Peter Gray Parr Project: At the Peter Gray Hatchery

2012 – 2019 Summary

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A project of the Downeast Salmon Federation

A summary of the Peter Gray Parr Project at the Peter Gray Hatchery, 13 Willow St. East Machias, ME.

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Table of Contents

Introduction: 3

Review 3

The Peter Gray Parr Project: 3

What Makes the Peter Gray Method Different? 3

Egg Source and Broodstock Management 9

Project Findings 10

Large Parr Assessment (Electrofishing) 10

Smolt Population Assessment (Smolt Trapping) 19

Adult Return Assessment (Redd Counting) 25

Hatchery Operations 27

Outreach 35

Adaptive Management 35

Hatchery Operations 35

Stocking 35

Habitat and Predation 36

East Machias River Habitat and how it could be impacting this Project 36

What Can We Do 37

Moving Forward: 38

Acknowledgment: 39

Glossary: 39

Literature Cited: 43

Introduction:

Review

The Peter Gray Hatchery (PGH) has been in operation at the Downeast Salmon Federation's (DSF) East Machias Facility since the winter of 2011. The Peter Gray Parr Project (Project) is modeled on the methods used successfully at the Kielder Hatchery on the River Tyne in northern England. This approach utilizes a river specific hatchery, using water directly out of the river in which the juvenile salmon will be stocked. Juvenile salmon are raised to the parr life stage under conditions designed to produce fish that approximate wild fish in terms of size, their ability to feed, and predator avoidance. These parr are then stocked in the fall of their first year (designated "0+ parr" because they are less than one year old, or "fall parr" because they are stocked in the fall) once river water temperatures have dropped and the metabolism of the salmon has slowed, allowing the salmon to spend less energy on feeding and more on finding shelter. The goal of the Project has been to demonstrate that this strategy can produce more adult returns than fry stocking and achieve smolt to adult return rates equivalent to, or higher than, smolt stocking at a much lower cost. Ideally, this strategy will also produce smolts and adult returns at rates equivalent to, or higher than, those of wild (naturally spawned) salmon. These parr will also spend more time in the river than stocked smolts, which should translate into superior survival behavior and natural selection.

Through this Project, and in collaboration with the US Fish and Wildlife Service (the Service), NOAA – Fisheries (NOAA) and the Maine Department of Marine Resources (DMR), over 1.2 million quality 0+ parr have been stocked into the East Machias River drainage, new smolt population data has been collected on a river that no historic smolt emigration data had been collected in the past, a focused effort in restoration has been put on the East Machias River, and thousands of area students and community members have been engaged in the Project.

The Peter Gray Parr Project:

What Makes the Peter Gray Method Different?

This method of rearing juvenile salmon was developed by the late Peter Gray on the River Tyne in the United Kingdom. Peter's approach was to raise juvenile salmon in a more natural environment, to stock these fish late in the fall, and to stock a large number of fish to saturate the river thereby maximizing the number of out-migrating smolts. This was successful on the River Tyne and helped to rebuild the Atlantic salmon population in that system (Figure 1). These techniques differ in some ways when compared to a traditional hatchery setting. One of the most important differences is the use of untreated, unfiltered river water, sourced from the river the fish will be stocked into. Using natal river water keeps the salmon developmentally in sync with the river and the wild salmon throughout it. Many life stage transitions, such as spring emergence and smoltification, as well as growth rate, are dependent on temperature (Sigurd 2008, Jonsson 2011). Fish reared in ambient river water are also exposed to fluctuations in pH and any bacteria that may be in the river water, helping to build their immune systems.

Substrate incubation boxes (Figure 3) are used to incubate fish from the alevin to fry life stage. These incubation boxes act as an artificial redd inside the hatchery and allow the fish to emerge from the substrate of their own volition and drop into the rearing tanks. This movement from the box to the tank is temperature-dependent, and the fish will only do this once developmentally ready; this typically occurs around a river temperature of 10^{o}C in the spring of the year. Alevin that develop in the substrate incubation boxes can use the energy being absorbed from their yolk sacs for growth and development, rather than movement. A more typical method for rearing fish through this life stage is to hold them either in a Heath style egg tray (Figure 2), or trough setup. These setups do not offer any shelter for the developing alevin and lead to alevin moving more than necessary, likely contributing to a smaller size at emergence when compared to the size of fry that have emerged from substrate incubation boxes (DSF Unpublished data).

The rearing tanks that emerging fry drop into are colored black. These black tanks give a darker rearing environment, which provides multiple benefits for the salmon. The dark-colored tanks help decrease stress and since the fish will turn darker or lighter depending on their background, salmon raised at the PGH are darker and more naturally colored at stock-out, potentially decreasing initial stock-out mortality. Figure 4 shows a tank of healthy fish at the PGH, notice the dark-colored tank, and the equally dark-colored fish. Throughout the rearing season, the volume and velocity of the water in the rearing tanks is increased. This keeps the fish swimming more and more as they grow, actively building muscle texture to develop salmon that are physically fit and naturally sized when released into the river.

Fish reared using the Peter Gray method are released late in the fall when competition for food resources is typically lower as metabolic rates of salmon decrease with colder temperatures. This allows the fish time to establish themselves before the ice begins to form in the river.

The final piece to this technique is stocking large numbers of fish, saturating the river in an attempt to increase production. An initial goal of stocking upwards of 400,000 parr was set by DSF at the outset of the Project. This goal has yet to be reached; however, stocking densities have reached some increased amounts (dependent on eyed egg production at the USFWS Craig Brook National Fish Hatchery) and the Project's position is to continue increasing stocking densities as long as the data suggests negative density-dependent effects are not seen in the salmon population of the East Machias River.

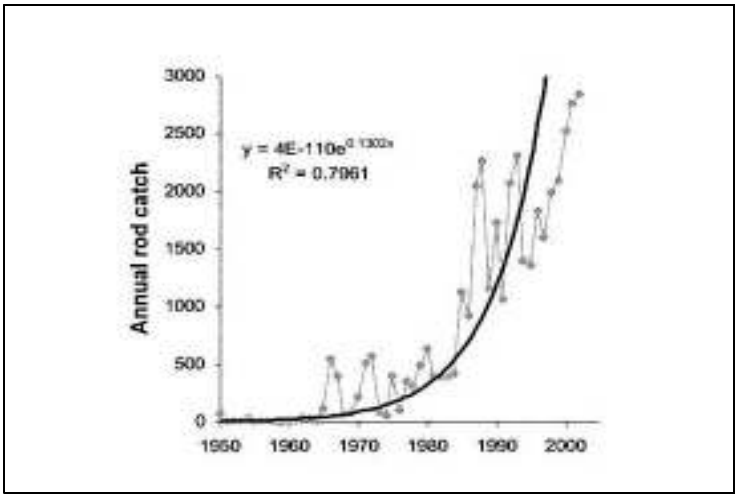

Figure 1 Exponential fit of River Tyne rod catches 1950 – 2000.

Figure 2 Heath style egg incubation trays at the Peter Gray Hatchery.

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Figure 3 Substrate incubation boxes implemented at the Peter Gray Hatchery.

Figure 4. Parr in late August at the Peter Gray Hatchery. The dark-colored tanks offer a less stressful environment for the fish and the fish take on a darker, more natural color.

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Initially, the Project outline suggested 400,000 fish would be raised at the PGH annually, starting in year two. Response from the US Atlantic Salmon Recovery Framework and other state and federal agency staff was that 400,000 was too many salmon for the East Machias River to support. They proposed increasing stocking numbers incrementally over five years. This would ensure that no undue environmental harm and potential harm to the salmon and fish populations resulted from high stocking densities. Table 1 shows the incremental increase of egg numbers received from the Craig Brook National Fish Hatchery (CBNFH). It also takes time to raise more broodstock from the captive broodstock line to generate a higher number of available eggs.

Table 1. Estimated eggs received and subsequent salmon stocked into the East Machias River, along with total (egg-parr) estimated in-hatchery survival.

	EGGS RECEIVED	FRY STOCKED	PARR STOCKED	% SURVIVAL IN THE HATCHERY (EGG – PARR)
2012	81,370	0	53,215	76.92
2013	102,141	18,940	77,568	84.24
2014	186,966	14,696	149,815	88.44
2015	346,201	10,300	192,032	77.02
2016	345,585	10,300	199,644	68.93
2017	378,289	10,087	211,559	69.67
2018	186,856	10,315	119,465	71.70
2019	369,857	10,369	226,348	66.86
2020	186,544	0		
TOTALS	**2,183,809**	**85,007**	**1,229,646**	**Avg: 75.48**

All fish reared in the PGH to date have been marked with an adipose clip before they are stocked into the river. This process begins in late September/early October when daily high river temperatures are at, or below, 18^{o}C. Tricaine methanesulfonate (MS222) is used to anesthetize the fish, which are then clipped and allowed to recover before returning to their rearing tank. This labor-intensive process typically takes around three weeks to complete and utilizes volunteer work hours numbering in the hundreds each year.

Following marking, fish are released throughout the East Machias watershed (Figure 5) using distribution trucks borrowed from the Service. Stocking densities are determined before stocking by DSF and Maine DMR scientists to fill as much quality salmon habitat as possible throughout the watershed. The stocking density for a particular stretch of the river and the number of surveyed habitat units will determine how many fish go to each site. Stocking typically takes place in mid to late-October, when river temperatures have fallen to around 10^{o}C.

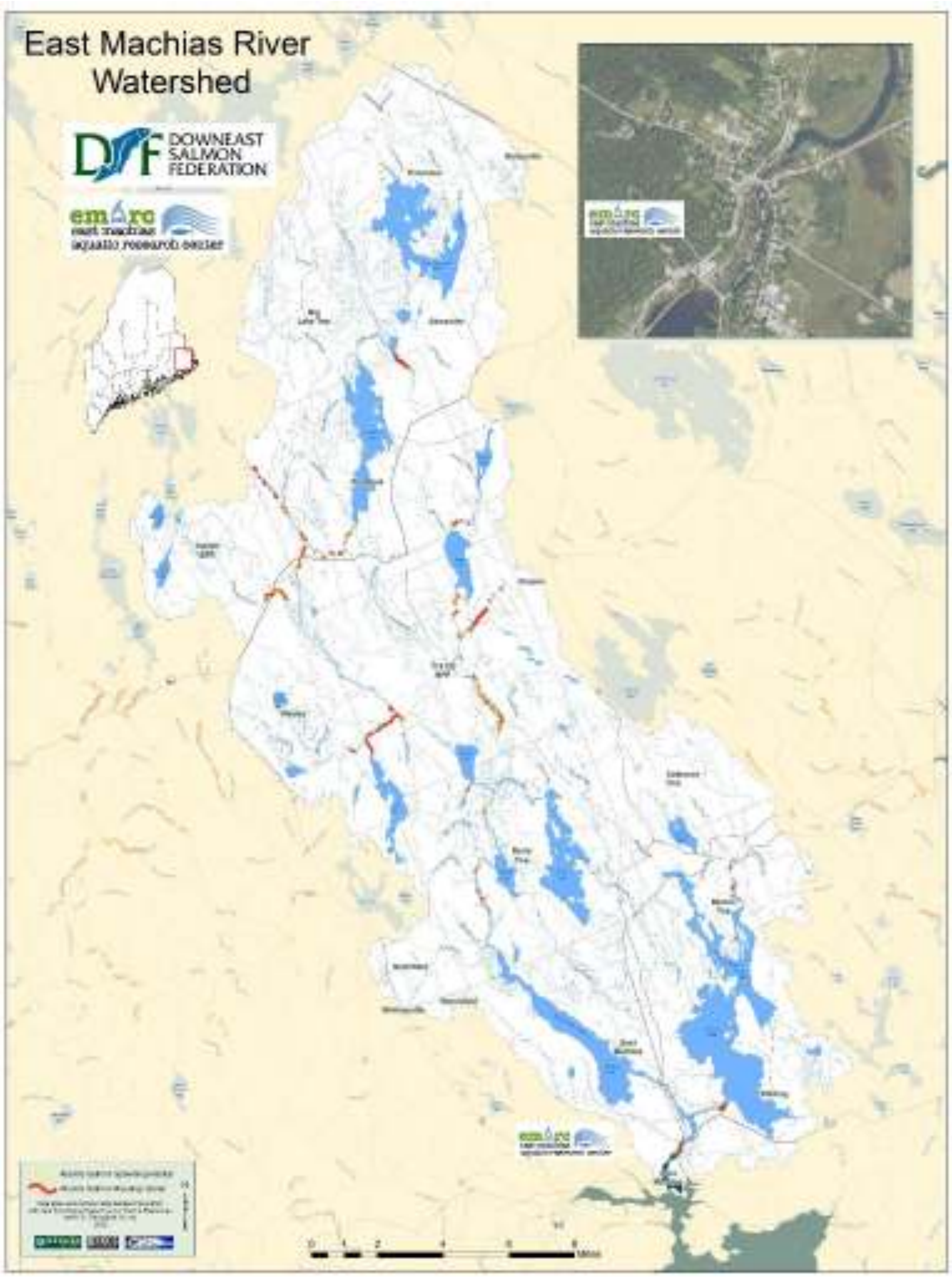

Figure 5. Stocking Sites (in red), East Machias River, Maine.

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Egg Source and Broodstock Management

Eggs are provided by the CBNFH, a facility run by the Service. The Service manages the broodstock program for the US Atlantic salmon recovery program. This is a river specific program focused on maintaining as much genetic diversity as possible and providing salmon for restoration efforts around the state, largely spearheaded by Maine DMR. All of the rivers, except for the Penobscot, have a captive line of broodstock where juvenile salmon (typically 1+ parr) are captured and transported to the CBNFH. Each river has its captive line, held in separate rooms at the facility. 200 - 250 East Machias River parr have been collected each year and sent to CBNFH to hold as broodstock. From there, genetics are analyzed to ensure a single-family group is not over-represented and the highest possible genetic diversity is retained in the broodstock population. Genetic screening also determines the salmon's family group origin, providing insight into how many family groups are recaptured from the river and brought back to CBNFH. The more family groups that are captured during broodstock collection, the more genetically diverse the broodstock will be, and more genetic diversity is good in a salmon population. The Project has been successful in retaining family groups, increasing genetic diversity for future broodstock. Since the Project began in 2012, the percentage of family groups retained has increased from about a 40% retention rate to about 60% (anecdotal data, USFWS).

Parr are then raised to adults until they are ready to spawn. The age at spawning varies and there are typically a mix of three, four, and five-year-old fish contributing to the production of eggs in any given year. In contrast, the Penobscot River broodstock comes from salmon returning from the sea to the Penobscot River. The majority of these fish were stocked as smolt. The adults are brought to CBNFH where they are held until spawning in the fall. In a typical year, a portion of the eggs are held in the hatchery and reared to the smolt life stage, and the rest are released as fry throughout the watershed. The Penobscot program relies on adults returning from smolt stocked salmon to provide broodstock for future production.

At the start of the Project, DSF signed a Memorandum of Agreement (MOA) with the Service (extending that MOA in 2017), entering a public-private relationship focused on the restoration of Atlantic salmon in the East Machias watershed. Through this MOA, the Service states that they will:

- Annually provide up to 400,000 East Machias River Atlantic salmon eggs to the Peter Gray Hatchery to be used for the East Machias River in support of fisheries restoration.
- The exact number of eggs will be dependent on overall egg production and survival for East Machias River Atlantic salmon at Craig Brook National Fish Hatchery and the need to maintain a river specific broodstock for this river.
- Maintain a broodstock collection program in the East Machias River and sufficient numbers of broodstock at Craig Brook National Fish Hatchery to supply eggs to the Peter Gray Hatchery.

- Lend technical expertise and consultation to the Peter Gray Hatchery.
- Agree to work collaboratively with DSF to meet mutual restoration goals and population targets for Atlantic salmon in the East Machias River.
- Work collaboratively with all the public and private stakeholders in the East Machias watershed to restore Atlantic salmon and the health of the watershed.

And DSF will:

- Lead an expanded Atlantic salmon restoration effort in the East Machias by using its river-based hatchery on the East Machias River to initiate a fall parr stocking program.
- Build out the Peter Gray Hatchery to accommodate up to 400,000 eggs.
- Continue to seek private and public resources to ensure the program can continue for a minimum of five years.
- Use an adaptive management approach to ensure resources are being used most effectively to increase returning numbers of adult Atlantic salmon.
- Engage and collaborate with the Service and other stakeholders in the watershed on the fall parr program and any other activities that could impact Atlantic salmon restoration in the East Machias watershed.
- Submit annual reports to USFWS to meet the requirements of the Section 10 permit.

Project Findings

To assess the success of this Project, surveys of three life stages are conducted each year. These surveys, overseen by Maine DMR, analyze changes in population abundance, monitors fish for indications of negative or positive impacts of stocking density, and estimates the overall size of the Atlantic salmon population in the East Machias River. Electrofishing surveys of juvenile salmon in freshwater, smolt trapping surveys that estimate the population of salmon smolts migrating to the ocean, and redd counts (adult return assessment) that estimate the number of adult Atlantic salmon returning to spawn are all completed. These surveys have been conducted each year this project has been in operation; however, redd surveys do not include two sea winter adult Atlantic salmon returning from PGH stocking efforts until 2016. All data collected during scientific sampling events are compiled and analyzed by Maine DMR scientists.

Large Parr Assessment (Electrofishing)

Electrofishing surveys accomplish many tasks. First and foremost, these surveys allow comparison of large parr densities throughout the watershed (and others) year to year and among different habitats. In the East Machias River, the electrofishing dataset dates back to the 1970s. Having this long term data set shows how large parr densities in the East Machias River have responded to fall parr stocked from the PGH at increasing densities since 2011. Surveys are conducted using an electrofishing backpack. A pulse of electricity is sent through the water and fish within the range of the electrical pulse are stunned and netted using nets. Figure 6 shows electrofishing set up using this method. Biometrics, including length (mm) and weight (g), are collected on captured parr, and any marks, i.e. an adipose clip, deformities, or wounds are also noted. Scale samples are collected and analyzed by Maine DMR staff to determine the age of parr collected. These surveys are conducted by Maine DMR and DSF staff. Maine DMR scientists analyze all of the data collected during these surveys; the following data summarized here has been pulled from Maine DMR reports and presentations.

Figure 6. Electrofishing set up using an electrofishing backpack. Photo: Beaverdam Stream, DSF - Sheller

The dataset of large parr densities in the East Machias River goes back into the mid-1970s (Figure 7). The red markers in Figure 7 indicate where drainage wide, median large parr densities in the East Machias River are a result of 0+ parr stocking from the PGH. Large parr densities in 2013, one year after the first fall parr stocking, were 5.3 parr/unit (100m^2), just above the previous decadal median of 4.9 parr/unit.

Density has increased significantly since 2013. Median large parr density increased in 2014 to 10.5 parr/unit, a density not seen since the mid-1990s, and there was a slight decrease in 2015, but only to a median density of 8.7 parr/unit, still well above the unfed fry decadal median. The median large parr density for the entire East Machias drainage was 14.9 parr/unit in 2016. This is the highest drainage wide median large parr density observed since the mid-1980s (Figure 7). Large parr density in 2017 decreased from the previous year resulting in 13.1 parr/unit across the drainage. In 2018, the median drainage wide large parr density was 13.9 parr/unit, a slight increase from the previous year. The median large parr density in 2019 was 7.7 parr/unit.

Decadal median large parr density during the span of the Project is 10.5 parr/unit, compared to the decadal median seen during unfed fry stocking of 4.9 parr/unit. This is a 114% increase over an 8-year timespan. Parr densities produced by stocking Peter Gray parr in the East Machias River are more than double what they were during the period of unfed fry stocking. This is the highest decadal median large parr density observed since electrofishing began in the mid-1970s.

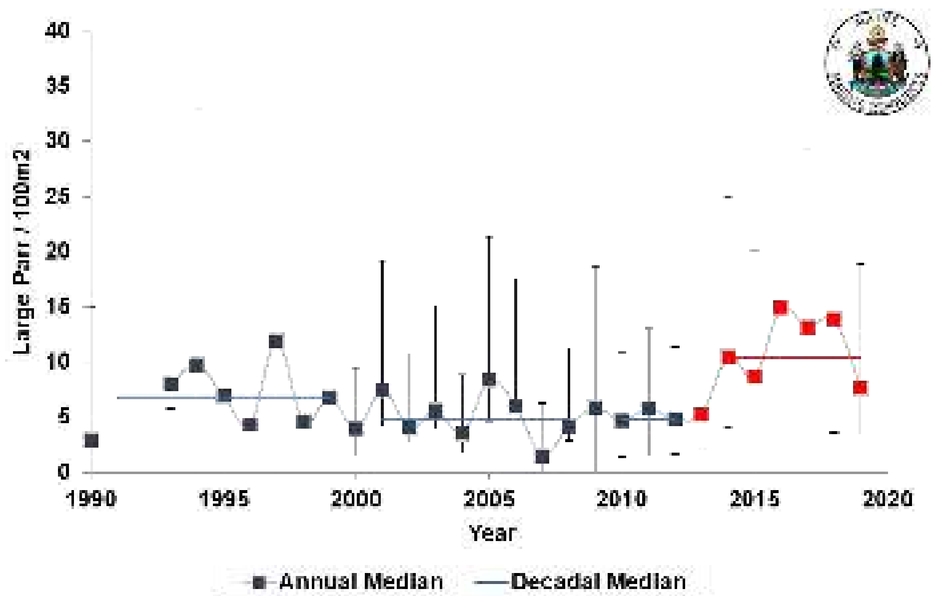

Figure 7. Median large parr density and associated 95% confidence interval, East Machias River, ME (1990-2019). Red markers indicated years that resulted from Peter Gray parr stocking and the Peter Gray Parr Project. Source: Maine DMR - Bruchs 2019

Throughout the previous 50 years, various life stages have been stocked to produce juvenile populations in the East Machias River. These stockings have occurred across the drainage in all habitat types and width classes. A comparison of all electrofishing sample events (n=380) throughout all width classes documented mean large parr density produced by Peter Gray parr stocking is significantly greater than unfed fry stocking (Tukey HSD; $p < 0.05$), (Figure 8).

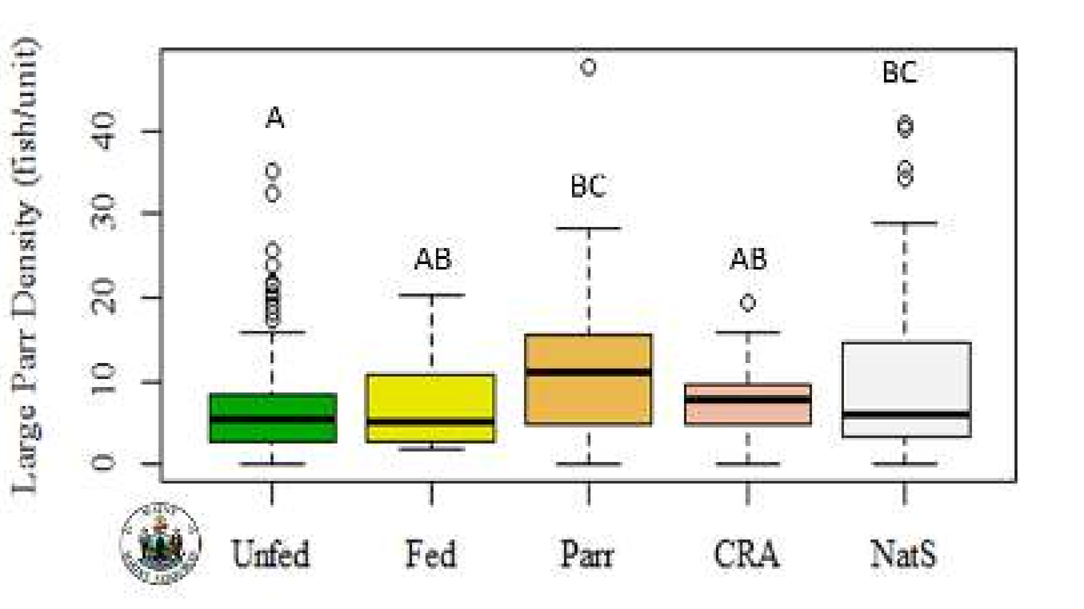

Figure 8. Box plots (max, +1 s.d., median, -1 s.d., and min) of large parr density (fish/100m^2) observed during electrofishing sampling by life stage stocked, East Machias River drainage, Maine (1997-2019). Like letters indicated no significant difference (p > 0.05; Tukey's HSD). Source: Maine DMR - Bruchs

Due to the general differences in habitat quality/suitability (substrate size, mean depth, water temperature, etc.) among various stream width classes in the East Machias River, a stratified analysis of mean large parr densities was employed to determine which stocking strategy is the most productive. Width classes were categorized as A (0-6 meters), B (6-12 meters), and C (12-18 meters). Width class A streams include the smaller headwater type streams to include Harmon Brook, Creamer Brook, Barrows Stream, and Beaverdam Stream. Width class B streams are larger tributaries to include Northern Stream, Seavey Stream, and Chase Mill Stream. The C width class of the East Machias River is comprised of the mainstem sections of the river.

Large parr densities produced in A width class streams from natural spawning are significantly greater than using any stocking strategy (Tukey HSD; $p < 0.05$), (Figure 9). However, given the lower number of adult returns to the watershed and lack of natural spawning, Peter Gray parr, although not statistically significant, has produced a greater mean density of large parr than unfed fry. In B width class streams, the Project produces large parr densities that are significantly greater than all other stocking strategies to include natural spawning, unfed fry, fed fry, and captive-reared adults (Tukey HSD; $p < 0.05$), (Figure 10). Peter Gray fall parr stocked into the mainstem portions of the East Machias River (C width class) don't produce a statistically significant higher large parr density than the other stocking strategies, but produces a slightly higher parr density on average and also a higher range of observed densities (Tukey HSD; $p < 0.05$), (Figure 11).

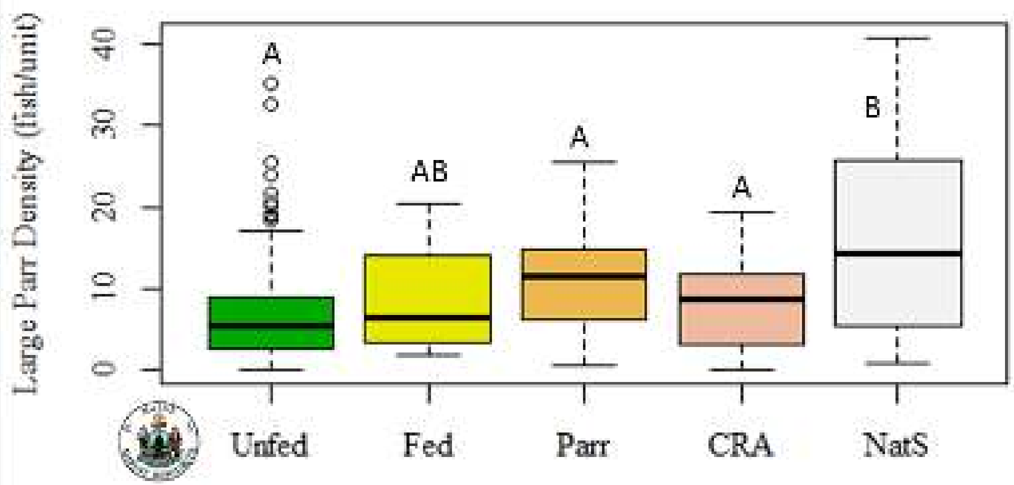

Figure 9. Box plots (max, +1 s.d., median, -1 s.d., and min) of large parr density (fish/100m^2) observed during electrofishing sampling by life stage stocked in A width class streams, East Machias River drainage, Maine (1997-2019). Like letters indicated no significant difference ($p > 0.05$; Tukey's HSD). Source: Maine DMR - Bruchs

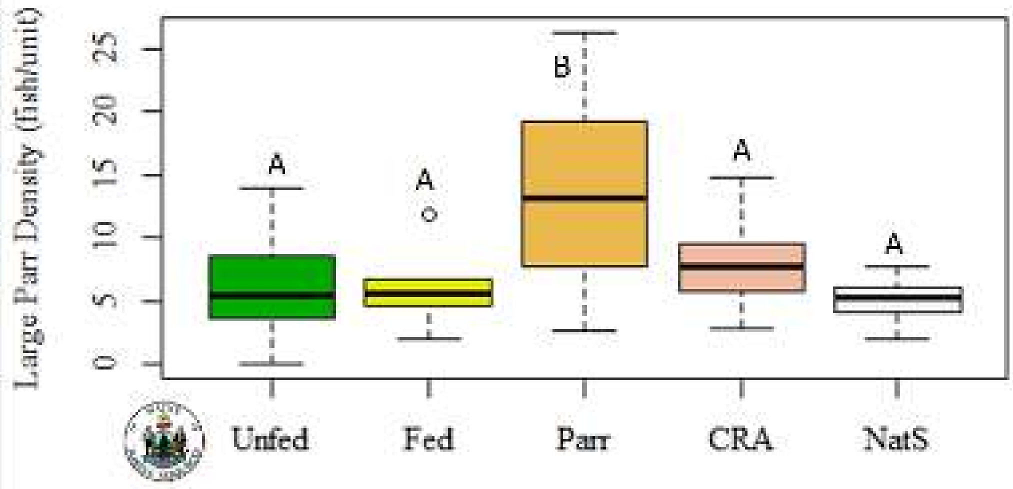

Figure 10. Box plots (max, +1 s.d., median, -1 s.d., and min) of large parr density (fish/100m²) observed during electrofishing sampling by life stage stocked in B width class streams, East Machias River drainage, Maine (1997-2019). Like letters indicated no significant difference ($p > 0.05$; Tukey's HSD). Source: Maine DMR - Bruchs

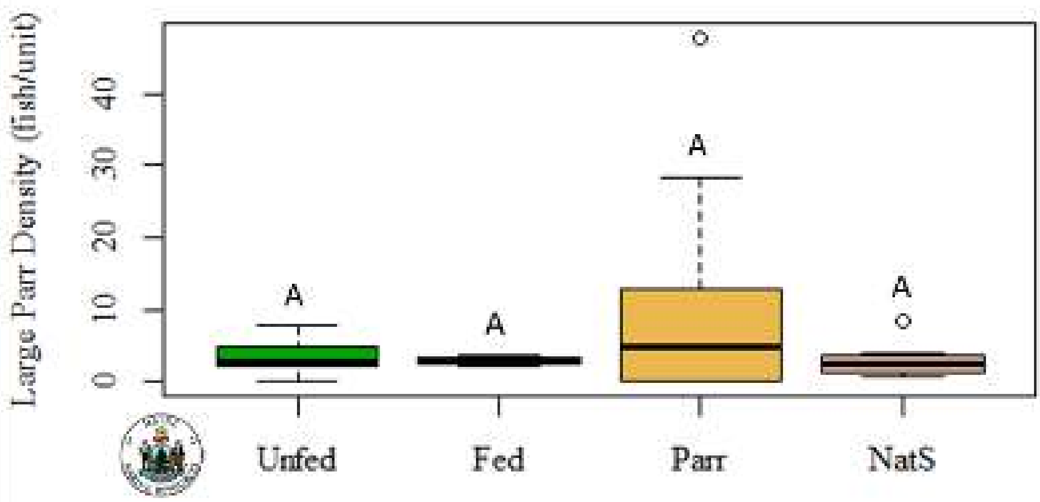

Figure 11. Box plots (max, +1 s.d., median, -1 s.d., and min) of large parr density (fish/100m²) observed during electrofishing sampling by life stage stocked in C width class streams, East Machias River drainage, Maine (1997-2019). Like letters indicated no significant difference ($p > 0.05$; Tukey's HSD). Source: Maine DMR – Bruchs

Northern Stream (B width class stream) has been used as a reference stream and control throughout the Project. Northern Stream was stocked at a consistently lower rate than the rest of the watershed up until 2019. From 2013-2015 it was stocked at a density of 45 parr/unit, 60 parr/unit in 2016, 2017-2018 at 90 parr/unit, and in 2019 Northern Stream was supplemented at 150 parr/unit. Initially, keeping one stream at a consistently lower stocking density allows us to compare fluctuations in population densities throughout the East Machias watershed. This helps to either rule out or point the finger at, density-dependent, population-level impacts. If a decrease in population density and/or condition factor was seen in areas of high stocking density, but not seen in Northern Stream where stocking density remained low, it could be a result of overstocking. This has not been the case throughout this Project and fluctuations in population densities were likely due to environmental factors.

Throughout the past 20 years, various stocking strategies have been used to populate Northern Stream. These stocking strategies include: fed fry (1997-2000), unfed fry (2001-2010), captive-reared adults (2011-2013), and most recently fall parr from the PGH (2014-2019). Maine DMR analysis determined Peter Gray fall parr stocking produced significantly greater large parr densities compared to all other stocking strategies (Tukey HSD; $p < 0.05$), and also produced the highest observed large parr density during this period (Figure 12) (Maine DMR – Bruchs).

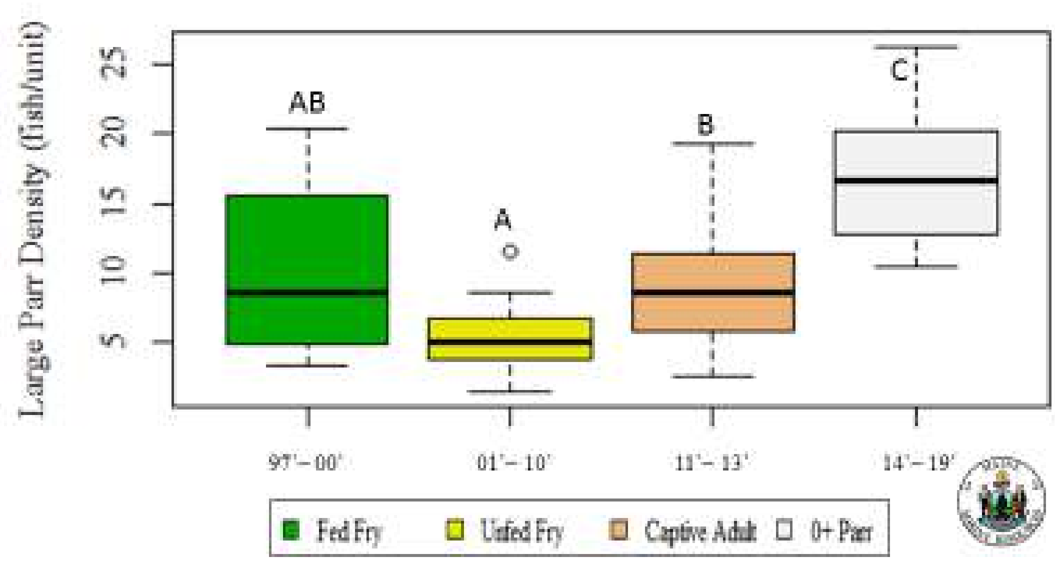

Figure 12. Box plots (max, +1 s.d., median, -1 s.d., and min) of large parr density (fish/100m^2) observed during electrofishing sampling by life stage stocked and period (years), Northern Stream, East Machias River drainage, Maine (1997-2019). Like letters indicated no significant difference ($p > 0.05$; Tukey's HSD). Source: Maine DMR - Bruchs

The condition factor (Fulton's K) of large parr collected during electrofishing sampling events is calculated each year. The condition factor looks at length and weight to determine the relative body condition of each parr. The closer to 1 the K-factor is, the healthier the fish is in terms of body condition. As the K-factor decreases from 1, health in terms of body condition goes down. If there is a very low K-factor, the fish would essentially be long and light in weight, if the K-factor is very high (above 1), the fish would be short and heavy. The mean K-factor has never shown to be poor (Figure 13).

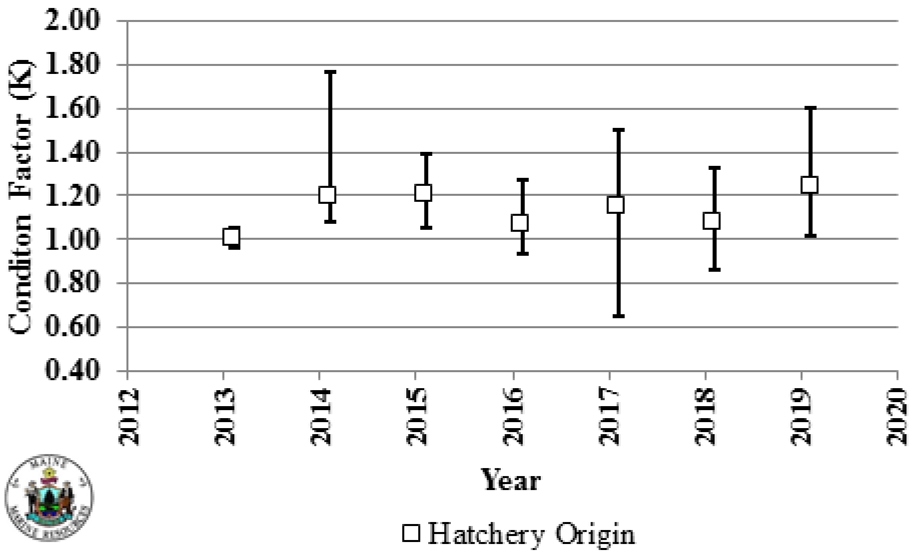

Figure 13. Mean condition factor (Fulton's K) of PGH large parr captured during electrofishing sampling. East Machias River drainage, Maine (2013-2019). Source: Maine DMR - Bruchs

The length/weight distribution between PGH origin 1+ parr and naturally reared 1+ parr were compared in 2015. There was no significant difference between the lengths and weights of wild and PGH parr (Figure 14). The length/weight distribution of parr stocked at higher densities (120 fish/unit) and those stocked in Northern Stream at lower densities (45/60 fish/unit) were compared. There was no significant difference in the length/weight distribution of parr between the stocking densities (Figure 15).

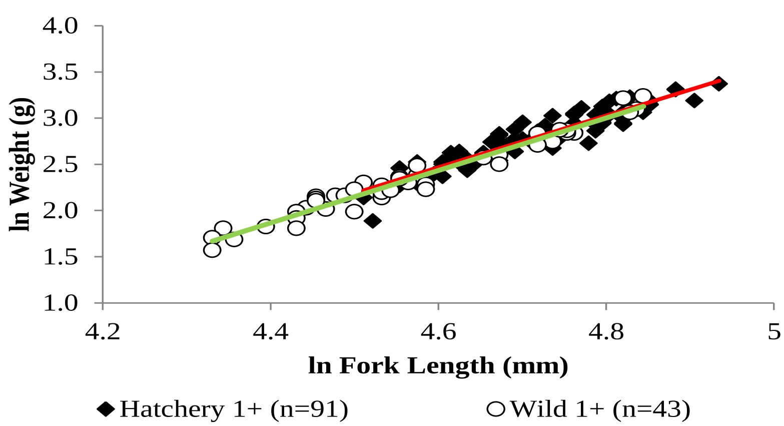

Figure 14 Length-weight distribution of large parr (2015). Source: Maine DMR - Bruchs

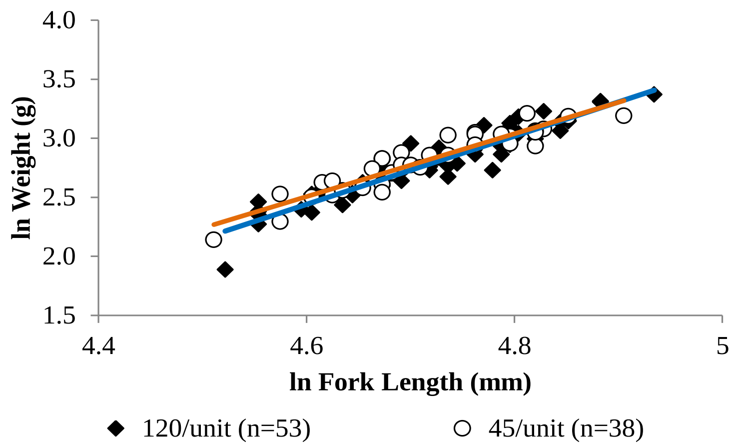

Figure 15 Length-weight distribution comparison between stocking densities. Source: Maine DMR - Bruchs

Electrofishing data collected to date points out several things. First, decadal median large parr densities have more than doubled during the Project compared to decadal medians before the Project. Second, the body condition of the fish and densities indicate no negative effects on the population of Atlantic salmon from the increased stocking densities; a significant concern of partners from the outset of the Project. Third, fall parr stocked into "B" (midsize) and "C" (mainstem) width class streams significantly outperform other stocking strategies in producing higher large parr densities.

Smolt Population Assessment (Smolt Trapping)

An important part of the Project is to estimate the number of smolts migrating from the East Machias River to the ocean (Bruchs et al 2016-2019). To obtain this data, in partnership with Maine DMR, two rotary screw traps (RST's) (2.4 m dia. or 8ft) are deployed at a single site below the Jacksonville Bridge on Route 191 each spring (Figure 16). Smolt trapping determines how many smolts are naturally-reared (wild origin or fry stocked) and how many smolts were produced from fall parr stocking by DSF. These RST's, borrowed from NOAA and Maine DMR, are the largest operating in the state of Maine. They have a cone that funnels from a wide opening down to a narrow end that empties into a live car (E.G. Solutions 2002; Music et al. 2010). As the river flows through the cone the trap spins, at which point the trap is in operation (i.e. fishing). The more water that flows through the cone, the faster the cone spins. The smolt data collected through the Project is the first smolt data ever collected on the East Machias River.

RSTs are tended in the morning of each day by Maine DMR and DSF staff. Smolt captured undergo biological sampling that includes: measurement of length (mm), live weight (g), observation of marks, fin condition, relative smolt development, and notation of any injury or mortality. Smolt that have been captured for the first time are marked with a caudal punch, indicating they have been captured in the trap; this also serves as a genetic tissue sample. After biological sampling, newly captured smolt are transported and released one kilometer upriver of the RST site. If these smolt are recaptured at the RST site they are enumerated then released well below the RSTs site to continue on their journey to the ocean. Data is analyzed by Maine DMR scientists and a population estimate is calculated from the data collected each smolt season (Bruchs et al 2016-2019)

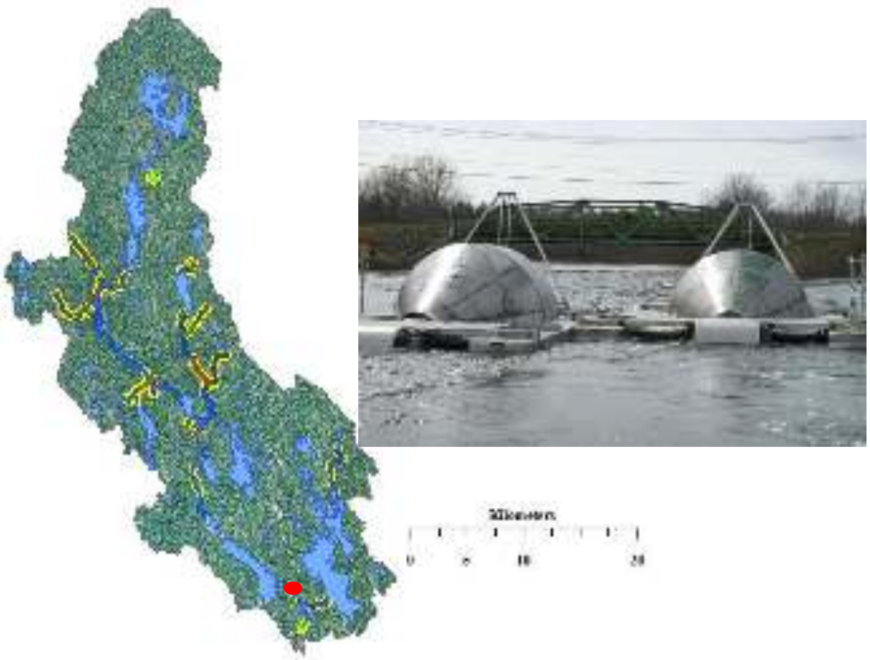

Figure 16. East Machias River watershed map (the red mark is the smolt trap assessment site) and the smolt traps in operation below the Rte. 191 Bridge in East Machias, Maine.

Figure 17 shows the smolt population estimates from 2013 to 2019. The proportion of smolt that were reared at the PGH ranged from 41% to 97% of the estimated smolt population. Stocking rates of fall parr were kept the same in 2014 and 2015 due to the low number of estimated smolts observed during the 2015 trapping season. Because the stocking rate remained the same, it was clear that low smolt numbers were likely due to harsh environmental conditions (i.e. the harsh winter of 2014/2015) and not high stocking densities.

Smolt numbers in 2018 fell slightly shy of the smolt numbers of 2017, which were the highest seen in the Project, but were almost 4 times higher than smolt populations generated from unfed fry stocking and limited natural spawning (Bruchs et al 2014 and Bruchs et al 2016). Since 2015, 243 units of habitat have been stocked below the RST site. Based on the estimated hatchery smolt production above the trap of 0.74 smolt/unit of habitat, an additional 180 hatchery smolts (Table 2) were estimated to have been produced in this habitat not represented in Figure 17. The two estimates combined the total smolt population for 2019 of approximately 1,281 PGH origin smolts; a 276% increase in smolt heading to sea from the East Machias River when compared to the number of smolts produced from unfed fry stocking observed in 2013. Daily smolt captures for 2019 can be seen in Figure 18.

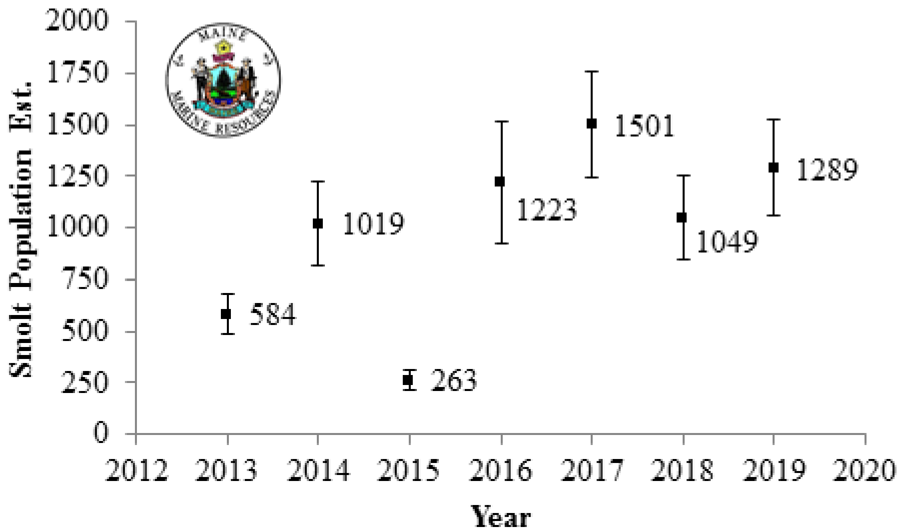

Figure 17. Total smolt population estimates and standard error (DARR 2.02 for program R), East Machias River, Maine (2013-2019). Source: Bruchs et al 2019

Table 2. 2019 total smolt population estimates including supplemented habitat below the smolt trap, East Machias River, Maine. Source: Bruchs et al 2019

Year	Drainage Location	Origin	Population Estimate	Habitat Units[1]	Production Rate (Smolt/Unit)
2019	East Machias (Above RST)	Hatchery	1101	1481	0.74
		Wild	188*		
		All	1289	1584	0.87
	East Machias (Below RST)	Hatchery	180**	243	
		Total	**1469**		

[1] Based on supplemented mapped units

* Wild estimate = (total estimate - hatchery estimate)

** Lower river estimate = (H production rate above RST x H supplemented habitat units below RST site)

DOWNEAST SALMON FEDERATION

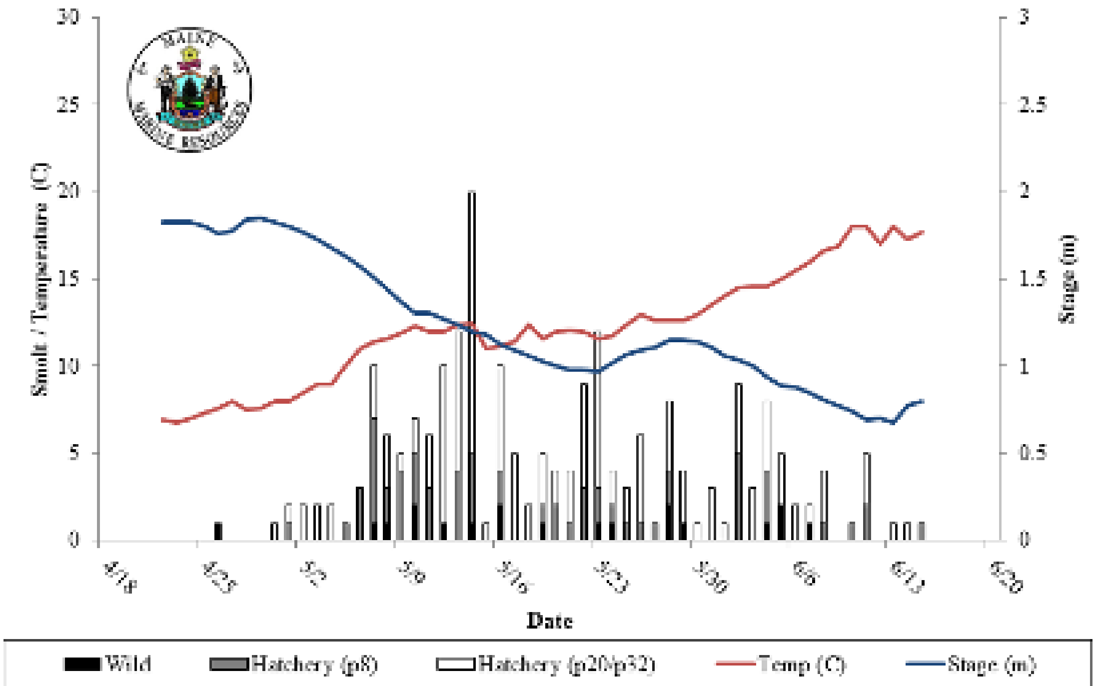

Figure 18. Daily smolt catch (by origin), water temperature (°C), and stream stage (m) at the Route 191/Jacksonville Bridge RST transect, East Machias River, Maine, 2019. Source: Bruchs et al 2019

Data on the age distribution of the smolt leaving the East Machias River is collected through this smolt trapping effort. Ages are determined by analyzing scales sampled from each smolt. Naturally reared (natural spawning and fry stocking) fish from the East Machias River typically migrate at either age2 or age3, which is a typical observation in Maine's rivers for decades (USASAC 2016). Hatchery reared fish can be classified into three age groups: p8s, p20s, or p32s. The numbers after the letter "p" indicate how many months the salmon have lived in the river after being stocked from the PGH in late October of the previous year. Table 3 shows the age distribution (in percent of the estimated smolt population) of smolt captured during RST operations from 2013-2019. In the early years of the Project, densities in rearing tanks were lower and parr were stocked at significantly larger sizes than parr stocked in 2015, 2016, and 2018 (Figure 24). Stocking these larger fish translated to a higher percentage of p8s comprising the smolt population.

A goal of the Project is to raise naturally sized fish that live in the river for 2 to 3 years, a similar life history as wild East Machias River smolts. Staying in the river for that amount of time also gives the salmon stocked from the PGH in-river experience that translates to improved survival at sea (USASAC 2020). Our goal is to produce hatchery origin p20s and p32s smolts that are hatchery-reared equivalents to age2 and age3 wild smolt. P8s will always be present, as they are a product of raising fish in the hatchery, but smolts sampled since 2015 had an age distribution more equivalent to what is seen in the wild population with the majority of hatchery-reared smolt being p20s. This positive result is noteworthy as 0+ parr reared at CBNFH and stocked in the Narraguagus and Sheepscot Rivers typically produce p8 dominated populations (USASAC 2016, USASAC 2020). This shift in age distribution from smolt produced from the Project has been attributed to the smaller size of fall parr at stock out the past few years. An example of the age distribution of smolt captured in the East Machias River can be seen in Table 3, which has the data from the 2014 - 2019 trapping seasons.

Table 3. Age distribution for wild and hatchery origin Atlantic salmon smolt emigrating from the East Machias River, Maine (2014-2019). Smolt ages p8, p20, and p32 designate freshwater residency in months for hatchery origin smolt stocked as 0+ parr. Source: Bruchs et al 2019

			Smolt Age					
Drainage	**Year**	**Origin**	**1**	**2**	**3**	**p8**	**p20**	**p32**
East Machias	2014-18 (5yr mean)	H	--	--	--	36.6%	58.3%	5.1%
		W	0.0%	55.2%	44.8%	--	--	--
	2019	H	--	--	--	31.2%	57.2%	11.6%
		W	0.0%	47.1%	52.9%	--	--	--

Estimating the number of smolts generated in the East Machias River gives the number of smolts produced per unit of habitat supplemented. Figure 19 shows the smolt production rate throughout the Project. Producing 1 smolt/unit was a target goal set for the Project by Maine DMR scientists. The red line in Figure 19 indicates this mark of 1 smolt/unit. There was an estimated naturally reared smolt production of 0.22 smolt/unit based on the 2013 smolt data. Since the start of the Project, there has an upward trend in smolt production (despite poor environmental conditions). The estimated average PGH smolt production during the Project is 0.53 smolt/unit. Parr stocking produces greater than 2 times more smolt/unit than unfed fry stocking in 2013. In comparison, during the same period the neighboring Narraguagus River, which has three times more salmon habitat than the East Machias River, had a mean smolt production of 0.22 smolt/unit. In 2019, the smolt production per unit of habitat supplemented in the Narraguagus River was 0.16 smolt/unit. In 2019, parr stocking in the East Machias River produced 5.4 times the number of smolt per unit of habitat supplemented when compared to the Narraguagus. The Narraguagus River is primarily supplemented with unfed fry and variable natural reproduction.

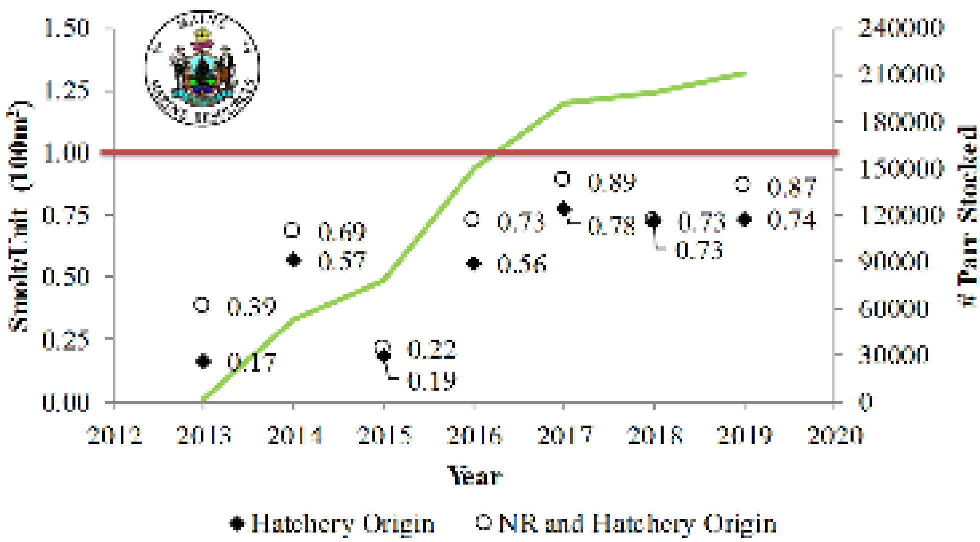

Figure 19. Smolt production rate per unit (100m2) of supplemented rearing habitat, East Machias River, Maine (2013-2019). Source: Bruchs et al 2019

Smolt population assessment allows us to calculate the survival of each cohort of salmon that have been stocked during the Project. Table 4 shows the estimated percent survival to the smolt life stage. The 2011 cohort was a small, pilot stocking of 1,362 fall parr at the Route 9 river crossing in Crawford, Maine, and had percent survival to smolt of 4.3%. With the data we have to date, the mean percent survival to smolt is 1.2%. Mean percent survival since drainage wide stocking began is 0.7%. A significant contributing factor to this lower than ideal survival rate is environmental. Environmental factors (i.e. cool wet high flow years, drought conditions, heavy ice cover in winter, etc.) fluctuate from year to year and impact healthy populations and impaired populations of fish alike. Through a continued restoration stocking effort, all environmental conditions will come into play including ideal, and less ideal, conditions.

Table 4 Cohort survival of 0+ parr stocked from the Peter Gray Hatchery into the East Machias River, Maine (2011-2018). Source: Bruchs et al 2019

Drainage	0+ Parr Cohort	Parr Stocked	Stocking Density	Smolt Estimate at Age p8	p20	p32	Estimated Total Smolts	% Survival to Smolt
East Machias	2011	1364	5/unit	5	46	8	59	4.3%
	2012	53215	45/unit	203	298	7	508	1.0%
	2013	77568	90/unit	546	154	51	751	1.0%
	2014	149815	120/unit	67	634	123	824	0.6%
	2015	192032	120/unit	260	882	71	1213	0.6%
	2016	198174	150/unit	318	573	126	1017	0.5%
	2017	211559	180/unit	399	635	-	1026	0.5%
	2018	119465	150/unit	340	-	-	-	-
							Mean	**0.7%**

Adult Return Assessment (Redd Counting)

The methodology to date for estimating the number of returning adult Atlantic salmon to the East Machias River is redd counting. Redds are the gravel nests created by spawning females. In late October through December, each section of the spawning habitat in the watershed that is accessible is counted either by foot or canoe. All redds are counted and evaluated by either DSF or Maine DMR staff. A female salmon will typically create two redds during the spawning season, and in Maine rivers, adults typically return at a 1:1 sex ratio, it is estimated that one redd is equivalent to one salmon. It is also documented during redd counts if adult salmon are seen in the river. This method is not an absolute count but gives a pretty good indication of the conservative number of spawning adult Atlantic salmon present in the drainage. Further, Maine DMR estimates adult returns extrapolated from redd count data using a return-redd regression [lnAdults = 1.1986 + 0.6098(lnRedds)] based on redd and adult counts from 2005-2019 on the Narraguagus River (USASAC 2020).

Long term data exists for adult returns on the East Machias River through annual redd counts conducted by Maine DMR. The number of redds observed each year in the East Machias River can be seen below in (Figure 20). In 2016, Maine DMR's equation estimated 16 adult returns based on redd counts; the first year two sea-winter salmon originating from the PGH returned to the East Machias River to spawn. This result is identical to the previous five year average of estimated returns from wild parents and/or unfed fry stocking. Based on the number of estimated adult returns (16) in 2016 and the estimated smolt cohort (1,019) of 2014, the smolt-to-adult return (SAR) rate was 1.57%. The (9) estimated adult returns in 2017 provide a SAR of 3.42% from the small smolt cohort (263) observed in 2015. 2018 had 14 estimated adult returns resulting in a SAR of 1.11%. The 60 redds observed in 2019 was the highest number of redds since 1998 in the East Machias River. The resulting smolt to adult return rate was 2.37%. Figure

21 displays the estimated smolt to adult return rates for parr stocking in the East Machias River, naturally reared salmon on the Narraguagus River and smolt stocking on the Penobscot River. The average SAR resulting from the Project (2.117%) is 2 times greater than the previous 5-year average SARs for naturally reared salmon on the Narraguagus River (1.055%) and nearly 20 times greater than return rates of smolt stocked salmon on the Penobscot River (0.107%) (USASAC 2020).

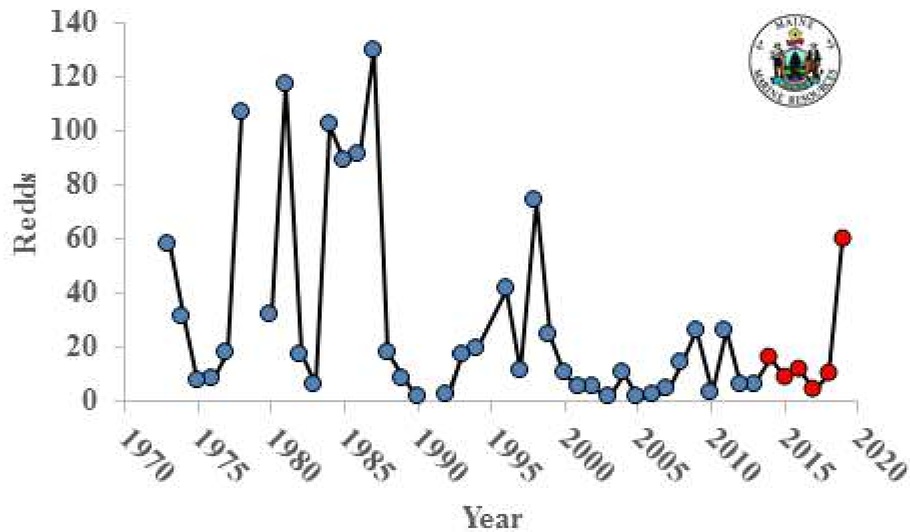

Figure 20. The number of observed Atlantic salmon redds, East Machias River, Maine (1973-2019). Source: Maine DMR - Bruchs

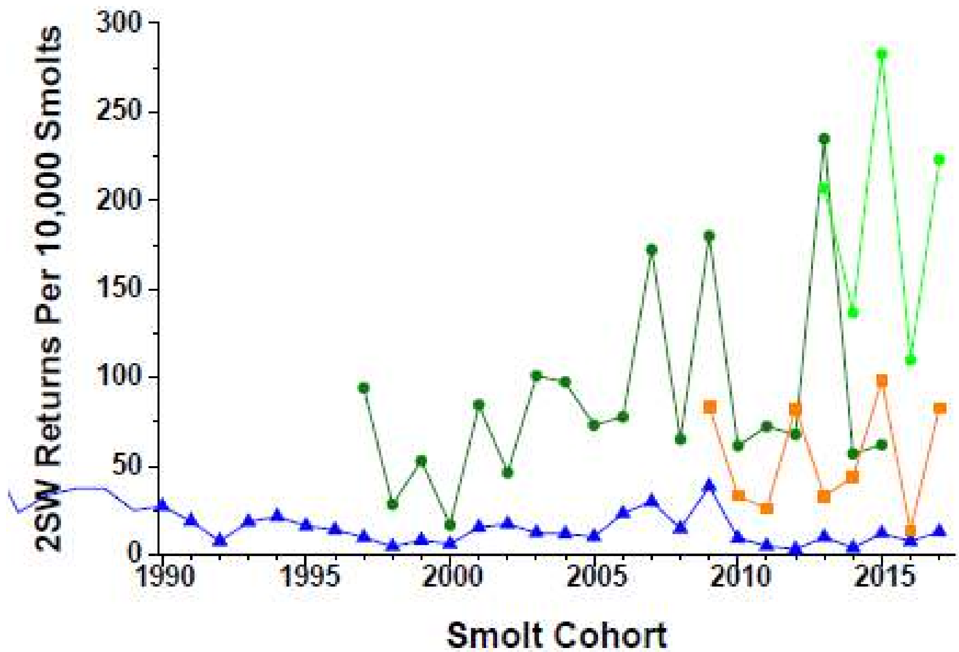

Figure 21. The return rate of 2SW adults to Gulf of Maine area rivers by smolt cohort year (1990 – 2017) of hatchery-reared Atlantic salmon smolts (Penobscot River blue triangles), estimated naturally-reared smolt emigration (Narraguagus River dark green dots), and fall parr (Sheepscot River orange squares), (East Machias River light green dots) the USA. Source: USASAC 2020, Kocik

Hatchery Operations

Through 2019, the Peter Gray Hatchery has successfully stocked an estimated 1,229,646 healthy, 0+ parr into the East Machias River drainage. Survival in the hatchery has fluctuated over the years and is dependent on several factors. Due to the nature of this conservation hatchery, there is a higher risk of mortality due to bacterial exposure (source water is not treated or filtered before distributed to the rearing tanks) and problems related to fluctuations in temperature, especially high temperatures, have an impact on fish health as well. However, the benefits of raising fish in this manner are significant and are shown in the quality of the fish stocked from the hatchery annually (DSF unpublished data). Since the beginning of the Project, many hatchery techniques and protocols have been adjusted, taking what we learn year to year and continually trying to better the quality of salmon being stocked from the PGH. Employing this adaptive management strategy allows the Project to try and maximize its impact on the Maine Atlantic salmon program. Rearing densities have fluctuated throughout the Project, starting low in 2012 when only 81,000 eggs were available and up to the estimated 378,000 received in 2017. The total number of eyed eggs received each year is dependent on the fecundity and eye up rates at CBNFH.

Table 5 outlines the number of eggs received from 2012 through 2020, as well as survival in the PGH from egg to parr stocking. Also shown are the number of unfed fry and fall parr stocked each year. See Figure 22 for a graph showing the rate of mortality from 2012 through 2019.

Table 5 Eggs received and the number of fry and 0+ parr stocked from the Peter Gray Hatchery. East Machias, ME

	EGGS RECEIVED	FRY STOCKED	PARR STOCKED	% SURVIVAL IN THE HATCHERY (EGG – PARR)
2012	81,370	0	53,215	76.92
2013	102,141	18,940	77,568	84.24
2014	186,966	14,696	149,815	88.44
2015	346,201	10,300	192,032	77.02
2016	345,585	10,300	199,644	68.93
2017	378,289	10,087	211,559	69.67
2018	186,856	10,315	119,465	71.70
2019	369,857	10,369	226,348	66.86
2020	186,544	0		
TOTALS	**2,183,809**	**85,007**	**1,229,646**	**Avg: 75.47**

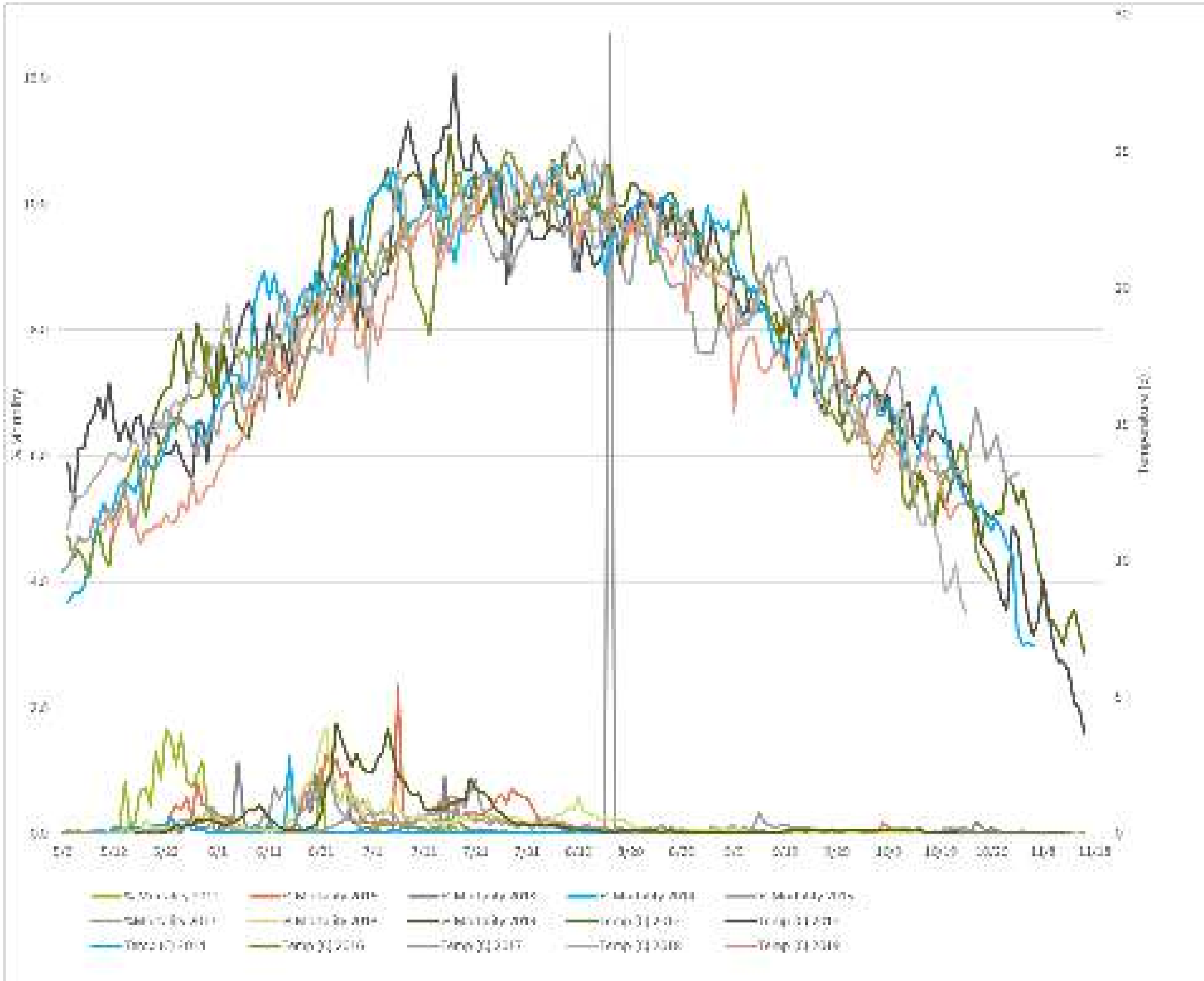

Figure 22. Daily percent mortality and daily morning temperature, Peter Gray Hatchery (2012 – 2019). Source: DSF - Sheller

The high rate of mortality at the beginning of 2012 was due to underfeeding directly after fry emerged from the substrate incubation boxes. The increased mortality in June and July of most years correlates to bacteria that are present in the river water coming through the PGH. Other spikes in mortality typically consist of single event situations such as oxygen and screen issues. These specific issues have been addressed and ways to keep these mortality events from happening in the future were added to the Project's operations manual.

Figure 24 shows the estimated size of Peter Gray parr at stocking. It has taken several years of smolt trapping to key in on a proper size of fish to stock in late fall. If the parr stocked in the fall are too large, they will be more likely to smolt after only one winter in the river (p8). This is not a natural cycle and may lead to decreased survival once at sea (DMR – unpublished data).

Closely monitoring the growth rate of fish in the hatchery enables staff to keep fish more naturally sized, which will, in turn, keep the age distribution of smolt more similar to wild age distribution (Table 3).

The size of the fish is also regulated by warm water temperatures in the summer months and impacts of bacterial infections on feed rates. As temperatures fall in September, the feeding rate increases dramatically and this is when the fish gain most of their size. Increasing the volume and velocity of the water in the rearing tanks can also help keep fish more naturally sized and fit at their time of release. Figure 23 shows the growth rate in the PGH.

The condition of the fish has been very good throughout the Project. There has been very little gill cover and fin erosion. Such erosion can occur due to fin biting, bacterial infection, or an abrasion from rearing tank walls (Latremouille 2003). Though tank densities have not shown a direct impact on fin condition in other species (Brown 2002), flow velocity has. Increased flow velocity may help to reduce aggressive behavior, thus reducing the incidence of fin biting which is the most prevalent cause of degraded fins (Latremouille 2003). Figure 25 below shows a typical 0+ parr at stock-out raised in the Peter Gray Hatchery - note the near-perfect pectoral, dorsal, and caudal fins. Figure 26 shows a fish after about 10 months in the river captured during electrofishing surveys. The adipose clip indicates the fish was stocked from the PGH. The fins of this fish are comparable to a naturally reared fish and show no signs of having been degraded in the past.

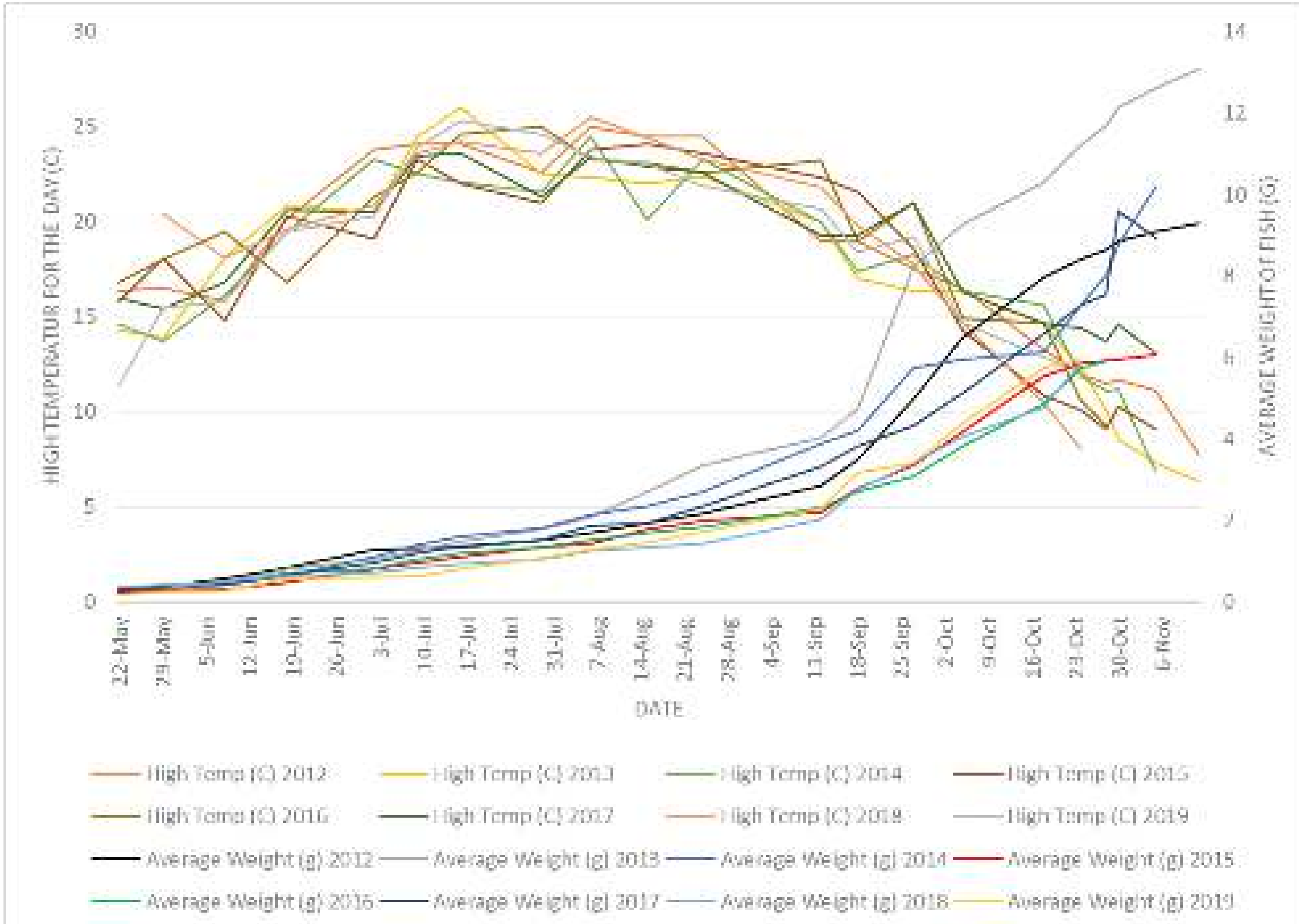

Figure 23. Growth rate and high temperature at sampling (2012 – 2019). Source: DSF - Sheller

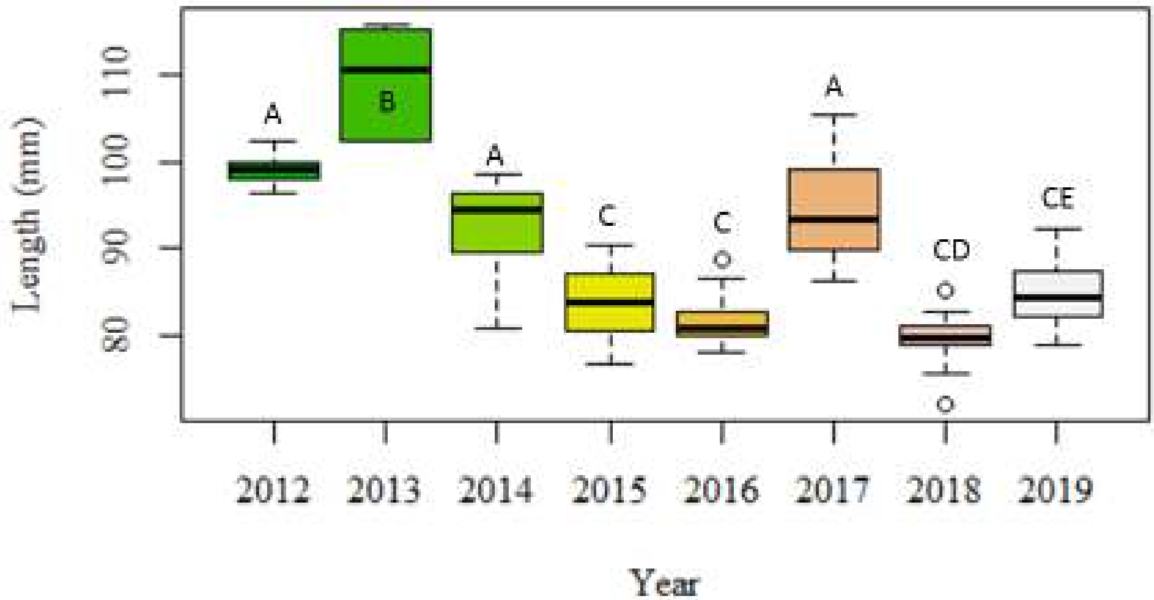

Figure 24. Box plots (max, +1 s.d., median, -1 s.d., and min) of estimated fall parr fork lengths at stocking by year, East Machias River drainage, Maine (2012-2019). Like letters indicate no significant difference (p > .05; Tukey's HSD). Source: Maine DMR/DSF – Bruchs/Sheller

Figure 25. 0+ parr at stock-out reared at the Peter Gray Hatchery, East Machias, ME

Figure 26. Hatchery origin parr (note adipose clip) collected during electrofishing surveys, East Machias River, ME.

Operations in the PGH have been positive overall. Peter Gray made several visits before his passing to help get the hatchery set up, train staff, and ensure the fish were up to his standards. Without his contributions, the PGPP would not be as successful as it is, and has been. This

Project has successfully stocked over 1 million quality salmon parr into a watershed that had previously only been receiving the standard, 100 fry/unit ration, or around 150,000 fry/year. A number that has not moved the population of salmon toward recovery.

An important factor impacting the relative success of salmon stocked as part of this Project is environmental. Throughout the Project, we have had extremes in weather conditions. In 2014 and 2015 we had record snowfall, and a very long, cold winter. The summer of 2016, 2017, and 2018 saw record low water conditions, and anecdotally, the fall of 2014 was very dry. Unfortunately to this point, 2020 has also been abnormally dry. These conditions make for poor rearing conditions in the wild and can be seen in the large parr assessments and smolt assessments. Although, it is important to note that the populations of large parr and smolts in the East Machias River don't seem to be as impacted as other neighboring Downeast rivers. Figure 27 shows stream stage data collected at a USGS staging station on the lower Narraguagus River in Cherryfield, ME. 2016 data indicates not only very low water conditions but persistently low water conditions without much in terms of rainfall (note there are no spikes in stream stage after May.)

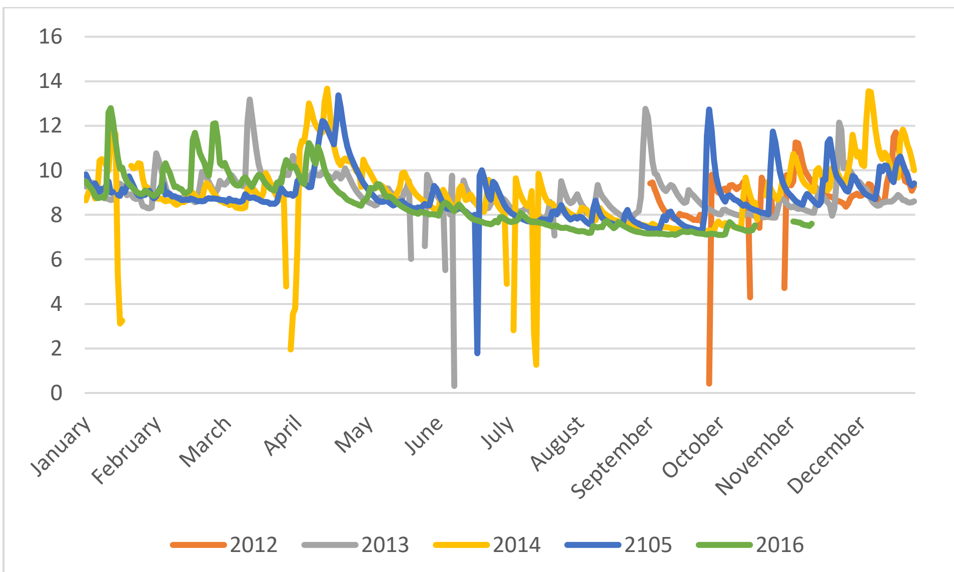

Figure 27. Narraguagus River Stream Stage Data, USGS, 2016.

Adapting to changes throughout this Project has been important, as no two rivers, and no two hatcheries, are alike. Hatchery staff has created an operating manual outlining the operations and procedures for the PGH. The operations manual is an important document for general operations, but will be especially important should this hatchery be replicated elsewhere.

Outreach

This Project has offered significant opportunity to reach out to the local community, getting community members and school groups involved in the Project. One of the largest forms of the outreach of the Project is fin clipping. Since 2012, thousands of students and community members have put in thousands of hours to help mark salmon in the fall before stocking. Fin clipping is a powerful tool because it allows individuals to see, hold, and help an endangered species. On top of that, there is a discussion about the fish, its habitat, and the efforts DSF and its partners are making to help restore this species. Next time those volunteers go fishing, drive over a stream, or enjoy a paddle down a river there's a chance they will remember the salmon.

As an offshoot of the Project, we also participate in the Atlantic Salmon Federation's Fish Friends Program (formerly USFW's Salmon in the Schools Program). During this program, a classroom (and/or school) is given a tank set up with a chiller and 200 salmon eggs in the winter. Recently, ten different classrooms have participated in the Fish Friends program. The schools will raise these eggs until the spring when they will stock them into the river. DSF also gives presentations to the participating classrooms during the winter that discuss the lifecycle of Atlantic salmon and wild vs. hatchery incubation and rearing of salmon. Another interaction between the classrooms and DSF occurs at stocking where we perform macroinvertebrate sampling and identification with the students before stocking the salmon fry into the river.

Adaptive Management

Hatchery Operations

Through the course of this Project, hatchery operations have adapted as needed. These adaptations are reflected in the Operations Manual for the Peter Gray Hatchery. The goals are to keep mortality down when possible, create a healthy environment to raise the fish, as well as creating a rearing environment that will best prepare them for introduction into their natural environment. To this end, hatchery space was increased through a hatchery expansion that began operation in 2019. Initially, this expansion will allow the large numbers of fish to be spread throughout more rearing tanks. Decreasing rearing densities should decrease the demand for oxygen in stressful situations and potentially help with bacterial infections. Down the road, this expansion could be used for a variety of different tasks to aid in the restoration of the Atlantic salmon to include rearing Peter Gray fall parr for other rivers.

Stocking

After the first meetings with the Atlantic Salmon Recovery Framework (the Framework) at the outset of the Project, it was decided that an incremental approach to stocking was to be taken so a close eye could be kept on potential impacts of inter and intraspecific competition (competition for resources within the salmon population being supplemented, as well as competition with other species). These impacts are referred to as "density-dependent" impacts. That is, a high stocking density may negatively impact the survival of salmon or other species they coexist with

– brook trout, black nose dace, creek chub, etc. Condition factor (Figure 13) has not indicated density-dependent impacts within the population of Atlantic salmon, and there have been no noted differences in other species in terms of abundance or species composition. However, in the spring of 2015, smolt numbers were estimated to be extremely low (Figure 17). This prompted the suggestion that stocking densities remain the same as the previous year to remove the variable of density when trying to point to a potential cause of the low smolt estimate. Doing this helped to show that environmental factors (an extremely cold and long winter in 2014/2015) were likely the contributing factor (Bruchs, 2016). Stocking locations and densities are decided each year by DSF and Maine DMR scientists based on the number of Peter Gray parr available, juvenile distributions, environmental conditions, and redd locations.

Habitat and Predation

East Machias River Habitat and how it could be impacting this Project

The state of the habitat within the East Machias watershed is a complicated issue. Though there is little in the way of urbanization or pollution from agricultural runoff, there is a rich history of heavy logging within the watershed, including log driving, and forestry remains the dominant land use practice potentially impacting river habitat currently. It may be, however, that past land-use practices are what has impacted river habitat within the watershed the most. A lack of habitat complexity in the form of large wood, the lack of which can impact physical habitat, stream morphology, and nutrient retention, is a concern (Magilligan 2007). When log driving was the dominant transportation practice, small and large log drive dams were peppered throughout the landscape, many of them remaining long after the last of the log drives. As practices shifted from river driving to trucking logs, road systems across the landscape increased, impacting many of the streams they crossed. Both log drive dams and improperly sized (small) and hung culverts can create unnatural areas of dead water, destroying the natural riparian zone, slowing the water flow through the system, and increasing the water temperature. For a migratory, cold-water species, these have significant implications for survival at various life stages.

Embeddedness and lack of habitat complexity and structure can decrease overwinter survival as well (Cunjak 1996). This was apparent following the winter of 2014/2015 when smolt numbers dropped significantly. The impact of the 2016 - 2018 droughts has affected survival to a degree, but fortunately, large parr densities and smolt numbers have still been relatively good. It could be argued that the loss during the cold winter could have been exacerbated by these habitat-related factors, and could be mitigated in the future through habitat improvements.

Introduced, invasive species such as large and smallmouth bass are ubiquitous in the East Machias River watershed. Chain pickerel have historically been moved from waterbody to waterbody and to be found in every corner of the system (Halliwell 2005). These fish species, in particular, are of concern because of their voracious appetite, and their ability to occupy diverse habitats, especially small and largemouth bass.

What Can We Do

Habitat improvement projects are considered part of the Project moving forward. The efforts of the PGH are significant, and the salmon population on the East Machias River will benefit from being supplemented with fish reared from this facility. However, if this Project is to be a success, and if the smolt production in the river is to be maximized, habitat restoration must be considered to increase smolt production where possible. DSF is working to increase staffing capacity to take on the types of restoration work needed to be done to accomplish this, as well as begin in earnest the work regarding habitat surveying outlined in the Project description (section 7 p.20). DSF is also in the process of outlining a habitat restoration project which would be focused in a sub-watershed within the East Machias River watershed and would include physical habitat restoration in the form of large wood additions, seek ways to address water chemistry impairments (low pH and low calcium levels) and work with landowners to protect sensitive riparian corridors. Included would be increased assessment of the out-migrating smolt population and the juvenile population to identify increases in production related to these efforts.

The DSF, in partnership with ASF and others, has worked to restore access to the Beaverdam Stream sub-watershed. Two sets of culverts at two road crossings, close in proximity to each other, inhibit the upstream movement of many if not all fish at certain flows. In the late summer of 2015, DSF worked to remove the uppermost crossing (Figure 28). A crossing downstream was removed during the summer of 2018. This is important not only to Atlantic salmon but other migratory fish such as river herring, lamprey, eel, as well as resident fish like brook trout. Such habitat restoration projects are complicated by the number of landowners involved, changing ownership as projects move forward, and differing views and opinions people have when it comes to land use. As ownership changes or new partners are brought into projects or fundraising campaigns, there is an opportunity to connect at different levels with landowners, and opportunities present themselves where they may not have been previously.

As part of any restoration project, protecting the land is important to ensure that the hard work of the project is not undone. Protecting the land through purchasing outright, or through conservation easements, makes accessibility easier, thus making restoration work much easier by taking out the complication of multiple landowners, or landowners who may not choose to allow access for projects to take place.

In increasing the habitat diversity and complexity within the river system, it may be that the impact of invasive species such as large and smallmouth bass have on juvenile salmon would be decreased. These restoration projects may offer more shelter for fish to hide and evade predators and could create more types of habitat for different species of fish to occupy, increasing habitat segregation.

As mentioned in the previous section, increases in habitat diversity and structural complexity can aide in overwinter survival (Cunjak 2005). These complex habitats lead to stream stability in the cold winter months and can decrease the degree of embeddedness, offering more available shelter for juvenile fish riding out the winter in the stream.

Figure 28. Beaverdam Stream culvert removal before and immediately after culvert removal and tree planting, 2015, Wesley, ME.

Moving Forward:

Data collected to this point are encouraging and, from the viewpoint of DSF and our partners, suggest that as this Project continues the populations of smolt and juvenile parr will continue an upward trend, with the number of returning adults to follow suit. Deepening our assessment at different life stages would also be of benefit to the Project. We are unsure where mortality is happening in the river and whether this mortality is a result of predation, poor overwinter survival, poor habitat conditions, etc.

Stocking intensity is something to consider moving forward as well. It may be that stocking at a lower rate, either throughout the watershed or in certain areas of the drainage, could produce the same number of smolt or more. It may also be that increasing the stocking density could produce more smolt. It is hard to say at this point what the best option is, mainly because the atypical weather patterns we have seen since the start of the Project have not been optimal for survival at certain life stages; the long, cold winter of 2014/2015 showed low overwinter survival, and warm, unusually dry summers from 2016 – 2018 have very likely impacted survival throughout the summer and into the fall. DSF believes that stocking densities should, at the very least, remain the same, and likely be increased in the future. This would ensure that many quality fish are in the river as to not miss an optimal natural rearing season. Healthy populations of Atlantic salmon deposit as many eggs as possible, whether growing conditions are projected to be optimal or not. Some years growing conditions are great and a lot of young survive, other years there could be significant losses due to poor environmental conditions; it is a numbers game. Since Peter Gray fall parr stocking has shown to outperform all other stocking strategies in B and C width classes of the East Machias River, Peter Gray fall parr should be reared and stocked for all other Downeast Rivers. This is a path that could lead to the recovery of the species in the Downeast SHRU.

Acknowledgment:

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Glossary:

- Atlantic Salmon Framework: The organizational structure outlined in the *2011 Atlantic Framework* to manage the recovery of Atlantic salmon in Maine, including the Conservation Hatchery Action Team
- ASF: Atlantic Salmon Federation
- BSFH: Bureau of Sea-Run Fisheries and Habitat of the ME DMR
- CBNFH: Craig Brook National Fish Hatchery
- DMR: Maine Department of Marine Resources
- DSF: Downeast Salmon Federation
- Downeast SHRU: the Downeast Coastal Salmon Habitat Recovery Unit, one of three SHRUs in the GOM DPS that includes the East Machias and the other small coastal rivers north of the Penobscot
- ESA: Endangered Species Act of 1973
- East Machias River: as used herein includes all tributaries

- GOM DPS: Gulf of Maine Distinct Population Segment, the remnant Atlantic salmon population listed under the EPS in 74 FR 29344 (generally from the Androscoggin River northward along the coast to the Dennys River and includes conservation hatchery populations therein)
- NASF: North Atlantic Salmon Fund
- NOAA: National Marine Fisheries Service of the National Oceanic and Atmospheric Administration
- SEI: Sustainable Ecosystems Institute
- USFWS: United States Fish and Wildlife Service
- Alevin: The period after hatching of the egg when the salmon is entirely dependent upon the yolk sac for nutrition. In the natural environment, alevin are buried within the substrate of the stream bottom.
- Anadromous: An anadromous fish, born in freshwater, spends most of its life in the sea and returns to freshwater to spawn. Salmon, smelt, shad, striped bass, and sturgeon are common examples.
- Black salmon: A synonymous term for Kelt. Occasionally referred to as a slink, racer, or snake.
- Bright salmon: A fresh-run salmon that has entered its natal stream. Synonymous with maiden or virgin salmon.
- Catadromous: Opposite from anadromous, catadromous fish live in freshwater and enter saltwater to spawn. American eels are a good example of a catadromous fish.
- Diadromous: A general term for fish in the anadromous and catadromous categories.
- Electrofishing: Electrofishing is the technique and science of utilizing electrical current to momentarily stun fish or force them to involuntarily swim towards an electrical field for collection.
- Eyed egg: The stage from the appearance of faint eyes until hatching (April).
- Fed Fry: Atlantic salmon of hatchery origin that have fully absorbed the yolk and have begun feeding upon artificial foods.
- Fingerling: An obsolete, non-specific term for parr that is often found in the literature before 1960.
- Fry: Salmon become fry when they have absorbed their yolk sac and emerge from the gravel nest they have been developing in since they were fertilized as an egg. Fry emerge in the spring once river temperatures reach about 50F (10C) and begin feeding on invertebrates as they drift by in the stream current. (Note: this date is not appropriate for all rivers because of the wide variation in the growth and development of salmon in North America).
- Green Egg: The stage from spawning (November) until faint eyes appear in the eggs. The eggs at this stage are very fragile.
- Grilse: A 1SW salmon that has matured (or is about to mature) after one winter at sea. This term is applied to salmon in their natal river, not while at sea.
- Habitat Unit: $100m^2$

- Iteroparous: Unlike semelparous, iteroparous fish can recondition itself and return to sea to repeat the migration and spawning patterns multiple times.
- Kelt: A spawned out (spent) adult salmon (male or female) that is found in the freshwater portions of rivers, normally between November of the year of spawning until the salmon returns to the sea the following year.
- Long-absence RS: Alternate year repeat spawners that have spent one year (or more) at sea before spawning again. Long-absence repeat spawners are often referred to as LARS.
- Maiden salmon: Any virgin salmon (1SW, 2SW, 3SW) found in freshwater on its first spawning migration.
- Mended-kelt: Infrequently used term for a post-kelt that has regained the weight lost during the first spawning cycle and has resumed feeding and growth at sea.
- Milt: The male gametes (sperm).
- MSW salmon: Multi sea-winter (MSW) salmon have matured (or are about to mature) after two or more winters at sea. (Note: also see repeat spawner)
- Natal Streams: The stream a salmon hatched in.
- Otoliths: Small bones of the inner of fish that have "growth rings" on them that can be used in aging.
- Parr: The period which follows the fry stage; subdivisions have been adopted based upon the age and size of the young salmon.
- Parr marks 0+ Parr: The period from July 1 to December 31 of the year of hatching. 0+ Parr are less than one year old.
  1 Parr: The period from January 1 to June 30 one year after hatching.
  1+ Parr: The period from July 1 to December 31 one year after hatching.
  2 Parr: The period from January 1 to June 30 two years after hatching.
  2+ Parr: The period from July 1 to December 31 two years after hatching.
  3 Parr: The period from January 1 to June 30 three years after hatching.
  3+ Parr: The period from July 1 to December 31 three years after hatching.
- Precocious Parr: An Atlantic salmon that becomes sexually mature in freshwater without ever going to sea. Nearly all precocious parr are males, although a few females have been documented on rare occasions.
- Post-kelt: A spent salmon that has left the freshwater environment, until December 31 one year after spawning.
- Post-smolt: The life stage during the first year of life at sea, from July 1 to December 31 of the year the salmon left the river as a smolt.
- Pre-smolt: Parr that have commenced the smoltification process in preparation for migration to the sea. Another commonly used term for this stage is silvery parr.
- Redd: A gravel nest made by a spawning female. The female uses her tail to dig a pit in the stream bed where she will lay her eggs which are immediately fertilized by a male salmon. The female then covers the eggs with gravel, protecting them for the winter until they emerge in the spring as fry.
- Repeat spawner (RS): An adult salmon when found in freshwater on its second (or greater) spawning migration. Alternatively termed a previous spawner.

- River Herring: A general term used to describe the anadromous sea-run alewives and blueback herring that migrate from the ocean into the river systems April-June. These herring are the "fish that feeds all", acting as a vital food source and nutrient source at every part of its life stage. Other fish, marine mammals, and birds are just three examples of the animals that consume the river herring.
- Rotary Screw Trap (RSTs): The type of trap commonly used to evaluate the health, age distribution, and the number of smolts out-migrating from the rivers in the spring (April – June). The traps consist of a large cone that is turned by the river moving down through it. The fish that swim into the cone end up in a live well that sits behind the cone. The entire trap is held afloat by large aluminum pontoons on either side of the cone.
- Sac-Fry: Synonymous word for alevin; more commonly used in fish culture, where the young salmon can be observed in a hatching tray or trough.
- Salmon: Salmo salar ('the leaper') Atlantic salmon are an anadromous species. Many saltwater sport fishermen consider these fish to be "the king of fish" because of their great leaping ability and determined fight when hooked.
- SAR: Smolt-to-adult returns.
- 1SW salmon: A one sea-winter (SW) salmon has passed one December 31st since becoming a smolt.
- 2SW salmon: A two sea-winter (SW) salmon has passed two December 31sts since becoming a smolt.
- 3SW salmon: A three sea-winter (SW) salmon has passed three December 31sts since becoming a smolt.
- Semelparous: Fish that die after spawning one time (Pacific salmon species).
- Short-absence RS: Consecutive year repeat spawners that have spent less than one year at sea before spawning again. Short-absence repeat spawners are often referred to as SARS.
- Smolt: A silvery-colored, juvenile Atlantic salmon during its active migration to sea in the spring (late April – mid-June). Smolts (unlike parr) can survive the natural transition from fresh to saltwater.
- 1+ Smolt: The birth date of Atlantic salmon is arbitrarily set on April 1. Since smolts migrate to sea between April and June, a 1+ smolt migrates 1+ years after hatching. In hatchery terms this is referred to as a P8, meaning after the parr was stocked in its first year of life it only spent 8 months (one fall and winter) in the river before outmigration as a smolt.
- 2+ Smolt: The period from January 1 to June 30 of the year of migration. The migration year is two years after hatching. In hatchery terms this is referred to as a P20, meaning the young salmon spent 20 months in the river after being stocked before outmigration.
- 3+ Smolt: The period from January 1 to June 30 of the year of migration. The migration year is three years after hatching. In hatchery terms this is referred to as a P32, meaning the young salmon spent 32 months in the river after being stocked before outmigration.
- Smoltification: The parr-to-smolt transformation (smoltification) results in river adaptations giving way to seawater readiness. This is where physiological changes occur in the fish to allow it to survive in saltwater environments.

- Underyearling: An obsolete, non-specific term for parr (or fingerling), often found in the literature before 1960.
- Unfed Fry: Atlantic salmon of hatchery origin that have fully absorbed the yolk sac and have not been fed artificial foods.
- YOY: Young of the year salmon. Juvenile salmon found in the rivers the first summer/fall of their lives.

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