink salmon observations were highest in 2015 with several hundred animals observed compared to all other years where counts ranged from 0–13.

Table 5.–Adult salmon count data, 2012–2016.

Date	Live Chum Salmon	Chum Salmon Carcasses	Live Pink Salmon	Pink Salmon Carcasses
07/15/12				
07/22/12	4			
07/29/12	58	8		
08/05/22	226	20		
08/12/12	152	216		
08/19/12	10	377		
08/26/12	9	200[a]	2	
09/02/12	8	91		
09/09/12	6	9		
07/15/13				
07/22/13	44	12		
07/29/13[a]				
08/05/23	21	59		
08/12/13	2	107		1
08/19/13	245	102		1
08/26/13	1	142		
09/02/13	13	150	13	5
09/09/13	0	8		
07/15/14	15			
07/22/14	46	4		
07/29/14	30	38		
08/05/14	146	33		
08/12/14	99	64		
08/19/14[a]				
08/26/14	14	27		
09/02/14				
09/09/14				
07/15/15	3			
07/22/15	61	33		
07/29/15	130	13	103	
08/05/15	187	185	117	5
08/12/15	148	152	39	22
08/19/15	151	170	44	3
08/26/15	105	80	119	2
09/02/15	8	2	144	
09/09/15			73	
07/15/16				
07/22/16	10	1		
07/29/16	16	9		
08/05/16		28		
08/12/16		15		
08/19/16	6	148		
08/26/16				
09/02/16				
09/09/16				

[a] Weekly survey not conducted.

Figure 16.–Adult chum salmon constructing a redd, August 13, 2015.

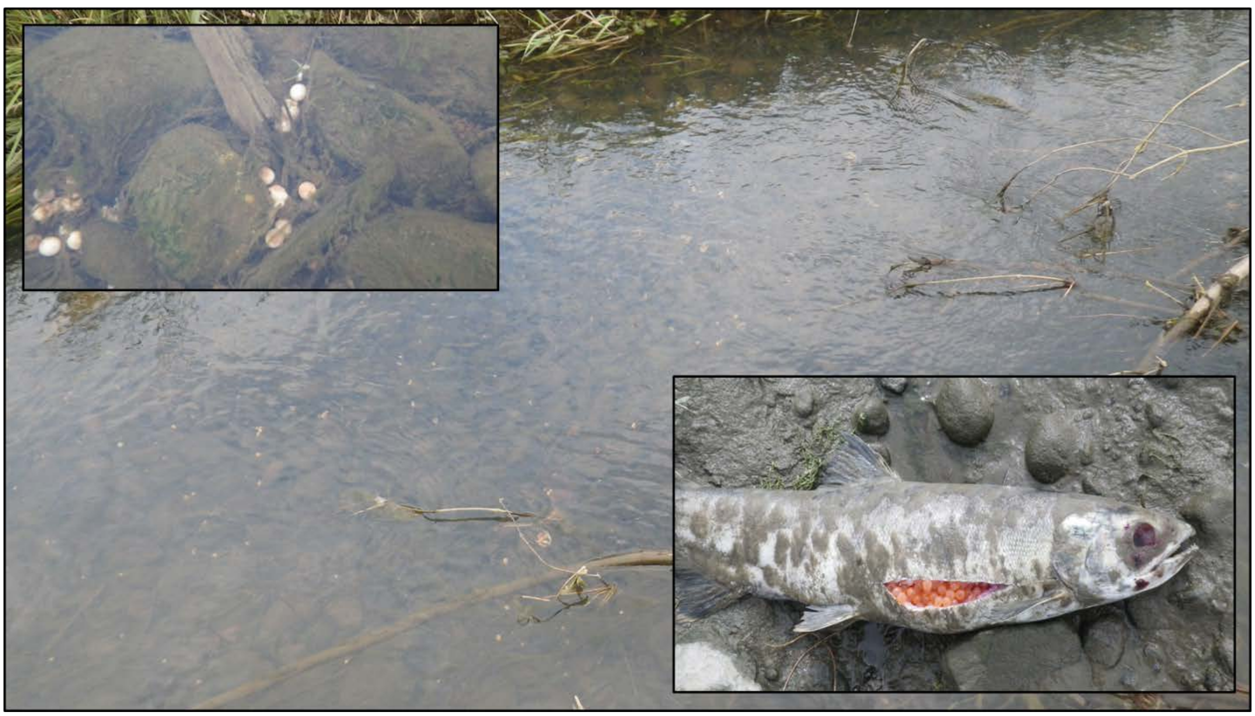

Figure 17.–Chum salmon eggs and an unspawned female carcass.

In November and December of 2012, 2013, and 2014, we sampled stream gravel throughout the realignment to assess egg viability (Figure 18; Table 6). In each year we found only dead and degraded salmon eggs and alevins. Ice was present during the surveys with some areas of the stream frozen solid into the gravel and others retaining stagnant water. We recorded DO values in stagnant water and found them generally increasing with movement downstream where tidal influence is more regular and ice cover was reduced (Table 6). Below the security fence, where the bentonite liner is not present, the channel was consistently dry until water seeping from the Mendenhall River entered the stream 60 m from the mouth of Duck Creek.

Figure 18.–Redd excavation and dead chum fry (inset), December 18, 2012.

In March, 2016, we observed a total of 18 chum salmon fry at three locations during electrofishing attempts over about 30% of the stream, which was wetted sufficiently to operate the electrofisher.

Table 6.–Winter egg viability investigations data, 2012–2014.

Site	Water Temperature (°C)	Dissolved Oxygen	Observations
			12/18/2012
1	-0.2	38.0%	Ice, 2 sites near minnow trap 9.
2	-1.1	15.0%	Ice, 2 sites 15 m downstream of minnow trap 8.
3	-1.1	15.0%	Ice beneath salt water layer, 2 sites at photo point 4.
4	-1.7	17.0%	Ice beneath salt water, 2 sites 15 m downstream of minnow trap 6.
5	-1.7	47.7%	Ice under salt water, 2 sites at minnow trap 2, 15 dead alevins and 5 dead eggs.
6	-1.5	65.0%	Salt water, 2 sites 30 m downstream from minnow trap 2.
7	-1.5	87.7%	Salt water, 2 sites at minnow trap 1.
8	-1.6	69.6%	Salt water, 2 sites at security gate, 1 dead egg.
9	2.75	44.2%	4 sites near confluence with Mendenhall River, warmer ground water 20 cm below dry streambed surface.
			12/9/2013
1			Ice, 2 sites near minnow trap 9.
2			Ice, 1 site 15 m downstream of minnow trap 9.
3	0.3	2.8 mg/L	2 sites near minnow trap 8.
4			Ice, 2 sites 3 m downstream of minnow trap 8.
5			Frozen, 1 site at minnow trap 7
6	0	3.2 mg/L	Frozen, 2 sites 12 m downstream of minnow trap 7.
7	-0.4	5.9 mg/L	Standing water, 1 site at photo point 5.
8	-0.3	3.4 mg/L	Standing water, 1 site 25 m downstream of photo point 5.
9			Standing water, 1 site at minnow trap 7, 5 dead eggs.
10	-0.5	3.0 mg/L	standing water, 3 sites at minnow trap 6.
11			Standing water, 2 sites 15 m downstream of minnow trap 6.
12	-0.6	9.6 mg/L	Salt water, 1 site at photo point 7.
13			Salt water, 2 sites at minnow trap 3.
			11/12/2014
1	3.2	7.4 mg/L	Ice, 3 sites, near minnow trap 9, 5 dead eggs.
2			Ice, 5 m downstream of photo point 4.
3			Ice, 5 m downstream of photo point 5.
4			Ice, 5 m upstream of minnow trap 6.
5			Ice, 1 site 15 m upstream of minnow trap 5.
6			Ice, 2 sites at minnow trap 5, 3 dead eggs.
7	1.1	11.2 mg/L	Ice, 1 site 3 m downstream of minnow trap 5
8			Ice, 2 sites 10 m upstream of minnow trap 4.
10	1.1	10.4 mg/L	Ice, 1 site 8 m upstream of minnow trap 4.
11			Ice, 2 sites at minnow trap 4.
12	1.1	12.0 mg/L	1 site 9 m downstream of minnow trap 4.
13			Ice, 2 sites 30 m downstream of minnow trap 2.
14	2.9	11.0 mg/L	1 site 6 m upstream of the plane ramp.
15	0.3	14.4 mg/L	1 site 15 m downstream of security gate, 6 dead eggs.

Note: 2012 measurements taken with an *Oakton PD300* could only be recorded as a percentage.

BENTHIC MACROINVERTEBRATES

We generally did not find environmentally sensitive EPT taxa in Duck Creek samples (0.0% EPT; Table 7; Figure 19; Appendix C). Pollution tolerant taxa, such as chironomids and annelids, were abundant. Shannon Diversity and Evenness, and % EPT values were consistently higher in Jordan Creek than Duck Creek (Table 7). We observed 25 taxonomic groups across all 5 years of Duck Creek sampling, including 2 EPT taxa. We observed 26 taxonomic groups across all 5 years of Jordan Creek sampling, including 10 EPT taxa (Appendix C). Invertebrates per m^2 ranged from 2,588–9,391 in Duck Creek and 1,495–9,133 in Jordan Creek across all years. The Jordan Creek site is 3 ft lower in elevation than the Duck Creek site, though field observations indicate tidal influence at the two sites produces similar salinity conditions (maximum recorded 0.4 ppt at both sites; Figure 20).

Table 7.–Benthic macroinvertebrate data, 2012–2016.

	2012		2013		2014		2015		2016	
	DC	JC	DC	JC	DC	JC	DC	JC	DC	JC
Benthic Macroinvertebrates/m^2	9,391	7,746	2,588	3,896	2,760	9,133	3,075	1,495	4,756	5,796
% EPT	0.0%	0.8%	0.0%	0.4%	0.0%	0.2%	0.1%	0.5%	0.1%	0.4%
Total taxa (EPT taxa)	11(0)	13(3)	6(0)	12(3)	5(0)	15(3)	17(1)	15(2)	12(1)	16(6)
Shannon Diversity Score	0.31	0.31	0.08	0.37	0.15	0.34	0.33	0.45	0.43	0.52
Evenness Score	0.39	0.34	0.15	0.43	0.16	0.35	0.34	0.50	0.46	0.52

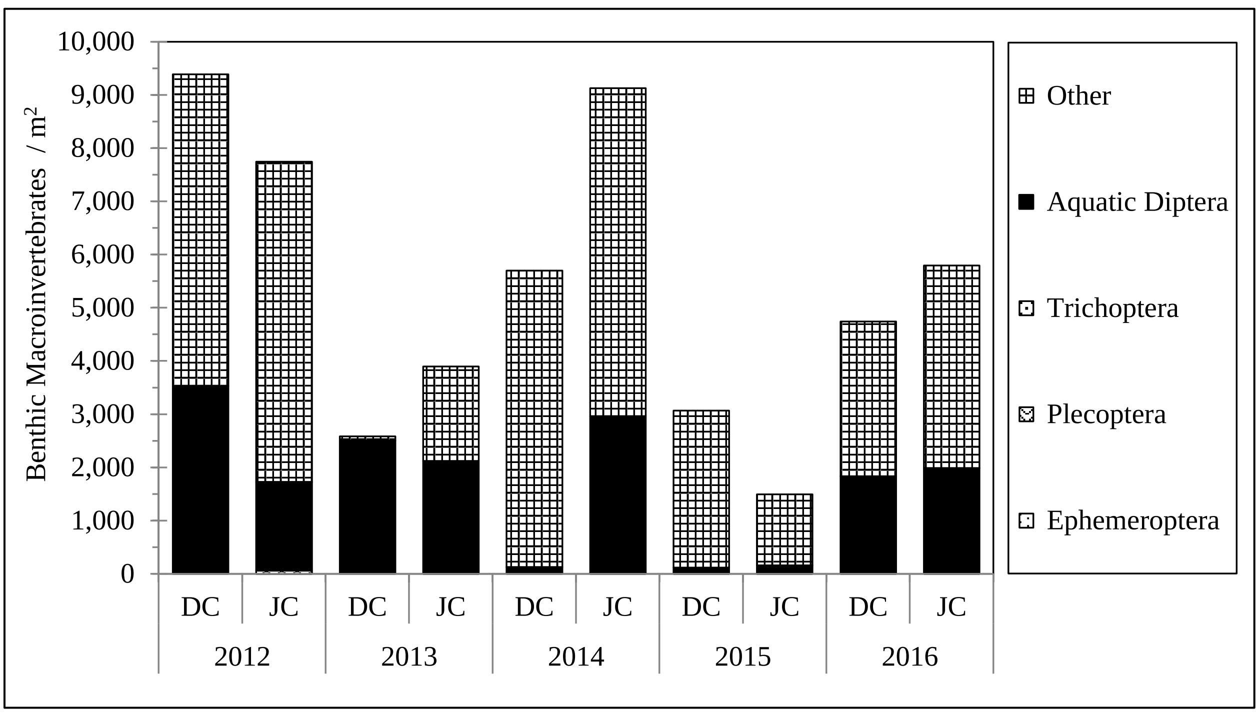

Figure 19.–Mean benthic macroinvertebrate community composition and density, 2012–2016.

Figure 20.–Jordan Creek (left) and Duck Creek (right) benthic macroinvertebrate sampling sites.

RIPARIAN VEGETATION AND STREAM CHANNEL MORPHOLOGY

We observed seeding, willow staking, and bank treatments in Duck Creek produced mixed results for vegetative growth. Willow plantings upstream of photo point six grew well and have matured to form a canopy cover over the channel upstream of photo point two (Figure 21). Some willows that were not watered following planting[i] failed to regenerate and willow stakes downstream of photo point six failed to grow due to tidal flooding (Figure 21).

The hydroseed mix used above photo point eight has flourished with native species including bluejoint reedgrass *Calamagrostis canadensis* and lupine *Lupinus arcticus*. The invasive orange hawkweed *Hieracium aurantiacum* and reed canary grass, both present upstream, have established in the realignment. Reed canary grass has expanded its coverage through the realignment each year (Figure 22).

The area downstream of photo point eight, where the floodplain is frequently tidally inundated, was seeded with a beach wildrye *Leymus* spp. which transitioned from patchy to complete coverage over the course of the study. The area upstream of the pedestrian bridge was disturbed during the September 2011 installation of the security fence. It was subsequently stabilized with jute matt and seeded with the beach wildrye mix which achieved 100% coverage within three growing seasons.

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[i] George Campbell, Little Diggers LLC, Juneau, personal communication, October 16, 2012.

Figure 21.–Successful (top left, lower right), and unsuccessful (top right, bottom left) willow plantings.

The cabled spruce visible at photo point 6A broke loose during February, 2013, when heavy icing and 19 ft tides occurred, but remains in the area providing habitat function (Figure 23). The cross log weir at minnow trap site two was lifted out of place following similar events and remains at the high tide line on the floodplain. The cabled spruce trees lost their needles within a few months of placement, but retained limbs (Photo points 5, 8, 9 in Appendix C). Cottonwood trees placed in the floodplain have generated new growth (Figure 23).

Photo points show almost no scouring of the streambed and rootwad revetments outside of a January 2015 rain on snow event. Mostly cobble sized (64–256 mm diameter) material was used to line the uniformly sloped banks of the realignment which have remained largely unchanged, aside from vegetation growth.

Figure 22.–Reed canary grass (inset) expansion map.

Figure 23.–Spruce tree anchor (inset) failure (left) and floodplain cottonwood (right).

DISCUSSION

STREAM STAGE AND TEMPERATURE

When low flow limits fish passage in the realignment, we observe similar intermittent dry streambed conditions in Duck Creek to a point 2.8 km upstream where streamflow is present year round. In 2013, fish passage was hindered for 42 of the 48 days between July 15 and September 1. During four days of rain in mid-August, several hundred chum salmon moved into the realignment only to be stranded and die when rain stopped. A similar event occurred in late August 2016 when 148 chum carcasses were counted on August 26 following two weeks with no live fish observed in the stream. These events along with minnow trapping results highlight the role flow plays in pre-spawn mortality and fish use in Duck Creek.

SPAWNING SUBSTRATE

Based on the *dg,* substrate sampled in the realignment falls within the range reportedly used in the wild by chum salmon (0.1–65 mm), but exceeds the range reported for pink salmon (6–10 mm; Kondolf and Wolman 1993). Stream gravel used to fill the realignment was reported as 100% passing through a 102 mm sieve, 82% passing through a 76.2 mm sieve, 13% passing through a 38.1 mm sieve, and 1% passing through a 19.1 mm sieve. It is unclear why these gradations were chosen and why the proportion was weighted towards larger sized particles. The trends of decreasing *dg* and increasing percent fines reflect the recruitment of fine sediment from upstream which is more pronounced at Site 1, 10 m from the undisturbed channel.

MINNOW TRAPPING AND JUVENILE FISH PRESENCE

Minnow trapping results show stickleback and sculpin reside in the realignment year round and rearing coho salmon and Dolly Varden char are present intermittently. The low relative abundance of juvenile coho salmon in Duck Creek, when compared to Jordan Creek, may be the result of flow and habitat components; Duck Creek lacks cut banks with overhead cover and consistent flow at a depth greater than 18 inches, elements of Jordan Creek at the same elevation.

The high number and large average size of the August 1, 2012, juvenile coho salmon mortalities (70-130 mm) suggests these fish may have been holding in low water refugia upstream of the realignment when they died and washed downstream with rainfall that began 10 hours before our observations. The Cessna Drive Culvert is about 100 m upstream of the realignment and typically maintains a minimum depth of 48 cm year round, which fish use for rearing habitat. Other ponds and overwintering sites exist further upstream[j]. We recorded 6.64 mg/L DO in the realignment during the mortality event, though previous observations show DO rises rapidly during rainfall, indicating DO may have been lower during the mortalities.

ADULT SALMON COUNTS AND EGG VIABILITY

We observed no successful spawning in the realignment. The reach with the bentonite liner maintains some wetted area during time periods when the channel directly up and downstream is dry. Assuming there was no perennial groundwater source covered by the liner, this construction strategy serves to extend the time water remains pooled in the creek, allowing for the possibility

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[j] Greg Albrecht, Habitat Biologist, ADF&G Habitat Division, to Jackie Timothy, Southeast Regional Supervisor, ADF&G Habitat Division, Memorandum: Duck Creek Pond Trapping January 10, 2014; dated January 17, 2014.

of successful egg incubation in a relatively mild and wet winter. Adults returning to Duck Creek could potentially be products of successful spawning further up in the Duck Creek drainage or straying from nearby drainages and hatchery release sites. We expect straying played a role in the 2015 pink salmon return based on low pink salmon counts in previous years and similar observations of unusually high pink salmon counts in Juneau area streams (personal field observations and unpublished data from the Auke Creek Weir obtained from John Joyce, National Oceanic and Atmospheric Administration, Auke Bay Laboratories, Juneau, Alaska.)

BENTHIC MACROINVERTEBRATES

The domination of benthic macroinvertebrate communities at both Duck and Jordan Creek sample sites by pollution tolerant taxa may be influenced not only by water quality and substrate type, but by tidal influence and prolonged lapses in streamflow. Jordan Creek is reported to have slightly better water quality than Duck Creek, but remains on Alaska's 303(d) list for water quality impairment due to high sediment loads, low DO, and debris (ADEC 2010).

RIPARIAN AND STREAM CHANNEL MORPHOLOGY

Despite successful revegetation in many areas, invasive plants are present and expanding coverage in the realignment. Photo points show the realignment channel is stable with minimal bed load movement. Stream substrate placed during construction is large enough to resist scour from most floods and acts like armoring on the banks. The rock on the banks displaces riparian vegetation and will delay the formation of cut bank habitat, typical of tidal reaches of Mendenhall estuary streams.

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APPENDIX A: SPAWNING SUBSTRATE DATA

Appendix A.1.–Site 1 spawning substrate data, 2012–2016.

Sample Date	Sample No.	Volume (mL/L) Retained in Each Sieve (mm)							
		101.60	50.80	31.75	19.00	2.36	0.06	Imhoff	GMPS
05/18/2012	1	0	1050	740	50	20	65	120	38.9
05/18/2012	2	0	900	390	500	5	61	53	39.9
05/18/2012	3	500	510	455	0	0	160	91	28.2
07/01/2013	1	0	1050	725	475	175	600	140	24.2
07/01/2013	2	0	1575	475	275	100	700	294	21.4
07/01/2013	3	0	1250	0	800	50	0	273	25.9
06/24/2014	1	1050	525	500	325	25	80	62	33.0
06/24/2014	2	0	500	1175	525	100	550	164	21.0
06/24/2014	3	0	1000	825	325	50	300	128	30.4
11/24/2015	1	0	900	625	500	1125	600	210	17.0
11/24/2015	2	0	325	425	650	650	2075	550	4.2
11/24/2015	3	0	675	350	325	1025	850	570	7.3
10/06/2016	1	0	900	725	375	1100	600	349	14.4
10/06/2016	2	0	775	300	575	1150	525	490	10.2
10/06/2016	3	0	1850	525	550	400	800	410	17.3

Appendix A.2.–Site 2 spawning substrate data, 2012–2016.

Sample Date	Sample No.	Volume (mL/L) Retained in Each Sieve (mm)							
		101.60	50.80	31.75	19.00	2.36	0.06	Imhoff	GMPS
05/18/2012	1	0	615	700	515	15	15	2	43.1
05/18/2012	2	0	1000	900	300	0	70	76	40.7
05/18/2012	3	0	950	625	325	55	225	107	31.9
07/01/2013	1	0	675	800	175	0	275	180	24.0
07/01/2013	2	0	900	390	500	5	61	53	39.9
07/01/2013	3	500	510	455	0	0	160	91	28.2
06/24/2014	1	0	1000	950	500	75	425	640	12.9
06/24/2014	2	0	750	750	675	200	750	510	11.4
06/24/2014	3	0	1650	750	150	25	130	75	46.2
11/24/2015	1	0	825	425	275	150	150	47	35.0
11/24/2015	2	0	1550	425	275	175	325	152	31.9
11/24/2015	3	0	1825	525	275	275	400	151	23.4
10/06/2016	1	0	525	550	250	0	275	925	3.9
10/06/2016	2	0	1175	650	550	0	200	122	34.0
10/06/2016	3	0	300	1075	600	0	150	110	26.9

APPENDIX B: MINNOW TRAPPING DATA

Appendix B.1.–Duck Creek minnow trapping data summary, 2012–2016.

Date	Coho Salmon	Dolly Varden Char	Sculpin	Threespine Stickleback	Chum Salmon	Temperature (C°)	DO (mg/L)	Notes
03/12/2012	0	0	0	0	0	ND	ND	Low flow.
04/10/2012	0	0	0	58	0	ND	ND	No flow, 3 traps set downstream of sites.
05/18/2012	0	0	0	12	0	ND	ND	
06/13/2012	0	0	0	3	0	ND	ND	
07/02/2012	0	0	0	1	0	ND	ND	6 in Dolly Varden char observed.
07/13/2012	1	8	5	3	0	12.4	11.4	
08/01/2012	1	0	13	37	0	14.0	6.6	Low flow.
09/18/2012	1	0	2	15	0	9.3	7.5	
10/02/2012	3	0	9	25	0	7.5	8.65	Moderate flow.
11/13/2012	0	0	0	0	0	0.8	11.2	Lower flow, lots of thick ice and some snow. Passage below site 7.
12/11/2012	6	0	2	70	0	-0.9	13.4	2 traps in culvert, 2 at minnow trap 1 due to ice.
12/18/2012	0	0	0	2	0	ND	ND	1 trap in culvert, entire realignment frozen.
01/25/2013	0	0	0	19	0	ND	ND	DO probe not working.
03/04/2013	0	0	0	10	0	2.8	9.1	Clear skies, no precipitation for 3 days, flow moderate, spirogyra present.
04/09/2013	0	0	1	9	0	5.1	11.8	High flow, algae recently died off.
05/03/2013	0	0	1	27	15	5.8	12.3	Dolly Varden char sighted.
06/03/2013	1	0	11	31	0	12.4	10.5	Moderate flow, only brown clumps of spirogyra left.
07/01/2013	2	0	2	144	0	16.8	7.7	Water rising with rain, minnow traps 4 and 6 placed downstream due to low water.
08/08/2013	14	0	0	313	0	18.1	15.3	1600, no passage above culvert and within reach, heavy rain earlier.
09/05/2013	6	1	1	418	0	13.3	9	
10/03/2013	44	0	14	128	0	8.6	10.1	Numerous coho mortalities, possibly due to stress and low DO. Traps coated in brown goo.

Note: Trapping events prior to 7/13/2012 included only 6 minnow traps in the upper 100 m of the realignment.

-continued-

Appendix B.1.–Continued.

Date	Coho Salmon	Dolly Varden Char	Sculpin	Threespine Stickleback	Chum Salmon	Temperature (C°)	DO (mg/L)	Notes
11/08/2013	0	0	0	38	0	4.5	12.2	
01/08/2014	0	0	0	16	0	1.8	11.9	
03/12/2014	0	0	0	1	0	0.1	10.5	
06/24/2014	0	2	3	32	0	17.2	10.2	
08/01/2014	0	1	2	3	0	14.6	9.8	
09/09/2014	12	1	35	167	0	10.5	10.3	
10/14/2014	5	0	0	88	0	8.6	9.1	
11/12/2014	13	1	14	254	0	2.7	12.3	Maximum depth at riffles <5 cm, passage marginal, following 2 days cold and clear weather.
02/19/2015	2	0	3	97	0	2.6	ND	2 shrimp captured at minnow trap 2.
04/13/2015	0	0	2	234	0	6.9	12	13 in of green algae, grey film on rocks.
07/23/2015	6	3	45	24	0	ND	ND	Creek dry since March.
08/24/2015	0	0	1	17	0	12.9	9.7	
10/05/2015	5	0	9	135	0	7.4	9.8	
10/27/2015	21	0	17	425	0	ND	ND	
01/13/2016	0	0	1	6	0	3.0	13.8	1 shrimp in minnow trap 2.
04/28/2016	55	0	2	78	0	8.4	8.6	Minnow trap 4 dry. Coho mortality at minnow trap 9 on 27th when dry, cutthroat trout trapped in pool on the 27th .
09/16/2016	28	3	22	344	0	12.2	7.4	1 week of constant flow, tree visible in upstream photo point 6 moved down to photo point 6. 2 35 mm coho salmon fry.
11/08/2016	12	0	0	576	0	6.2	9.7	No flow for weeks until today.

Appendix B.2.–Jordan Creek minnow trapping data summary, 2013–2016.

Date	Coho Salmon	Dolly Varden Char	Sculpin	Threespine Stickleback	Chum Salmon	Temperature (C°)	DO (mg/L)	Notes
11/08/2013	9	4	3	26	0	4.4	13.1	
03/12/2014	0	0	2	3	0	0.5	13.6	
06/24/2014	86	28	4	1	0	10.2	8.3	
08/01/2014	12	0	0	0	0	10.6	9.7	
09/09/2014	79	18	1	0	0	8.9	10.6	Minnow traps 1-3 in work area impoundment for new culvert.
10/14/2014	26	5	2	0	0	7.2	10.1	Minnow traps 1 and 2 in new culvert.
11/12/2014	23	3	0	5	0	3.3	11	
02/19/2015	4	3	13	1	0	2.5	ND	
04/13/2015	6	1	0	3	5	4.5	11.1	
07/24/2015	332	7	24	0	0	11.2	10.1	1 cutthroat trout at minnow trap 11.
08/24/2015	206	0	6	0	0	10.5	9.8	
10/05/2015	38	0	9	0	0	6	9.8	
10/27/2015	22	0	4	5	0	4.4	9.1	
01/13/2016	3	1	17	0	0	ND	ND	
04/28/2016	45	1	11	0	1	7	9.9	
09/16/2016	32	2	26	0	0	11.2	10.4	1 140 mm coho salmon smolt.
11/08/2016	6	0	5	0	0	6.5	9.9	

APPENDIX C: BENTHIC MACROINVERTEBRATE DATA

Appendix C.1.–Duck Creek benthic macroinvertebrate data summary, 2012–2016.

Class	Order	Family	Genus	2012	2013	2014	2015	2016	Tolerance
Insecta	Trichoptera	Limnephilidae	*Unidentified*	0	0	0	1	0	
		Lepidostomatidae	*Lepidostoma*	0	0	0	0	1	1
	Coleoptera	Unidentified	*Unidentified*	0	0	2	1	2	
		Dytiscidae	*Agabus*	0	0	0	1	0	5
		hydrophilidae	*Unidentified*	0	0	1	0	0	5
		Staphylinidae	*Unidentified*	0	0	1	3	10	8
	Hemiptera	Unidentified	*Unidentified*	0	0	0	1	0	
	Diptera	Unidentified	*Unidentified*	1	0	1	1	0	
		Tipulidae	*Dicranota*	2	0	0	0	1	3
			Unidentified	0	0	0	1	0	
			Limonia	1	0	0	1	0	6
		Chironomidae	*Unidentified*	981	698	28	36	507	6
		Empididae	*Clinocera*	0	0	0	0	4	6
			Oreogeton	0	0	0	2	0	5
			Chelifera	0	0	0	1	0	6
		Simulidae	*Prosimulium*	0	1	4	0	0	3
			Simulium	0	0	3	0	0	6
	Acari	Unidentified	*Unidentified*	2	1	6	12	3	
	Gastropoda	Unidentified	*Unidentified*	8	0	0	6	8	7
	Amphipoda	Gammaridae	*Unidentified*	9	0	0	0	0	4
Maxillopoda	Cyclopoida	Unidentified	*Unidentified*	2	0	0	0	0	
	Harpacticoida	Unidentified	*Unidentified*	0	0	28	19	52	
Entognatha	Collembola	Unidentified	*Unidentified*	1	1	9	87	6	10
Oligochaeta	Unidentified	Unidentified	*Unidentified*	1611	19	1504	692	605	5
Ostracoda	Unidentified	Unidentified	*Unidentified*	1	2	3	2	125	8

Note: values not available for all taxa.
Note: environmental tolerance values (1: most sensitive, 10: least sensitive) reported from Barbour et al (1999).

Appendix C.2.–Total benthic macroinvertebrates collected during three samples annually in Jordan Creek, 2012–2016.

Class	Order	Family	Genus	2012	2013	2014	2015	2016	Tolerance
	Ephemeroptera	Baetidae	*Baetis*	1	0	2	0	0	5
		Heptageniidae	*Cinygmula*	0	0	0	0	1	4
		Leptophlebiidae	*Paraleptophlebia*	0	0	0	0	1	2
	Plecoptera	Chloroperlidae	*Sweltsa*	0	0	2	0	1	1
			Suwallia	1	0	0	0	0	1
		Capniidae	*Capnia*	0	1	0	0	0	1
		Nemouridae	*Zapada*	14	2	2	0	0	2
	Trichoptera	Limnephilidae	*Ecclisomyia*	0	0	0	1	1	2
		Limnephilidae	*Grensia*	0	0	0	0	2	6
		Lepidostomatidae	*Lepidostoma*	0	0	0	0	1	1
	Coleoptera	Carabidae	*Unidentified*	0	0	3	0	0	4
		Dytiscidae	*Hydaticini*	4	0	0	0	0	5
	Diptera		*Unidentified*	0	6	8	2	9	
		Tipulidae	*Dicranota*	10	2	3	1	2	3
			Holorusia	0	0	0	1	0	
		Chironomidae	*Unidentified*	454	580	808	39	537	6
		Ceratopogonidae	*Probezzia*	1	0	1	0	0	6
	Acari	Unidentified	*Unidentified*	1	1	4	3	4	
	Gastropoda	Unidentified	*Unidentified*	6	8	1	44	60	7
	Amphipoda	Gammaridae	*Unidentified*	0	0	0	1	0	4
	Bivalva	Sphaeriidae	*Unidentified*	1	0	3	1	2	
Maxillopoda	Harpacticoida	Unidentified	*Unidentified*	2	5	22	16	164	
Entognatha	Collembola	Unidentified	*Unidentified*	0	0	1	1	1	10
Oligochaeta	Unidentified	Unidentified	*Unidentified*	1651	459	1618	291	810	5
Ostracoda	Unidentified	Unidentified	*Unidentified*	14	7	32	15	21	8
Nematoda [Phylum]	Unidentified	Unidentified	*Unidentified*	0	15	1	0	0	5

Note: values not available for all taxa.

Note: environmental tolerance values (1: most sensitive, 10: least sensitive) reported from Barbour et al (1999).

APPENDIX D: PHOTO POINTS

Appendix D.1.–Photo point 1, upstream view.

Appendix D.2.–Photo point 1, downstream view.

Appendix D.3.–Photo point 2, upstream view.

Appendix D.4.–Photo point 2, downstream view.

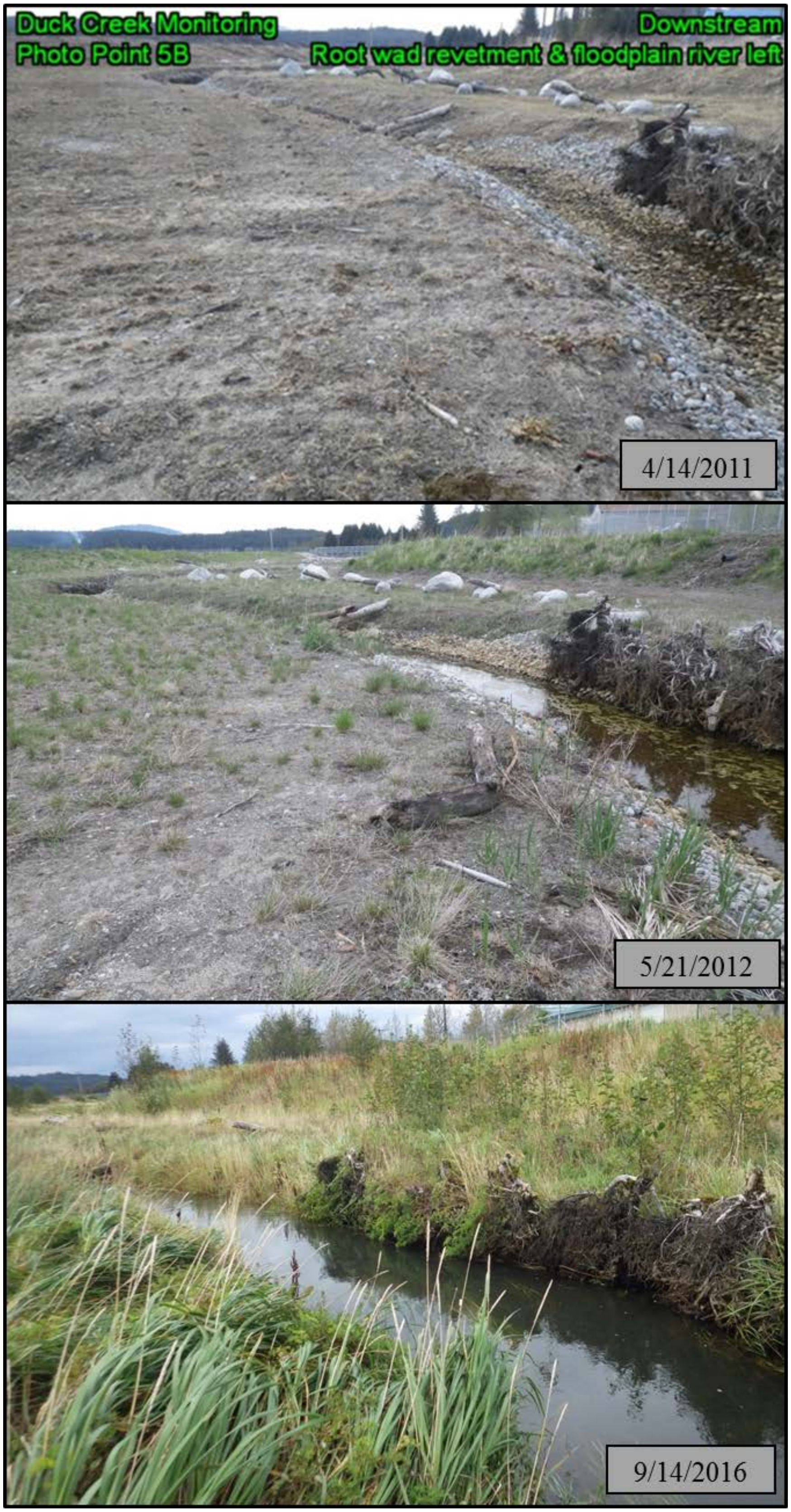
Appendix D.5.–Photo point 3, upstream view.

Appendix D.6.–Photo point 3, downstream view.

Appendix D.7.–Photo point 4, upstream view.

Appendix D.8.–Photo point 4, downstream view.

Appendix D.9.–Photo point 5, upstream view.



Appendix D.10.–Photo point 5, downstream view.

Appendix D.11.–Photo point 6, upstream view.

Appendix D.12.–Photo point 6, downstream view.

Appendix D.13.–Photo point 7, upstream view.

Appendix D.14.–Photo point 7, downstream view.

Appendix D.15.–Photo point 8, upstream view.

Appendix D.16.–Photo point 8, downstream view.

Appendix D.17.–Photo point 9, upstream view.

Appendix D.18.–Photo point 9, downstream view.

Appendix D.19.–Photo point 10, upstream view.

Appendix D.20.–Photo point 10, downstream view.

Appendix D.21.–Photo point 11.