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1 Executive Summary

1.1 Abstract

Total returns to USA rivers in 2021 was 680 salmon; this is the sum of documented returns to traps and returns estimated by redd counts. Returns to the USA ranks 28th out of the 31-year time series (1991-2021) and 47th out of the full 55-year time series (1967-2021). Most returns (676; 99.4%) were to the Gulf of Maine Distinct Population Segment (GoM DPS), which includes the Penobscot River, Kennebec River, Sheepscot River and Eastern Maine coastal rivers with only 4 returns documented outside of the GoM DPS. Documented returns to traps totaled 591 and returns estimated by redd counts were 85 adult salmon. Overall, 34.6% of the adult returns to the USA were 1SW salmon, 63.8% were 2SW salmon and 1.7% were 3SW or repeat spawners. Most (77.6%) returns were of hatchery smolt origin and the balance (23.4%) originated from either natural reproduction, hatchery fry, or planted eggs. A total of approximately 4,404,500 juvenile salmon (eggs, hatchery fry, parr, and 1 smolt), and 2,212 adults were stocked into U.S. rivers. Atlantic salmon at various origins and life-stages had marks applied during the year, with a total of 116,711 marks administered in 2021. Eggs for USA hatchery programs were taken from a total of 1,370 females consisting of 77 sea-run females and 1,293 captive/domestic and domestic females. Total egg take (5,266,000) was lower than the previous year of 6,404,000 eggs. Production of farmed salmon in Maine was not available, due to regulations concerning privacy.

1.2 Adult Returns to USA Rivers

Total returns to USA rivers was 680 (Table 1.2.1), which is a significant decline from 2020 (1,715, Table 1.2.2). Returns are reported for three distinct population segments (Figure 1.2.1): Long Island Sound (LIS, 4 total returns), Central New England (CNE, 0 total returns), and Gulf of Maine (GOM, 676 total returns). The ratio of sea ages for fish sampled at traps and weirs was used to prorate the number of spawners by sea age for the adults estimated via the redd counts conducted in 2021. The majority of the 680 adult returns to USA were 2SW (434 = 63.8%), with 1SW (235 = 34.6%), 3SW (7 = 1.0%) and repeat spawners (4 = 0.6%) making up the remainder of the total (Table 1.2.2). The percentage of 2SW returns in 2021 (63.8%) was less than the previous 10-year average of 75.6%. Most (76.6%) returns were hatchery smolt origin, with the remainder (23.4%) natural origin. Age and origin of returns in 2021 were consistent with historical numbers with 2SW salmon making up the largest proportion for both origins (Figure 1.2.2).

In the U.S., returns were well below conservation spawner requirements (i.e. conservation limit; CL). Returns to monitored rivers represented only 3.1% of the USA CL in these 14 populations. While returns to unmonitored rivers are unlikely, the observed total returns would only be 2.3% of the overall CL. In monitored populations, the Kennebec (Sandy Tributary) ranked the highest at 37.3% of CL followed by the Pleasant (19.4%) and East Machias (13.3%) and no fish were observed in 5 rivers (Table 1.2.3. Because of changing management practices, the US is working to revise tracking to best capture these changes moving forward.

Marine return rate estimates are calculated based on known smolt migrants (estimated populations of naturally reared, or hatchery stocked) and corresponding adult returns. The Penobscot River hatchery origin smolts until 2020 used total smolts stocked and subsequent adult returns by sea age to generate a smolt-to-adult return rate (SAR). Beginning in 2021, the time series was revised by using the methods of Stevens et al. (2019) to decouple losses of smolts in the river and the estuary to provide an estimate of postsmolts entering the Gulf of Maine. This method accounted for stocking location and subsequent natural mortality in the riverine and estuarine environments and flow-specific mortality related to dam passage. This postsmolt estimate was then compared to subsequent adult returns to calculate a postsmolt to adult return rate (PSAR). The US Atlantic Salmon Assessment Committee (USASAC) discussed the approach and agreed it would provide a better estimate of marine return rate by eliminating the impact of stocking location, dams and other river/estuary impacts.

Two sea-winter PSAR rates for Penobscot River smolts from the 2019 equaled 0.062% (PSAR) which was a decrease from the 2018 estimate (0.216%). The 2019 Penobscot River estimate was well below the East Machias (1.31%) and Narraguagus (0.39%) estimates, which is consistent for much of the time series. With exception of the Sheepscot River all return rates for 2021 were observed beneath the five and ten year means (Figure 1.2.3 and Table 1.2.4).

1.3 Description of Fisheries and By-catch in USA Waters

Atlantic salmon (*Salmo salar*), are not subject to a plan review by the National Marine Fisheries Service because the current fishery management plan prohibits their possession as well as any directed fishery or incidental (bycatch) for Atlantic salmon in federal waters. Similar prohibitions exist in state waters. Atlantic salmon found in USA waters of the Northeast Shelf could be from 4 primary sources: 1) Gulf of Maine Distinct Population Segment (endangered); 2) Long Island Sound or Central New England Distinct Population Segments (non-listed); 3) trans-boundary Canadian populations (many southern Canadian stocks are classified as Endangered by Canada); or 4) escaped fish from USA or Canada aquaculture facilities. Bycatch and discard of Atlantic salmon is monitored annually by the Northeast Fisheries Science Center using the Standardized Bycatch Reporting Methodology (Wigley and Tholke 2020). While bycatch is uncommon, we summarize observed events from 1989 through September 2020 using reports and data queries. Prior to 1993, observers recorded Atlantic salmon as an aggregate weight per haul. Therefore, no individual counts are available for these years, however 8 observed interactions occurred. After 1993, observers recorded Atlantic salmon encounters on an individual basis. Between 1993 and 2020, 7 observed interactions have occurred, with a total count of 7 individuals. In total, Atlantic salmon bycatch has been observed across 7 statistical areas in the Gulf of Maine region, primarily in benthic fisheries. Four interactions were observed in bottom otter trawl gear and 11 interactions were observed in sink gillnet gear (Figure 1.3.1). Bycatch of Atlantic salmon is a rare event as interactions have been observed in only 7 years of a 30-year time series and no Atlantic salmon have been observed since August 2013.

1.4 Stock Enhancement Programs

During 2021, approximately 4,404,500, juvenile salmon were released into USA rivers (Table 1.4.1). Of these, 1,401,850 were hatchery fry; 1,882,257 were planted eyed eggs; 433,061 were parr; and 720,445 were smolts. Most of these restoration stockings were within the GoM DPS with the Connecticut (LIS), Pawcatuck (CNE) and Saco (CNE) rivers receiving limited allocations of fry (Table 1.4.1). Besides juveniles, 2,212 adult salmon were released into USA rivers, all of which were stocked into the GoM DPS (Table 1.4.2). Of these adults stocked only one was a pre-spawn release, therefore, were not expected to contribute to the spawning population in 2021.

1.5 Tagging and Marking Programs

Tagging and marking programs facilitated research and assessment programs including: identifying the life stage and location of stocking, evaluating juvenile growth and survival, instream adult and juvenile movement, and estuarine smolt movement. A total of 114,809 salmon released into USA waters were marked or tagged. Tags and marks for parr, smolts, and adults included: PIT, radio, clips and punches. All tagging and marking occurred within the GoM (Table 1.5.1).

1.6 Farm Production

Reporting an annual estimate of production of farmed Atlantic salmon has been discontinued because of confidentiality statutes in Maine Department of Marine Resources (MDMR) regulations since 2010 (Table 1.6.1).

In 2021, four aquaculture origin fish were reported captured in Maine rivers. MDMR maintains a protocol; "Maine Department of Marine Resources Suspected Aquaculture Origin Atlantic Salmon Identification and Notification Protocol" (MDMR, 2016) that guides procedures and reporting for disposition of captured aquaculture Atlantic salmon. There were no reportable escape events from the commercial salmon farming industry in Maine.

Atlantic salmon farming operations in the northeastern U.S. have typically been concentrated in marine net pens among the many islands in large bays characteristic of the Maine coast. There is recent interest in initiating land-based Atlantic salmon aquaculture in Maine. Two proposals are moving forward for building land based Recirculating Aquaculture Systems (RAS) within the boundaries of GoM DPS; one at the former site of the Verso Paper Mill along the shores of the Penobscot River, and the other facility proposed for the Belfast area at the former Belfast Water Works along the shores of the Little River. Both proposals are to build a RAS facility to produce Atlantic salmon for commercial sale. The facilities are planning to use Atlantic salmon that do not originate from North America for production. A potential source of Atlantic salmon eggs for importation annually would be Stofnfiskur; a company based in Iceland and is a well-known for exporting clean disease-free ova supporting salmon aquaculture throughout the world. A thorough review of the information provided along with discussions concerning designs of the facility for wastewater discharge permits are ongoing with the applicants. A quarantine facility will also be required for receiving imported eyed eggs from out of the State of Maine. The facility owned by Whole Oceans in Brewer, Maine was issued a discharge permit by the State of Maine Department Environmental Protection with further federal review of a facility Containment plan prior to building the facility and starting production.

1.7 Smolt Emigration

NOAA's National Marine Fisheries Service (NOAA) and the MDMR have conducted seasonal field activities assessing Atlantic salmon smolt populations using Rotary Screw Traps (RSTs) in selected Maine rivers since 1996. Monitoring has focused on estimating abundance of migrating populations via stratified mark-recapture methods (Figure 1.7.1, Table 1.7.1), as well as using the RST platform for tagging and sample collection. Currently three rivers are monitored: Narraguagus, Sandy and East Machias Rivers.

MDMR monitored smolt migration using RSTs at two sites (river km 11.16 and 47.69) on the Narraguagus River, which continued smolt assessments for a 25th year, although monitoring was suspended due to COVID in 2020. These sites were divided between the upper and lower drainages to determine the differential production between regions. Data is presented only for the lower site which encompasses the majority of the juvenile rearing habitat and is used for the historical time series (Table 1.7.1). A total of 537 smolts were captured at the lower site (533 naturally reared, 4 hatchery origin). The estimate of naturally-reared smolts exiting the system was 1,426 (95% 1,334 to 1,518).

MDMR scientists operated two RSTs at one site on the Sandy River (river km 27.48) which marked the 1st year of assessment (Table 1.7.1). A total of 1,574 naturally reared smolts were captured. The estimate of naturally-reared smolt migration was 13,229 (95% 11,935 to 14,523).

MDMR scientists, in partnership with the Downeast Salmon Federation (DSF), operated two RSTs at one site (river km 4.60) on the East Machias River for the 8th year of assessment. Scientists captured 168 smolts (14 naturally-reared; 154 parr stocked). The estimate of smolts from parr stocking was 792 (95% 636 to 948; Figure and Table 1.7.1).

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USASAC (U.S. Atlantic Salmon Assessment Committee). 2020. Annual report of the U.S. Atlantic Salmon Assessment Committee 32: 2019 activities. Portland, Maine.

Wigley SE, Tholke C. 2020. 2020 discard estimation, precision, and sample size analyses for 14 federally managed species groups in the waters off the Northeastern United States. NOAA Technical Memorandum NMFS-NE-261; 175 p.

Table 1.2.1 Estimated Atlantic salmon returns to USA by geographic area, 2021. Natural reared (Natural) includes fish originating from natural spawning, stocked and hatchery fry or eggs. Returns are composed of documented returns at traps and returns estimated by redd counts.

Area	1SW		2SW		3SW		Repeat Spawners		TOTAL
	Hatchery	Natural	Hatchery	Natural	Hatchery	Natural	Hatchery	Natural	
LIS	0	0	0	4	0	0	0	0	4
CNE	0	0	0	0	0	0	0	0	0
GOM	208	27	307	123	5	2	1	3	676
Total	208	27	307	127	5	2	1	3	680

Table 1.2.2 Estimated Atlantic salmon returns to the USA, 1967-2021. "Natural" includes fish originating from natural spawning and hatchery fry or eggs. Starting in 2003, returns estimated by redd counts are included.

Year	1SW	2SW	3SW	Repeat	Total	Hatchery	Natural
1967	75	574	39	93	781	114	667
1968	18	498	12	56	584	314	270
1969	32	430	16	34	512	108	404
1970	9	539	15	17	580	162	418
1971	31	407	11	5	454	177	277
1972	24	946	38	17	1,025	495	530
1973	18	623	8	13	662	422	240
1974	52	791	35	25	903	639	264
1975	77	1,250	14	30	1,371	1,126	245
1976	172	836	6	16	1,030	933	97
1977	63	1,027	7	33	1,130	921	209
1978	145	2,269	17	33	2,464	2,082	382
1979	225	972	6	21	1,224	1,039	185
1980	707	3,437	11	57	4,212	3,870	342
1981	789	3,738	43	84	4,654	4,428	226
1982	294	4,388	19	42	4,743	4,489	254
1983	239	1,255	18	14	1,526	1,270	256
1984	387	1,969	21	52	2,429	1,988	441
1985	302	3,913	13	21	4,249	3,594	655
1986	582	4,688	28	13	5,311	4,597	714
1987	807	2,191	96	132	3,226	2,896	330
1988	755	2,386	10	67	3,218	3,015	203
1989	992	2,461	11	43	3,507	3,157	350
1990	575	3,744	18	38	4,375	3,785	590
1991	255	2,289	5	62	2,611	1,602	1,009
1992	1,056	2,255	6	20	3,337	2,678	659
1993	405	1,953	11	37	2,406	1,971	435
1994	342	1,266	2	25	1,635	1,228	407
1995	168	1,582	7	23	1,780	1,484	296
1996	574	2,168	13	43	2,798	2,092	706
1997	278	1,492	8	36	1,814	1,296	518
1998	340	1,477	3	42	1,862	1,146	716
1999	402	1,136	3	26	1,567	959	608
2000	292	535	0	20	847	562	285
2001	269	804	7	4	1,084	833	251
2002	437	505	2	23	967	832	135
2003	233	1,185	3	6	1,427	1,238	189
2004	319	1,266	21	24	1,630	1,395	235
2005	317	945	0	10	1,272	1,019	253
2006	442	1,007	2	5	1,456	1,167	289
2007	299	958	3	1	1,261	940	321

			Sea Age			Origin	
Year	1SW	2SW	3SW	Repeat	Total	Hatchery	Natural
2008	812	1,758	12	23	2,605	2,191	414
2009	243	2,065	16	16	2,340	2,017	323
2010	552	1,081	2	16	1,651	1,468	183
2011	1,084	3,053	26	15	4,178	3,560	618
2012	26	879	31	5	941	731	210
2013	78	525	3	5	611	413	198
2014	110	334	3	3	450	304	146
2015	150	761	9	1	921	739	182
2016	232	389	2	3	626	448	178
2017	363	663	13	2	1,041	806	235
2018	324	542	2	1	869	764	105
2019	398	1,131	3	3	1,535	1,162	373
2020	234	1,452	22	7	1,715	1,324	391
2021	235	434	7	4	680	521	159

Table 1.2.3. 2021 2SW returns against 2SW Conservation Limits for select U.S. rivers. Note: Monitoring of the Pawcatuck was ceased in 2017; St. Croix was also removed as this was added to US but reported by Canada.

DPS	SHRU	Population	Habitat (metric units)	Conservation Limit	Count Return	Percentage of Requirement
GOM	DEC	Dennys	2,415	161	-	0.0%
GOM	DEC	East Machias	2,145	143	19	13.3%
GOM	DEC	Machias	6,685	446	16	3.6%
GOM	DEC	Pleasant	1,085	72	14	19.4%
GOM	DEC	Narraguagus	6,015	401	25	6.2%
GOM	DEC	Union	8,360	557	-	0.0%
GOM	PEN	Penobscot	102,575	6,838	561	8.2%
GOM	PEN	Ducktrap	585	39	-	0.0%
GOM	MMB	Sheepscot River	2,845	190	11	5.8%
GOM	MMB	Kennebec (Sandy tr.)	1,005	67	25	37.3%
GOM	MMB	Androscoggin	3,175	212	5	2.4%
CNE	-	Saco	12,540	836	-	0.0%
CNE	-	Merrimack	38,980	2,599	-	0.0%
LIS	-	Connecticut	145,900	9,727	4	0.0%
Monitored Rivers			334,310	22,288	680	3.1%
All US Rivers			437,835	29,189	680	2.3%

Table 1.2.4. Time series of 1SW and 2SW smolt to adult return rates (SAR) and postsmolt to adult return rates (PSAR) for monitored USA rivers. Estimated return rates for monitored rivers are identified as being derived from hatchery origin (Hat.) or naturally reared origin (NR). Smolt estimates were unavailable for smolt years 2016 and 2017 for the Narraguagus River and therefore no corresponding SAR estimates are available. The five and ten-year average are included.

River	Penobscot		Narraguagus		Sheepscot		East Machias	
Origin	Hat. PSAR		NR		NR		NR	
Smolt Year	1SW	2SW	1SW	2SW	1SW	2SW	1SW	2SW
1969								
1970	0.11%	1.56%						
1971	0.03%	0.82%						
1972	0.02%	1.23%						
1973	0.05%	1.58%						
1974	0.06%	0.72%						
1975	0.11%	0.84%						
1976	0.04%	1.30%						
1977	0.08%	0.39%						
1978	0.19%	2.34%						
1979	0.58%	2.13%						
1980	0.29%	1.52%						
1981	0.17%	0.60%						
1982	0.16%	1.11%						
1983	0.12%	1.26%						
1984	0.10%	1.34%						
1985	0.23%	0.61%						
1986	0.32%	0.88%						
1987	0.30%	0.85%						
1988	0.39%	1.14%						
1989	0.21%	0.52%						
1990	0.10%	0.69%						
1991	0.41%	0.55%						
1992	0.16%	0.29%						
1993	0.18%	0.70%						
1994	0.10%	0.75%						
1995	0.11%	0.22%						
1996	0.10%	0.33%						
1997	0.10%	0.25%	0.11%	0.94%				
1998	0.12%	0.15%	0.25%	0.28%				
1999	0.10%	0.29%	0.31%	0.53%				

River	Penobscot		Narraguagus		Sheepscot		East Machias	
Origin	Hat. PSAR		NR		NR		NR	
Smolt Year	1SW	2SW	1SW	2SW	1SW	2SW	1SW	2SW
2000	0.10%	0.18%	0.28%	0.17%				
2001	0.23%	0.53%	0.16%	0.85%				
2002	0.13%	0.61%	0.00%	0.46%				
2003	0.17%	0.41%	0.08%	1.01%				
2004	0.17%	0.41%	0.08%	0.98%				
2005	0.17%	0.28%	0.24%	0.73%				
2006	0.10%	0.60%	0.09%	0.78%				
2007	0.30%	0.71%	0.35%	1.72%				
2008	0.08%	0.36%	0.44%	0.65%				
2009	0.17%	0.90%	0.26%	1.80%	0.28%	0.84%		
2010	0.30%	0.23%	0.95%	0.62%	0.10%	0.33%		
2011	0.00%	0.12%	0.00%	0.72%	0.10%	0.26%		
2012	0.03%	0.10%	0.00%	0.68%	0.08%	0.83%		
2013	0.03%	0.20%	0.00%	2.35%	0.17%	0.33%	0.75%	2.07%
2014	0.02%	0.05%	0.00%	0.57%	0.13%	0.44%	0.32%	1.37%
2015	0.07%	0.15%	0.00%	0.62%	0.13%	0.98%	1.21%	2.83%
2016	0.06%	0.09%	na	na	0.14%	0.14%	0.18%	1.10%
2017	0.06%	0.16%	na	na	0.08%	0.83%	0.14%	2.23%
2018	0.06%	0.22%	1.59%	2.65%	0.33%	0.72%	0.80%	2.01%
2019	0.04%	0.06%	0.26%	0.39%	0.21%	0.64%	0.33%	1.31%
2020	0.04%							
5-Year Mean	0.06%	0.13%	0.62%	1.63%	0.18%	0.67%	0.53%	2.04%
10-Year Mean	0.07%	0.14%	0.35%	1.17%	0.15%	0.54%	0.53%	1.93%

Table 1.3.1 Overview of Northeast Fisheries Observer Program and At-Sea Monitoring Program documentation of Atlantic salmon bycatch. A minimum of one fish is represented by each interaction count. Total weights for 1990 and 1992 may represent 1 or more fish, whereas post-1992 weights represent individual fish.

Year	Month	Area	Interaction Count	Total Weight (kg)
1990	June	512	1	0.5
1992	June	537	1	1.4
1992	November	537	6	10.4
2004	March	522	1	0.9
2005	April	522	1	1.8
2005	May	525	1	1.3
2009	March	514	1	4.1
2011	June	513	1	5.0
2013	April	515	1	4.1
2013	August	513	1	3.2
		Totals	15	32.7

Table 1.4.1. Number of juvenile Atlantic salmon by life-stage stocked in USA, 2021 by area/DPS (Central New England (CNE); Gulf of Maine (GoM); Long Island Sound (LIS)) and drainage. Parr and smolt life stages broken out into age categories.

Area	Drainage	0 Parr	1 Parr	1 Smolt	2 Smolt	Eyed Egg	Fry	Total
LIS	Connecticut	-	-	-	-	-	34,000	34,000
LIS	Pawcatuck	-	-	-	-	-	3,000	3,000
CNE	Saco	-	-	-	-	9,000	-	9,000
GOM	Androscoggin	-	-	-	-	-	1,000	1,000
GOM	Dennys	-	-	-	-	43,000	313,000	356,000
GOM	East Machias	171,600	-	-	-	-	19,000	190,600
GOM	Kennebec	-	-	100,000	-	759,000	2,000	861,000
GOM	Machias	17,200	-	-	-	40,000	290,000	347,200
GOM	Narraguagus	112,800	-	-	-	283,000	280,000	675,800
GOM	Penobscot	112,200	-	620,400	-	306,000	242,000	1,280,600
GOM	Pleasant	-	-	-	-	178,000	165,000	343,000
GOM	Sheepscot	-	19,300	-	-	264,000	28,000	311,300
GOM	Union	-	-	-	-	-	1,000	1,000
		413,800	19,300	720,400	0	1,882,000	1,369,000	4,413,500

Table 1.4.2 Stocking summary for sea-run, captive reared domestic adult Atlantic salmon for the USA in 2021 by purpose and geographic area.

Area		Purpose	Captive Reared Domestic		Sea Run		Total
			Pre-spawn	Post-spawn	Pre-spawn	Post-spawn	
Long Island Sound	LIS	Restoration	0	0	0	0	0
Central New England	CNE	Restoration	0	0	0	0	0
Gulf of Maine	GOM	Restoration	0	2,070	1	141	2,212
Total for USA			0	2,070	1	141	2,212

Table 1.5.1 Summary of tagged and marked Atlantic salmon released in USA, 2021. Includes hatchery and wild origin fish.

Mark Code	Life Stage	CNE	GOM	LIS	Total
Adipose clip	0 Parr	-	112,835	-	112,835
Adipose punch	Adult	-	1,134	-	1,134
Adipose clip	Adult	-	-	-	-
Floy tag	Adult	-	4	-	4
Passive Integrated Transponder	Adult	-	1,898	-	1,898
Radio tag	Adult	-	-	-	-
Caudal punch	Adult	-	768	-	768
Acoustic Tag	Smolt	-	72	-	72
Adipose clip	Smolt	-	-	-	-
Passive Integrated Transponder	Smolt	-	-	-	-
Radio tag	Smolt	-	-	-	-
	Totals	-	116,711	-	116,711

Table 1.6.1. State of Maine - USA commercial Atlantic salmon aquaculture production and suspected aquaculture captures to Maine rivers 2000 to 2021. Due to confidentiality statutes in MDMR regulations related to single producer, adult production rates are not available 2011 to 2021.

Year	Total Salmon Stocked (smolt + fall parr + clips)	RV clipped fish stocked	Harvest total (metric tons)	Suspect aquaculture origin captures (Maine DPS Rivers)
2000	4,511,361	-	16,461	34
2001	4,205,161	-	13,202	84
2002	3,952,076	-	67,988	15
2003	2,660,620	-	6,007	4
2004	1,580,725	-	8,514	0
2005	294,544	-	5,263	12
2006	3,030,492	252,875	4,674	5
2007	2,172,690	154,850	2,715	0
2008	1,470,690	-	9,014	0
2009	2,790,428	-	6,028	0
2010	2,156,381	128,716	11,127	0
2011	1,838,642	45,188	NA	3
2012	1,947,799	137,207	NA	7
2013	1,329,371	170,024	NA	0
2014	2,285,000	-	NA	0
2015	1,983,850	446,129	NA	0
2016	1,892,511	262,410	NA	3
2017	2,224,348	211,043	NA	0
2018	2,035,690	45,000	NA	0
2019	1,996,662	60,480	NA	0
2020	2,225,000	40,000	NA	0
2021	2,080,309	31,140	NA	4

Table 1.7.1 Smolt population estimate (± Std. Error) from maximum likelihood estimates for the Narraguagus (natural spawning, egg planting and fry stocking), Sandy (egg planting), and East Machias (fall parr stocking) Rivers, Maine USA.

	Narraguagus River			Sandy River			East Machias River		
Smolt Year	Low SE	Pop Est	Up SE	Low SE	Pop Est.	Up SE	Low SE	Pop Est.	Up SE
1997	2,429	2,869	3,309	N/A	N/A	N/A	N/A	N/A	N/A
1998	2,594	2,845	3,096	N/A	N/A	N/A	N/A	N/A	N/A
1999	3,711	4,247	4,783	N/A	N/A	N/A	N/A	N/A	N/A
2000	1,601	1,843	2,085	N/A	N/A	N/A	N/A	N/A	N/A
2001	2,191	2,562	2,933	N/A	N/A	N/A	N/A	N/A	N/A
2002	1,536	1,774	2,012	N/A	N/A	N/A	N/A	N/A	N/A
2003	1,096	1,201	1,306	N/A	N/A	N/A	N/A	N/A	N/A
2004	1,069	1,284	1,499	N/A	N/A	N/A	N/A	N/A	N/A
2005	1,062	1,287	1,512	N/A	N/A	N/A	N/A	N/A	N/A
2006	2,137	2,339	2,541	N/A	N/A	N/A	N/A	N/A	N/A
2007	1,063	1,177	1,291	N/A	N/A	N/A	N/A	N/A	N/A
2008	796	962	1,128	N/A	N/A	N/A	N/A	N/A	N/A
2009	1,086	1,176	1,266	N/A	N/A	N/A	N/A	N/A	N/A
2010	1,922	2,149	2,376	N/A	N/A	N/A	N/A	N/A	N/A
2011	1,023	1,404	1,785	N/A	N/A	N/A	N/A	N/A	N/A
2012	725	969	1,213	N/A	N/A	N/A	N/A	N/A	N/A
2013	974	1,237	1,500	N/A	N/A	N/A	147	249	351
2014	1,417	1,615	1,813	N/A	N/A	N/A	614	852	1090
2015	960	1,201	1,442	N/A	N/A	N/A	183	229	275
2016	NA	NA	NA	N/A	N/A	N/A	719	938	1157
2017	NA	NA	NA	N/A	N/A	N/A	1099	1,323	1547
2018	483	604	725	N/A	N/A	N/A	842	1,043	1244
2019	627	829	1,031	N/A	N/A	N/A	915	1,101	1287
2020	NA	NA	NA	N/A	N/A	N/A	NA	NA	NA
2021	1334	1426	1518	11,935	13,229	14,523	636	792	948

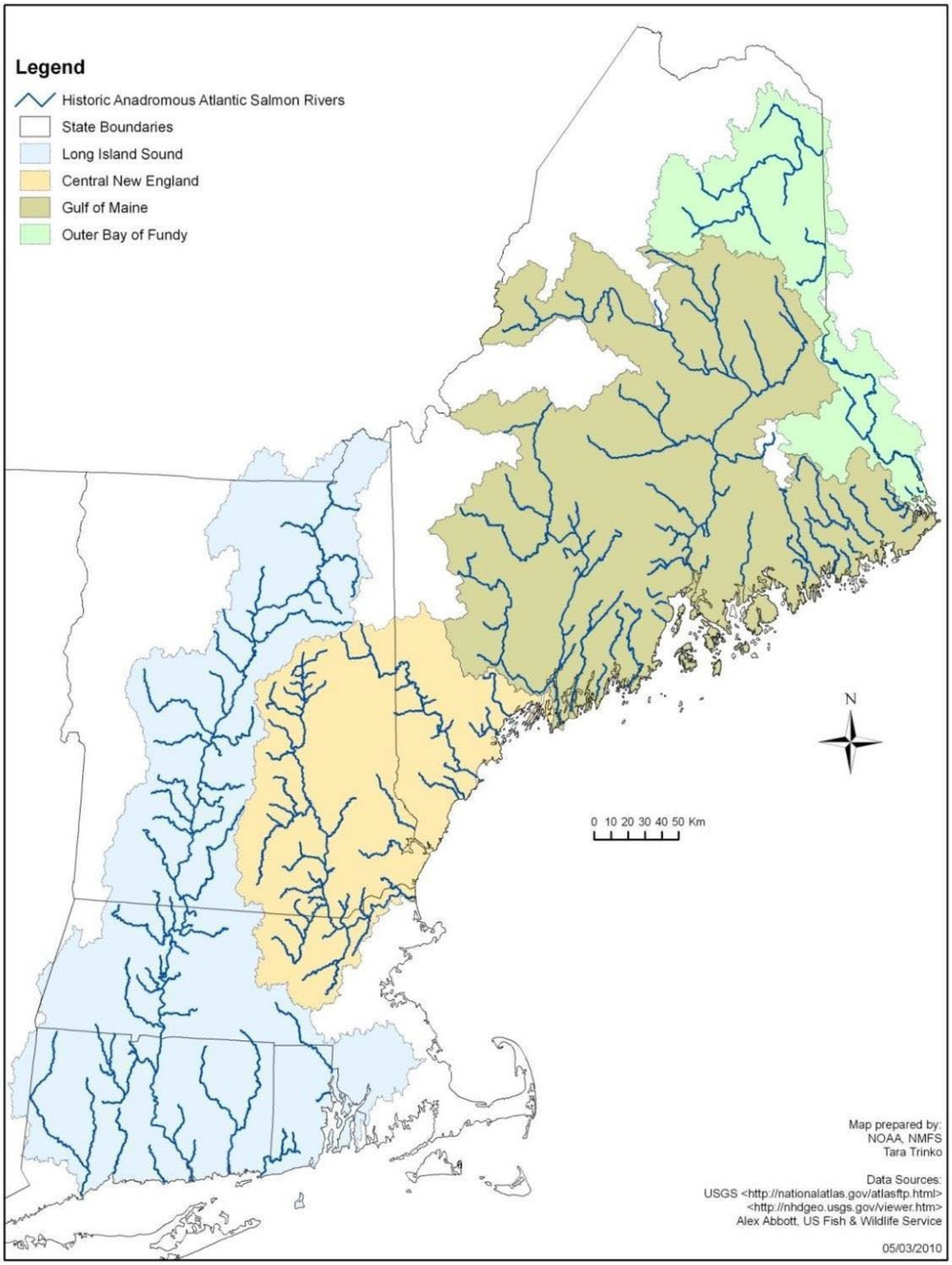

Figure 1.2.1 Map of Distinct Population Segments used in summaries of USA data for returns, stocking, and marking in 2021.

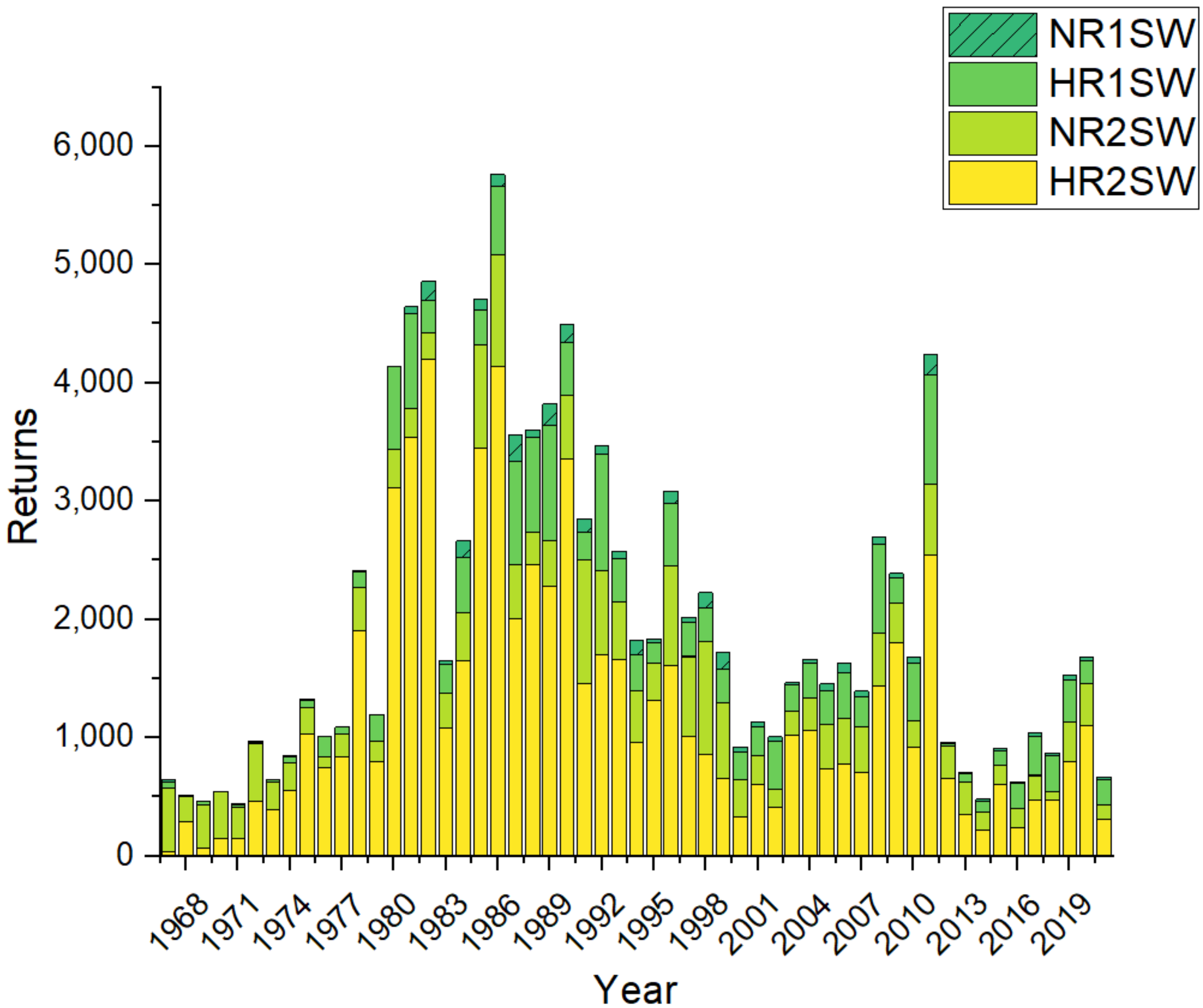

Figure 1.2.2 Origin and sea age (age 1 and 2 only) Atlantic salmon returning to USA rivers, 1967 to 2021 (NR1SW = Naturally Reared One Sea Winter; HR1SW = Hatchery Reared One Sea Winter; NR2SW = Naturally Reared Two Sea Winter; HR2SW = Hatchery Reared Two Sea Winter).

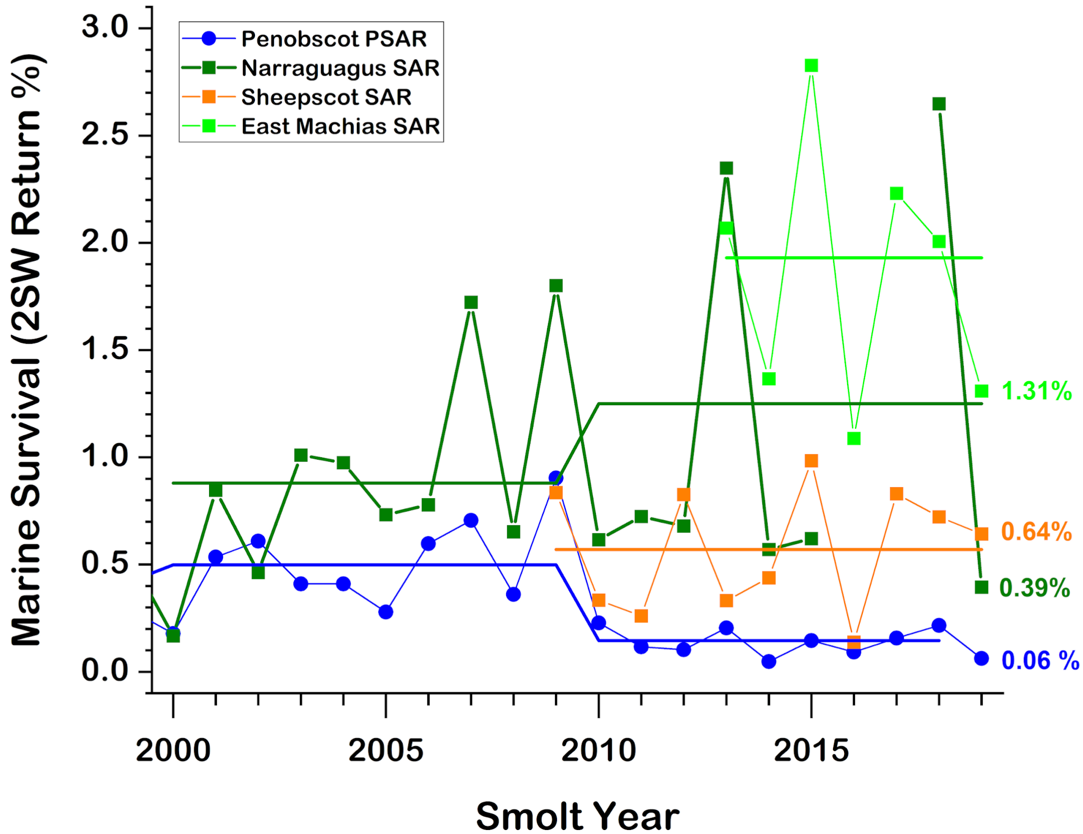

Figure 1.2.3 Smolt to Adult (SAR) and Postsmolt to Adult (PSAR) return rates for 2SW adults for fourMaine Rivers: Narraguagus, Sheepscot, East Machias and the Penobscot for the 2000 to 2019 Atlantic salmon smolt cohorts. Decadal (or time series) averages expressed as line labeled with percent returns.

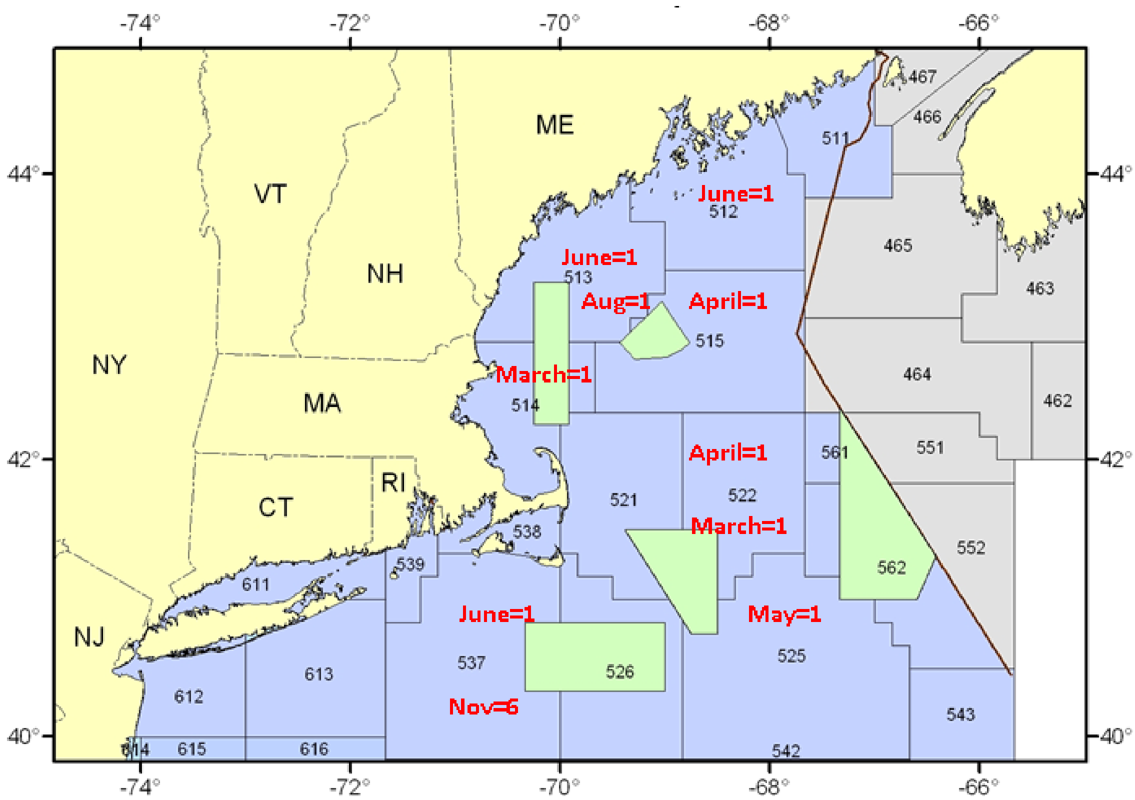

Figure 1.3.1 Map of Gulf of Maine region showing the month and number of Atlantic salmon interactions between 1993 and 202. Blue polygons are USA statistical areas, grey zones are in Canada and green-shaded polygons represent regulated access areas. Red text highlights the month and number of individuals for each documented interaction within each statistical area. Location of the label within the statistical grid does not denote more specific locations.

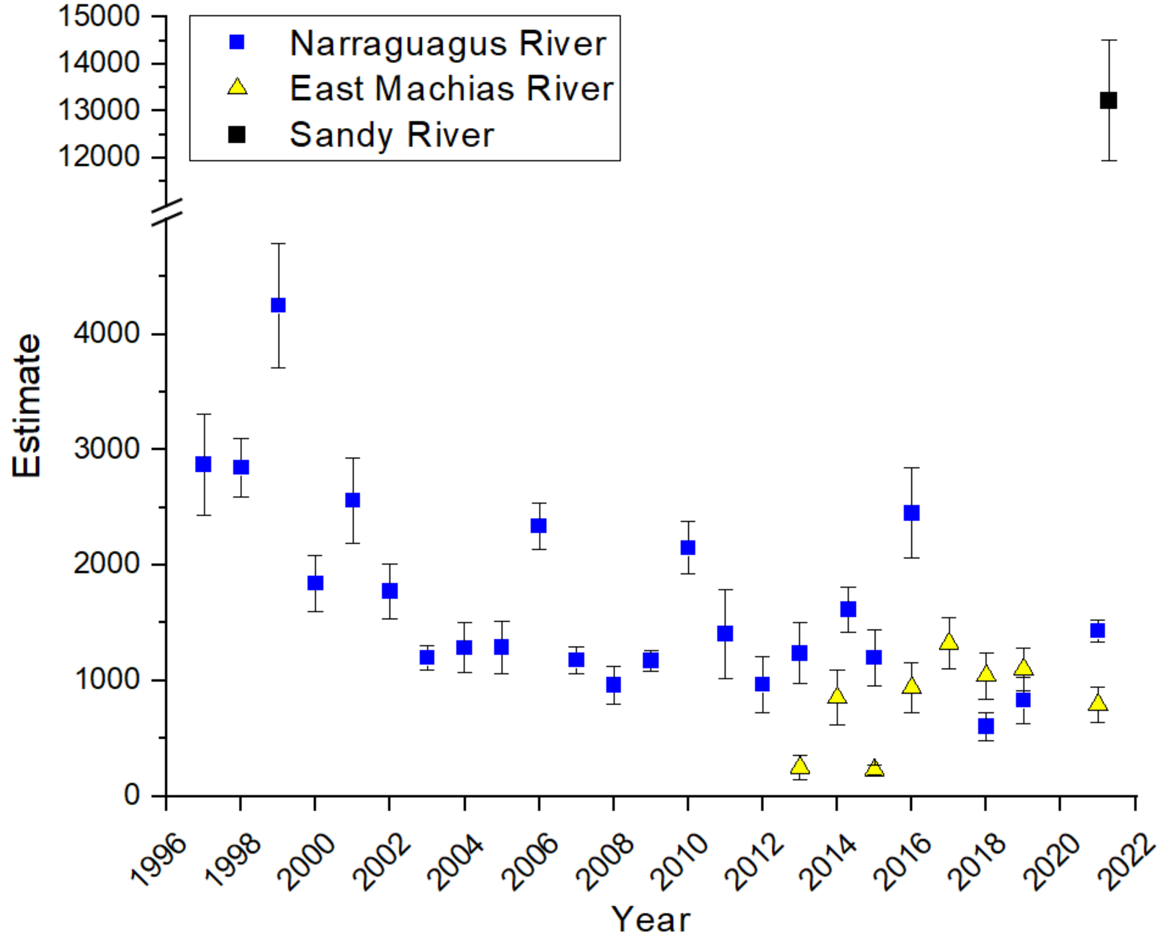

Figure 1.7.1. Population Estimates (± Std. Error) of emigrating naturally-reared smolts of naturally reared smolts on the Narraguagus (natural spawning, egg planting and fry stocking), Sandy (egg planting) and East Machias (fall parr stocking) Rivers, in Maine U.S.

2 Viability Assessment - Gulf of Maine Atlantic Salmon

2.1 Overview of DPS and Annual Viability Synthesis

2.1.1 Change in Status Assessment Approach

While this report summarizes all US populations related to metrics and general trends to national reporting needs in support of NASCO (e.g., Chapter 1), these populations are now dominated by the endangered GOM DPS in Maine. Section 2 summarizes the more detailed metrics needed to monitor the health of these populations using standard metrics for endangered salmonids in the United States. This section of the report represents an annual viability assessment of the GOM DPS using a Viable Salmonid Populations (VSP) approach (McElhany et al. 2000). Taking this approach allows U.S. stock assessment scientists to integrate an annual GOM DPS assessment within the overall U.S. assessment making more effective use of staff resources. Integrating this annual reporting (required under the GOM DPS Collaborative Management Strategy) will also allow additional review of the GOM DPS viability assessment by a wider group of professionals assembled at the USASAC. This section is meant to be a brief annual summary not a benchmark five-year viability assessment. Benchmark assessments will be produced and published separately.

2.1.2 DPS Boundary Delineation

This section synthesizes data on the abundance, population growth, spatial distribution, and diversity to better characterize population viability (e.g., McElhany et al. 2000; Williams et al. 2016). These characterizations also represent metrics used to monitor progress for the Recovery Plan. There are three Major Population Groupings (MPG) referred to as Salmon Habitat Recovery Units (SHRU) for the GOM DPS (NMFS 2009) based on watershed similarities and remnant population structure. The three SHRUs are Downeast Coastal (DEC), Penobscot Bay (PNB), and Merrymeeting Bay (MMB). The GOMDPS critical habitat ranges from the Dennys River southward to the Androscoggin River (NMFS 2009).

At the time of listing, nine distinct individual populations (DIPs) were identified. In the DEC SHRU, there were five extant DIPs in the Dennys, East Machias, Machias, Pleasant and Narraguagus Rivers. In the PNB SHRU, there were three - Cove Brook, Ducktrap River, and mainstem Penobscot. In the MMB SHRU there was one DIP in the Sheepscot River. Of these nine populations, seven of them are supported by conservation hatchery programs. These hatchery programs propagate wild-exposed parr or returning adults to increase effective spawning populations. The Ducktrap River DIP was not supplemented.

Because conservation hatchery activities play a major role in fish distribution and recovery, a brief synopsis is included in the boundary delineation. The core conservation hatchery strategy for six of these DIPs is broodstock collected primarily from wild-exposed or truly wild parr collections. These juveniles are then raised to maturity in a freshwater hatchery. All five extant DEC DIPs (Dennys, East Machias, Machias, Pleasant, and Narraguagus) are supported using this approach as well as the Sheepscot DIP in the MMB SHRU. For the mainstem Penobscot, the primary hatchery strategy is collection of sea-run adult broodstock that are a result of smolt stocking (85% or more of adult collections) or naturally reared or wild returns. For the Ducktrap River population, no conservation hatchery activities were implemented. In general, DIPs are stocked in their natal river. However, because there are expansive areas of Critical Habitat that are both vacant and of high production quality, these seven populations (primarily the Penobscot) can serve as donor stocks for other systems, especially the Kennebec River in MMB SHRU and Cove Brook within the PNB SHRU (native population was extirpated in 2009).

2.1.3 Synthesis of 2020 Viability Assessment

Totaling 676 estimated adult returns to the GOM DPS, the 2021 spawning run was ranked 27th out of 31 cohorts since 1991. Of these 521 (71%) of returns were of hatchery-stocked smolt origin. Naturally reared returns remained low across the GOM DPS (155) totaling 91 in PNB, 37 in DEC and 27 in MMB SHRUs. About 59% of naturally reared returns were documented in the PNB SHRU. Abundance remains critically low relative to interim recovery targets of 500 naturally-reared returns per SHRU. The PNB SHRU was at 18% of this target, 3.4-fold higher than returns to the MMB SHRU (5%). The populations in the DEC SHRU were estimated at 37 only 7% of recovery targets. With no documented returns in 2021, the Ducktrap DIP in PNB is at an elevated extirpation risk with returns documented in only 4 of the last 12 years.

Population growth is monitored by 10-year geometric mean population growth rates of naturally reared adults as per recovery plan criteria. The GOM DPS rate for 2021 returns was 0.96 (95% CL 0.57-1.16); because error bounds around this rate overlap 1.0, this indicates relative stability. This rate does not reflect the true wild population growth rates because naturally reared salmon returns include not only individuals that are the product of natural reproduction in the wild but products of the U.S. hatchery system (e.g., stocked fry and planted eggs). As such, the inclusion of hatchery products in the 10-year geometric mean replacement rate overestimates wild population growth rate. New methods are under development to evaluate the wild reared component (see Section 2.3.1). These newly calculated metrics of natural population growth suggest that wild population components have finite growth rates below 1 (declining population) for all three SHRUs. This new method will be undergoing peer review in the future year but is described in this report.

The spatial structure of juvenile populations represents a combination of wild production areas that are monitored for spawning activity and stream reaches that are stocked and produce naturally reared juveniles. Spawner surveys in 2022 covered 2,570 units (24%) of 10,900 units of mapped spawning habitat. Coverage is limited in MMB and PNB habitat but does focus on priority management areas. Overall survey coverage was limited to managed/focal areas so likely underrepresents Wild Protection Areas (WPAs). Modeling of juvenile production areas from these spawner surveys suggest that overall available juvenile rearing habitat is under seeded due to low spawner abundance. However, these WPAs will be buffered from stocking the following spring and fall to minimize competition between wild and hatchery origin juveniles.

This assessment also modeled occupied freshwater production habitat in December and summarized the production area from both natural redds (WPA) and geo-referenced stocking locations. For this analysis, we assume that 3 cohorts of fish comprise the standing juvenile fish population (2019, 2020, and 2021). Using this method, we visualized mean proportion occupancy for each of the three SHRUs at a HUC-12 resolution. This analysis shows that most juvenile rearing habitat is unoccupied and densities are below target in occupied areas.

Genetic diversity of the GOM DPS is monitored through assessment of sea-run adults for the Penobscot River and juvenile parr collections for six other populations. Allelic diversity has remained relatively constant since the mid-1990's. However, slight decreases have been detected in the Penobscot and Sheepscot populations. All populations are now above 10 of 18 monitored loci but stabilizing diversity is essential and genetic rescue methods could be further investigated. Estimates of effective population size have increased for the Penobscot, due to increased broodstock targets and equalized broodstock sex ratios, but for the remaining rivers effective population size estimates have either remained constant or slightly decreased. Implementation of pedigree lines have helped to retain diversity following bottleneck (Pleasant) and variable parr broodstock captures (Dennys) by retaining representatives of all hatchery families and supplementing with river-caught parr from fry stocking or natural reproduction. Populations below 100 LDNe are at elevated risk and the upward trajectory of all these populations between 2016 and 2018 should be maintained.

2.2 Population Size

Overall stock health can be measured by comparing monitored adult abundance to management targets. Because juvenile rearing habitat has been measured or estimated accurately, these data can be used to calculate target spawning requirements from required egg deposition. The number of returning Atlantic salmon needed to fully utilize all juvenile rearing habitats is termed the Conservation Limit (CL). These values have been calculated for all U.S. populations. The CL for the GOM DPS is 29,192 adults (Atkinson 2020). In self-sustaining populations, the number of returns can frequently exceed this amount by 50–100%, allowing for sustainable harvests and buffers against losses between return and spawning. When calculating the CL for U.S. populations in the context of international assessments by the ICES WGNAS, the metric focuses on only 2SW adult returns (hatchery and natural-reared). The 2SW CL is 22,134. These CL targets represent long-term goals for sustainable population sizes. Adult returns are partitioned into two categories. Hatchery returns are those adult salmon that are a product of an accelerated smolt program or released as fall parr or fall fingerlings. The other category, naturally reared returns are those adult salmon that are a product of natural spawning, egg planting, and fry stocking.

Given the endangered status of GOM ATS, the first management target for downlisting from endangered to threatened is 500 naturally reared returns in each of the three SHRUs. For delisting, the next target is 2,000 naturally reared returns. This level of abundance is the minimum population required to have a less than 50 percent chance of falling below 500 spawners under another period of low marine survival. Estimates of both abundance and population growth rate can be corrected for the input of hatchery fish, but this requires differentiating between returns of wild origin and egg/fry-stocked salmon. That metric requires genetic determination of parentage, but the ability to adequately sample returning adults on all rivers is limited. The estimate of 2,000 spawners thus serves as a starting point for evaluating population status, but this benchmark and the methods by which it is calculated should be re-evaluated in the future as more data and better methods for partitioning returning adults become available. The threshold of 2,000 wild spawners per SHRU, totaling 6,000 wild spawners annually for the GOM DPS, is the current recovery target for delisting.

Because the goal of the GOM DPS Recovery Plan is a wild, self-sustaining population, monitoring (counts and growth rates) of wild fish are desired metrics. However, with extensive and essential conservation hatchery activities (planting eggs and stocking fry and fingerlings), it is currently not feasible to enumerate only wild fish. Initially, NMFS (2009) attempted to minimize bias in estimating abundance (and mean population growth rates) by excluding the Penobscot River due to stocking of hatchery fish (smolts and marked parr). In subsequent years, managers have established an intermediate target –

500 naturally-reared adult spawners (i.e., returning adults originating from wild spawning, egg planting, fry stocking, or fall parr stocking). This is a helpful metric in the short-term to monitor recovery progress of wild fish combined with individuals that have had 20 + months of stream rearing before migrating to sea. However, full recovery will only be achieved with abundance from adult spawners of wild origin. All fish handled at traps are classified as to rearing origin by fin condition and scale analysis. For redd-based estimates, each population is pro-rated on an annual basis using naturally reared to stocked ratios at smolt emigration or other decision matrices to partition naturally reared and stocked returns (USASAC 2020).

Total adult returns to the GOM DPS in 2021 were 676 adults with 521 hatchery-origin fish returning to the Penobscot, Narraguagus, East Machias, and Sheepscot Rivers (Figure 2.2.1 and Table 2.2.1). Because of the abundance of the PNB SHRU smolt-stocked returns (470) there this SHRU dominated (83%) total abundance with 561 returns. An additional 51 hatchery returns were documented from the DEC (37) and MMB SHRU (14).

Naturally reared returns were also highest in PNB at 91 (Table 2.2.1 and Figure 2.2.2). However, the Ducktrap River population had zero documented returns for the fourth consecutive year. The 12-year average for this system was less than three with zero returns in eight of these years. The DEC SHRU had 37 documented naturally reared returns across all six of monitored river systems while the Merrymeeting Bay SHRU had 27 natural returns to all three of monitored systems.

Table 2.2.1. Documented returns from trap and redd-count monitoring for GOM DPS Atlantic salmon by SHRU for return year 2021 and percentage of naturally reared fish relative to the interim 500 fish target (% of 500) by SHRU.

SHRU	Hatchery	Natural	Sub Totals	% of 500
Downeast Coastal	37	37	74	7.4%
Penobscot Bay	470	91	561	18.2%
Merrymeeting Bay	14	27	41	5.4%
Gulf of Maine DPS	**521**	**155**	**676**	**-**

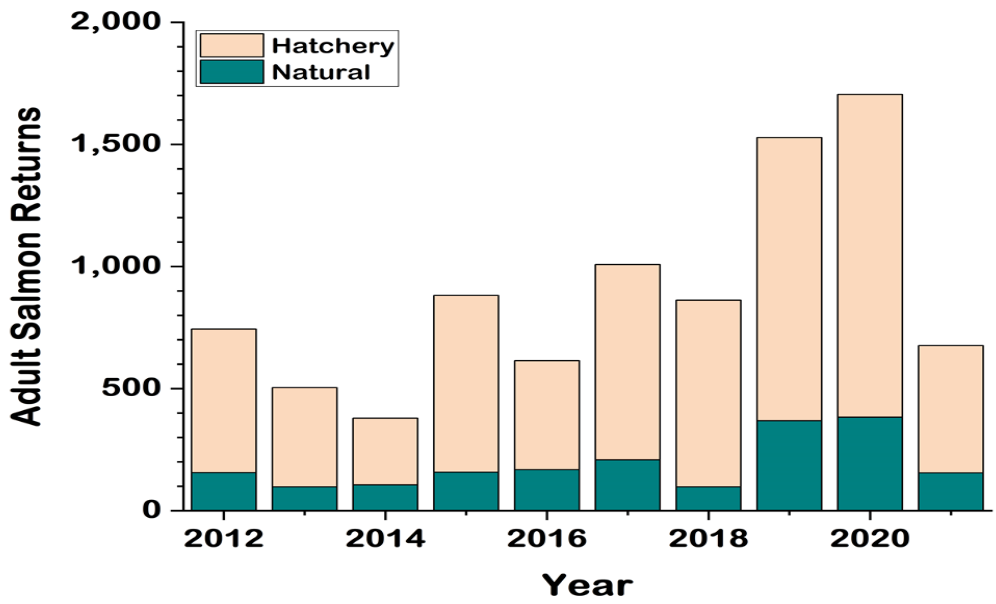

Figure 2.2.1. Time-series of total estimated returns to the GOM DPS of Atlantic salmon for the last decade illustrating the dominance of hatchery-reared origin (parr or smolt stocked; tan bars) Atlantic salmon compared to naturally reared (wild, egg stocked, fry stocked; teal bars) origin.

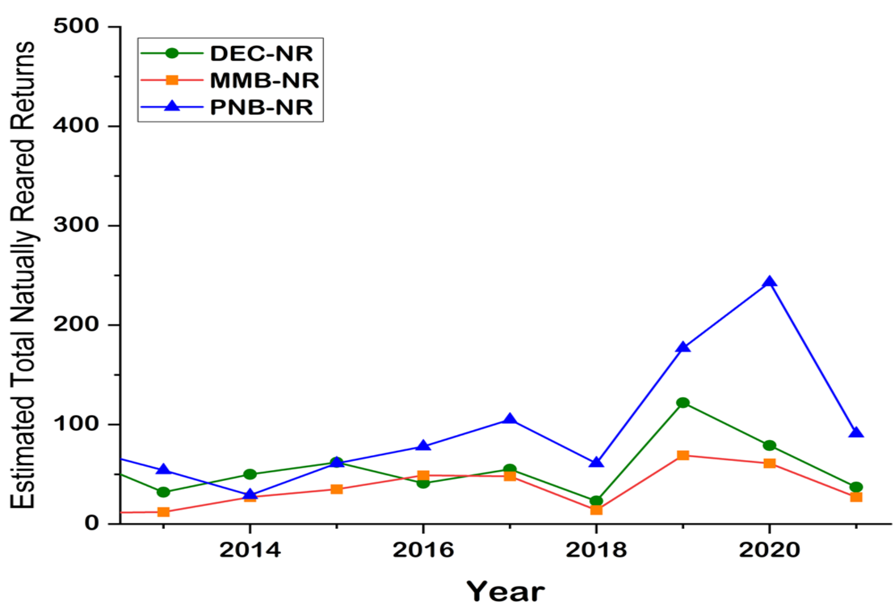

Figure 2.2.2. Time series of last decade of naturally reared adult returns to the Merrymeeting Bay (Orange), Penobscot Bay (Blue), and Downeast Coastal (Green) SHRUs. Note: naturally reared interim target of 500 natural spawners is maximum axis value.

2.2.1 Adult Return Rates Synopsis

The USASAC updated adult return rate metrics for Penobscot River hatchery origin smolts and naturally reared smolts produced in the Narraguagus, Sheepscot, and East Machias Rivers. In the later three populations, estimated smolt emigration and subsequent adult returns by sea age are used to generate a smolt-to-adult return rate (SAR). For the Penobscot River a revised estimate was developed that used the methods of Stevens et al. (2019) to decouple losses of smolts in-river and in the estuary to provide an estimate of postsmolts entering the Gulf of Maine. This method accounts for both stocking location and flow-specific mortality to generate a postsmolt estimate that was then applied to subsequent adult returns to calculate a postsmolt to adult survival rate (PSAR) for the Penobscot.

Naturally-reared smolt abundance in the Narraguagus, Sheepscot, and East Machias Rivers for the 2019 cohort was derived from mark-recapture population estimates. When combined with redd-based adult population estimates or trap counts by age, these provide additional indices of return rates for these Maine populations. Naturally-reared smolt abundance is the result of wild spawning, egg planting, fry stocking and stocking of fall parr (ambient-temperature reared parr). These parr were reared at Craig Brook National Fish Hatchery (Orland, Maine) for the Sheepscot and Narraguagus and the Peter Gray Parr Hatchery (East Machias, Maine) for the East Machias. The longest time series is for the Narraguagus River starting with the 1997 smolt cohort. Most of the adult return data for this population comes from trap counts of adults at the Cherryfield Dam. In years of high flow (more fish bypass the trap), redd counts are used as they more accurately reflect total returns. All these age-based adult estimates are in USASAC databases. Sheepscot River smolt monitoring started in 2009 and East Machias monitoring in 2013. When adult returns are estimated from redd counts, ages are pro-rated by standard methods used by USASAC.

The 1 SW PSAR for the Penobscot 2021 returns was 0.04% and was the only population estimated because of interrupted smolt estimates in 2020 due to the pandemic. However, tends in the last decade indicate Penobscot Hatchery 1SW population PSAR averaged 0.04% with higher averages for the SAR values in the Narraguagus River (0.26%), Sheepscot River (0.15%), and East Machias 7-year average (0.53%) were typically higher.

Because salmon predominantly return at 2SW, return rates are higher for these fish. In 2021, the 2019 smolt cohort PSAR for the Penobscot was 0.06% - lower than SARs for the Narraguagus (0.39%), Sheepscot (0.64%) or East Machias (1.31%; Figure 2.2.1.1). These are similar to returns of 2SW salmon in the last decade where the Penobscot PSAR averaged 0.14% (Figure 2.2.1.1). This PSAR is substantially lower than the decadal average SAR for 2SW returns in the Narraguagus (1.08%) and Sheepscot Rivers (0.55%) or the East Machias 7-year time series (1.84%). While the interannual variability is larger in these smaller populations, these data suggest better marine performance for naturally-reared smolts. Despite the average 7, 4, and 13 fold higher rates for the Narraguagus, Sheepscot, and East Machias, overall low smolt freshwater production results in lower number of adult returns in these 3 populations. Future work will focus on the variability of these estimates and continuing these time series to better understand the differences between hatchery and naturally-reared smolts. In the future, PSAR estimates will be reviewed for their utility in the Narraguagus River population where telemetry estimates of the lower river and estuary survival are available for eight years of the time series. Marine survival remains a primary threat to the recovery of all Gulf of Maine Atlantic salmon stocks. Reviews of marine survival indicate the best management strategy to address current ocean conditions is to maximize the production of wild or naturally reared smolts. Given the amount of vacant habitat across the DPS (Section 2.4), there is significant unused habitat capacity. Additional hatchery capacity is needed to utilize un-stocked habitat. For hatchery smolts, research and adaptive management changes could help close the marine performance gap and yield more natural spawners. Ongoing efforts to ensure safe downstream passage for both naturally-reared and hatchery smolts remains essential.

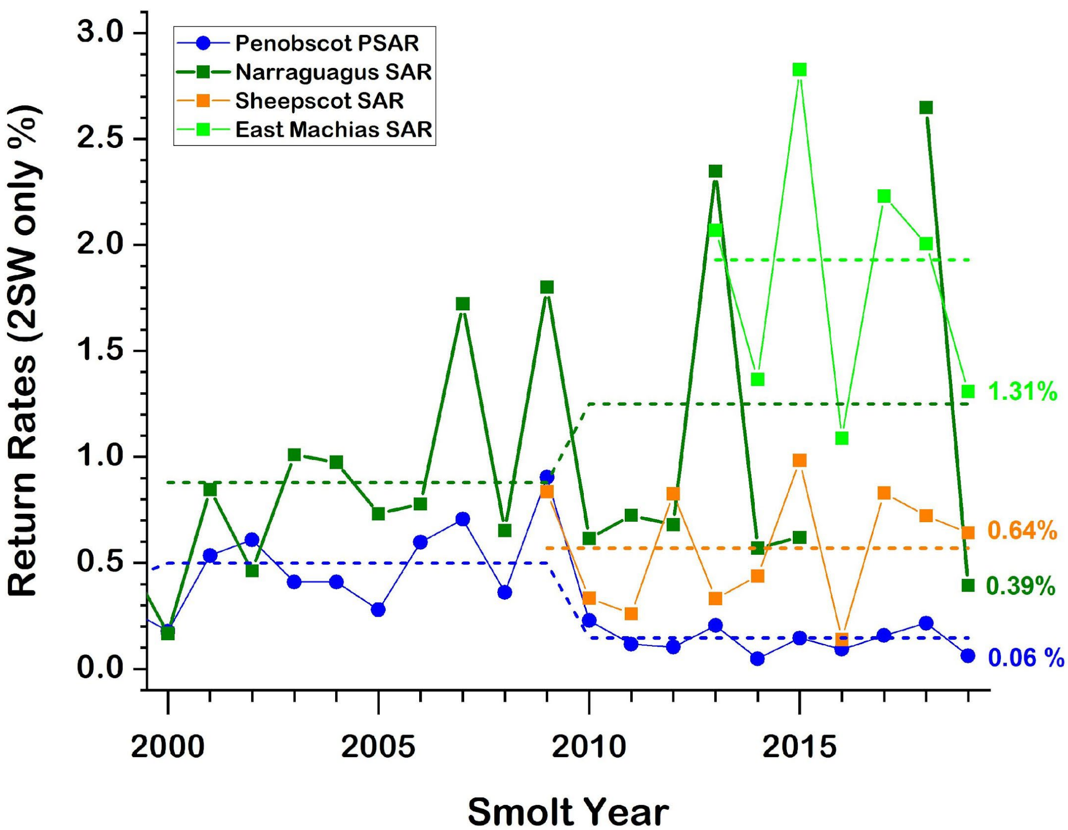

Figure 2.2.1.1. Time series of post-smolt to 2SW adult return rates for the Penobscot hatchery smolts (blue) and naturally reared smolt to adult return rates for the Sheepscot (orange), Narraguagus (olive), and East Machias (green) for the 2000-2019 smolt cohorts. Dashed lines are decadal averages of the populations and percentages listed are for the most recent cohort.

2.3 Population Growth Rate

Another metric of recovery progress in each SHRU demonstrates a sustained population growth rate indicative of an increasing population. The mean life span of Atlantic salmon is five years; therefore, consistent population growth must be observed for at least two generations (10 years) to show sustained improvement. If the geometric mean population growth rate of the most recent 10-year period is greater than 1.0, this provides assurance that recent population increases are not random population fluctuations but more likely are a reflection of true positive population growth. The geometric mean population growth rate is calculated as:

$$GM_{\underline{R}} = exp(mean[R_t, R_{t-1}, R_{t-2}, \dots, R_{t-9}])$$

where GMR is the geometric mean population growth rate of the most recent 10-year period and Rt is the natural log of the five-year replacement rate in year t. The five-year replacement rate in year t is calculated as:

$$R_t = ln\left(\frac{N_t}{N_{t-5}}\right)$$

where Nt is the number of adult spawners in year t and Nt-5 is the number of adult spawners five years prior. Naturally reared adult spawners are counted in the calculation of population growth rate in the current recovery phase (reclassification to threatened) objectives. In the future, only wild adult spawners will be used in assessing progress toward delisting objectives. As described in the 2009 Critical Habitat rule, a recovered GOM DPS must represent the natural population where the adult returns must originate from natural reproduction that has occurred in the wild.

In a future when the GOM DPS is no longer at risk of extinction and eligible for reclassification to threatened status, an updated hatchery management plan will detail how hatchery supplementation should be phased out. This plan would include population benchmarks that trigger decreasing hatchery inputs. The benchmarks should be based upon improved PVA models that incorporate contemporary demographic rates and simulate various stocking scenarios to assess the probability of achieving long-term demographic viability.

The geometric mean population growth rate based on estimates of naturally reared returns fell below 1.0 for all SHRUs during the mid-2000s as a result of declining numbers of returning salmon. In more recent years, the population in each SHRU has stabilized at low numbers and the geometric mean population growth rate increased to approximately 1.0 for all SHRUs by 2012 (Figure 2.3.1). In the most recent year (2021) the Merrymeeting Bay SHRU had the highest growth rate (1.40; 95% CI: 0.89 – 2.18) and the Downeast Coastal SHRU had the lowest growth rate (0.81; 95% CI: 0.51 – 1.30) (Table 2.3.1).

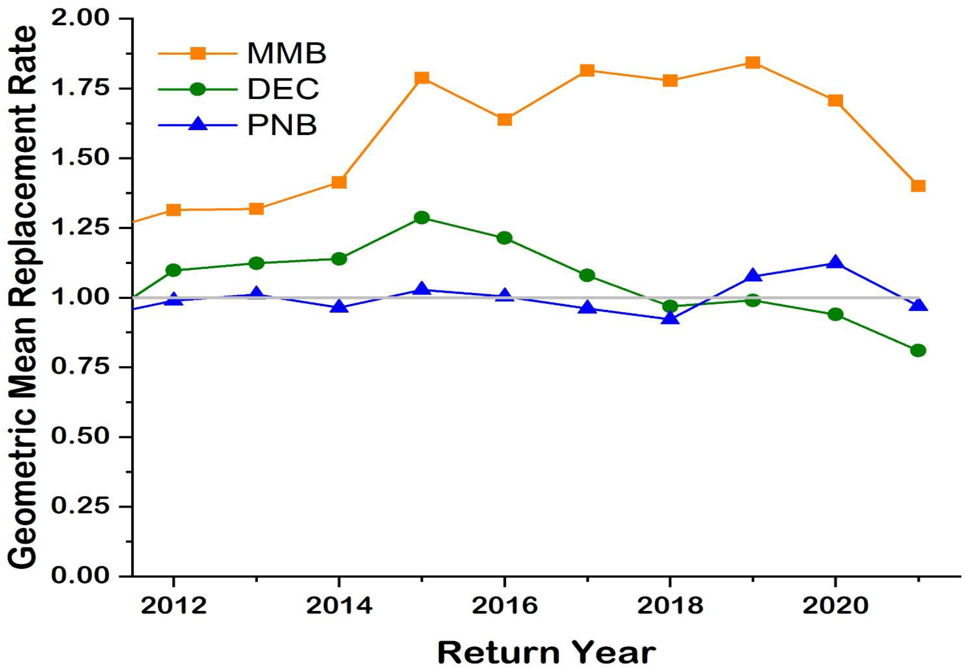

Figure 2.3.1. Annually calculated ten-year geometric mean replacement rates for the GOM DPS of Atlantic salmon for Merrymeeting Bay (orange), Penobscot Bay (blue), and Downeast Coastal (green) for each SHRU individually for the last decade.

Table 2.3.1. Ten-year geometric mean replacement rates (GM_R) for GOM DPS Atlantic salmon as calculated for 2020 return year with 95% confidence limits (CL).

SHRU	GM_R	Lower 95% CL	Upper 95% CL
Downeast Coastal	0.81	0.51	1.30
Penobscot	0.97	0.47	2.00
Merrymeeting Bay	1.40	0.89	2.18
Gulf of Maine DPS	**0.96**	**0.57**	**1.61**

The geometric mean population growth rate based on the five-year replacement rate does not completely reflect the true population growth rate because naturally reared salmon returns include individuals that are the product of natural reproduction in the wild as well as individuals that are products of our hatchery system (e.g., stocked fry and planted eggs). The inclusion of hatchery products in the 10-year geometric mean replacement rate gives an overestimate of the true wild population growth rate.

2.3.1 Genetic Parentage Analysis

In order to remove this bias and gain an estimate of the true wild population growth rate, we need to be able to discern returns resulting from hatchery inputs from those resulting from natural reproduction in the wild. We can determine if a returning adult salmon was stocked as a parr or smolt through the presence of marks or scale analysis but determining if a returning adult was a result of natural reproduction or stocking at the fry or egg stage is problematic because these life stages are not marked by the time of stocking.

A solution to this problem is to use genetic parentage analysis. All hatchery broodstock are genotyped and matings between individuals in the hatchery are known. By genotyping salmon collected in the wild at later life stages, we can determine if they were the product of a known hatchery mating. If the individual cannot be matched to a known set of parents in the hatchery, it can be assumed that individual is the product of natural spawning. Since we genotype returning adult salmon that are captured in trapping facilities and parr that are collected for future broodstock, we can use parentage analysis of the individuals deemed to be naturally reared to determine the proportion of these individuals that are produced from natural reproduction (truly wild) and the proportion that are the product of fry stocking and/or egg planting. We can then partition the total number of returning adult salmon into true wild versus hatchery components of the population and use analytical methods to gain better estimates of the true wild population growth rates.

<u>Model description</u>

This new method for estimating the wild population growth rate is described by Sweka and Bartron (*manuscript in preparation*) and uses methods described by Holmes (2001) and McClure et al. (2003). Underlying this approach was an exponential decline model (Dennis et al 1991):

$$N_{t+1} = N_t e^{(\mu+\varepsilon)} \qquad [1]$$

where N_{t+1} is the number of salmon at time t+1, N_t is the number of salmon at time t, μ is the instantaneous population growth rate, and ε is normally distributed error with a mean of 0 and variance of σ^2. Total estimated adult returns were used as input data and were the combination of salmon observed in trapping facilities and salmon estimated from redd surveys. The use of raw return data presents problems when estimating μ because spawners only represent a single life stage and the delay between birth and reproduction can lead to large fluctuations in annual spawner numbers (McClure et al. 2003). Therefore, we used a running sum (R_t) of five consecutive years of spawning counts (S_{t+j-1}) as input data to estimate μ as recommended by Holmes (2001) and Holmes and Fagan (2002).

$$R_t = \sum_{j=1}^{5} S_{t+j-1} \qquad [2]$$

Five consecutive counts were summed together because the majority of Atlantic Salmon in the GOM DPS will return to spawn five calendar years after their parents spawned. The population growth rate ($\hat{\mu}$) was estimated as:

$$\hat{\mu} = mean\left[ln\left(\frac{R_{t+1}}{R_t}\right)\right] \quad [3]$$

We used a slope method (Holmes 2001; Holmes and Fagan 2002) to gain an estimate of the variance on the population growth rate ($\hat{\sigma}^2$)

$$\hat{\sigma}^2 = slope\ of\ variance\ of\ \left[ln\left(\frac{R_{t+\tau}}{R_t}\right)\right] vs.\tau \quad [4]$$

for τ = 1,2,3,4, and 5 corresponding to time lags in the life history of Atlantic Salmon from spawning until offspring return to spawn.

The input of hatchery origin fish confounds estimates of the population growth rate (μ). If these hatchery origin fish successfully reproduce and contribute to the next cohort, which is the goal of stocking these hatchery fish, then estimates of μ based on total spawners is overestimated and subsequent extinction risks are underestimated. We estimated μ in two ways: (1) using running sums of total spawners as described in equation [3] (hereafter referred to as $\hat{\mu}_{Total}$) and (2) adjusting for the proportion of hatchery origin fish in the running sums of spawners (McClure et al. 2003; hereafter referred to as $\hat{\mu}_{Wild}$) as

$$\hat{\mu}_{Wild} = mean\left[\frac{1}{T} ln(\widehat{w}_t) + ln\left(\frac{R_{t+1}}{R_t}\right)\right] \quad [5]$$

where T = an approximate 5 year generation time for Atlantic Salmon and $\widehat{w}_t$= the proportion of the running sum of adult returns that were born in the wild. The value of $\hat{\mu}_{Wild}$ assumes that hatchery fish that survive to spawn, reproduce at the same rate as wild fish and that wild spawners in the time series could have come from either hatchery or wild parents. We can view the value of $\hat{\mu}_{Total}$ as the population growth rate under stocking levels that produced the observed time series of total spawners and the value of $\hat{\mu}_{Wild}$ as the population growth rate of wild fish only, in the absence of stocking.

Input Data

Time series of adult return data were obtained from the U.S. Atlantic Salmon Assessment Committee database. Although the available data extended back to 1967, we restricted the data used in this analysis to 2011 - 2021 which represents the last 10 years of the running sum of adult returns.

Genetic parentage analysis of broodstock taken to the hatchery was used to differentiate wild and hatchery fish within the naturally reared component of returning salmon. Penobscot River broodstock were obtained by trapping adults and transporting them to Craig Brook National Fish Hatchery. Other rivers used a captive broodstock program whereby fish were captured as age 1+ parr in the rivers and transported to Craig Brook National Fish Hatchery for culture until they matured and could be spawned in the hatchery. We make the assumption that the broodstock collected and subsequently analyzed for parentage are representative of all salmon in the natural environment.

Growth rates were estimated for each SHRU and for the GOM DPS as a whole. Therefore, adult returns and the proportion of naturally reared returns that were wild origin were combined among rivers within a SHRU and among all rivers for the entire GOM DPS. Information from parentage analysis to determine the proportion of naturally reared returns that were wild origin was available for spawning runs from 2003 – 2018. In the Penobscot SHRU, the year of broodstock collection and parentage analysis corresponded to the year the adults returned. However, in other SHRUs the year of broodstock collection and parentage analysis did not correspond to the year these fish would have returned as adults because they were collected as parr (mostly age 1). Therefore, we made the assumption that the proportion of naturally reared fish that were wild origin found in the parr collected for broodstock would be the same for fish from these cohorts that remained in the river and would return as sea run adults three years later. [The majority of naturally reared returns in the GOM DPS become smolts at age 2 and return after two winters at sea.] Within this assumption, we assumed that any differential survival between hatchery and wild origin fish took place over the first year of life when the fish were at the fry and age 0 parr stages.

Within a year, the proportion of returns that were wild $(\widehat{w}_t')$ was estimated as

$$\widehat{w}_t' = \frac{\rho_t S_{NR,t}}{S_{T,t}} \qquad [8]$$

where ρ_t = the proportion of naturally reared returns that were of wild origin as estimated through parentage analysis at time t, $S_{NR,t}$ = the number of naturally reared spawners, and $S_{T,t}$ = the total number of spawners. The number of wild origin returns in year t $\left(S_{W,t}\right)$ was then

$$S_{W,t} = \widehat{w}_t' S_{T,t} \qquad [9]$$

and the number of hatchery origin spawners in year t $\left(S_{H,t}\right)$ was

$$S_{H,t} = S_{T,t} - S_{W,t} \qquad [10]$$

<u>Results</u>

Instantaneous population growth rates were near 0 and 95% confidence limits overlapped 0 for all SHRUs and the Gulf of Maine as a whole when we include all returning Atlantic salmon regardless of origin. These results indicate neither increasing nor decreasing populations. However, when we account for the proportion of adult returns that were of hatchery origin, all SHRUs had wild population growth rates that were less than 0 with the Penobscot SHRU being the lowest. The reason why the Penobscot SHRU has the lowest population growth rate is because the vast majority of adult returns to this SHRU are of hatchery origin. The negative growth rates for the wild component of these populations indicates that if stocking hatchery origin fish were to cease, these populations would show abrupt declines.

Table 2.3.1. Population growth rates of Atlantic Salmon in the GOM DPS estimated by the running sum method for both the total population and the wild component. Growth rates are presented as both instantaneous (µ) and finite (λ) rates. Numbers in parentheses represent 95% confidence limits.

SHRU	μ_{total}	μ_{wild}	λ_{total}	λ_{wild}
	0.0380	-0.2851	1.0387	0.7519
Downeast Coastal	(-0.0381, 0.1140)	(-0.3612, -0.2091)	(0.9626, 1.1208)	(0.6969, 0.8113)
	-0.0386	-0.6871	0.9621	0.5030
Penobscot	(-0.2133, 0.1360)	(-0.8617, -0.5124)	(0.8079, 1.1457)	(0.4224, 0.5990)
	0.0119	-0.3198	1.0120	0.7263
Merrymeeting Bay	(-0.0556, 0.0794)	(-0.3872, -0.2523)	(0.9460, 1.0826)	(0.7770, 0.01114)
	-0.0305	**-0.6112**	**0.9699**	**0.5427**
Gulf of Maine	**(-0.1914, 0.1304)**	**(-0.7720, -0.4503)**	**(0.8258, 1.1392)**	**(0.4621, 0.6374)**

2.4 Spatial Structure of DPS

For the GOM DPS, a sustained census population of 500 naturally reared adult spawners (assuming a 1:1 sex ratio) in each SHRU was chosen to represent the effective population size for down listing to threatened. In 2020, none of the three SHRUs approached this level of spawning in the wild. Trap counts provide some insights into the spatial structure of spawners at a watershed level, but the details provided by redd counts during spawner surveys enhance our understanding of escapement and wild production at a finer geographic scale. Spawning was documented in all three SHRUs and monitoring of both spawning activity and conservation hatchery supplementation programs allow an informative evaluation of habitat occupancy and juvenile production potential.

We evaluated the spatial structure of juvenile production by modeling occupancy at a sub drainage level - USGS Hydrologic Unit Codes (HUC)-12 level - to describe recruitment at a spatial scale proposed to better manage critical habitat. This evaluation informs managers relative to the most likely habitats where wild spawning or juvenile stocking has produced freshwater production cohorts. These summaries provide visual products to better evaluate production habitat use at a SHRU level while also providing quantitative estimates of occupancy in Critical Habitat management areas. These evaluations can assist in evaluation of the spatial structure of production and set expectations for natural-reared production based on modeled habitat use.

Our spatial assessment objectives this year were to 1) calculate first-year salmon distribution for wild production of spawners in 2020 and 2) visualize and quantify distribution of the likely juvenile distributions of three freshwater production cohorts across watersheds. These evaluations provide metrics to measure the relative impact of wild spawning and supplementation in each of the three SHRUs. This is the first year this method has been applied to multiple cohorts and should be considered provisional. This approach is evolving to provide a tool to allow a better understanding of spatial drivers and relative contributions of wild and stocked production on pre-smolt populations. Our goal was to further develop and vet these summary metrics as tools to both investigate both gaps in assessment data and inform hatchery stocking practices to reduce interactions between wild-spawned and hatchery fish. Overall, improved spatial data should help managers understand production shortfalls (wild and hatchery supplementation) to better optimize natural smolt production across critical habitat at a watershed level.

2.4.1 Wild Production Areas – Redd Distributions and the 2022 Cohort

Spawner surveys in 2021 covered 2,570 units (24%) of 10,900 units of mapped spawning habitat (see Section 5). This coverage is similar to previous years since surveys are limited to managed drainages. Given the low spawner escapement relative to available habitat, monitoring is limited in MMB and PNB habitat but focused on priority management areas. In the DEC SHRU where redd surveys consistently exceed 80% coverage, estimates of wild production areas more accurately represent overall production. In MMB, redd counts generally capture expected redds related to documented escapement and likely closely represent overall wild production. In PNB, escapement and redd surveys are more variable and spawning areas are expansive and not well described nor well surveyed. As such, while provided for context, the PNB occupancy maps underrepresented wild production.

The geolocation of redds in 2021 was used to document WPA of the 2022 yearclass in these river systems. The spatial extent of WPA assumes an upstream distribution of juveniles of 0.5 km upstream and 1 km downstream (including tributary streams). Within a HUC-12 the proportion occupancy ranged from 0 to 0.67 (Figure 2.4.1.1). These WPA will be buffered from stocking next year to minimize competition between wild and hatchery origin juveniles. Additionally, in two years, these areas will be targeted for broodstock collection during electrofishing efforts to bring components of wild spawning into the reared brood program.

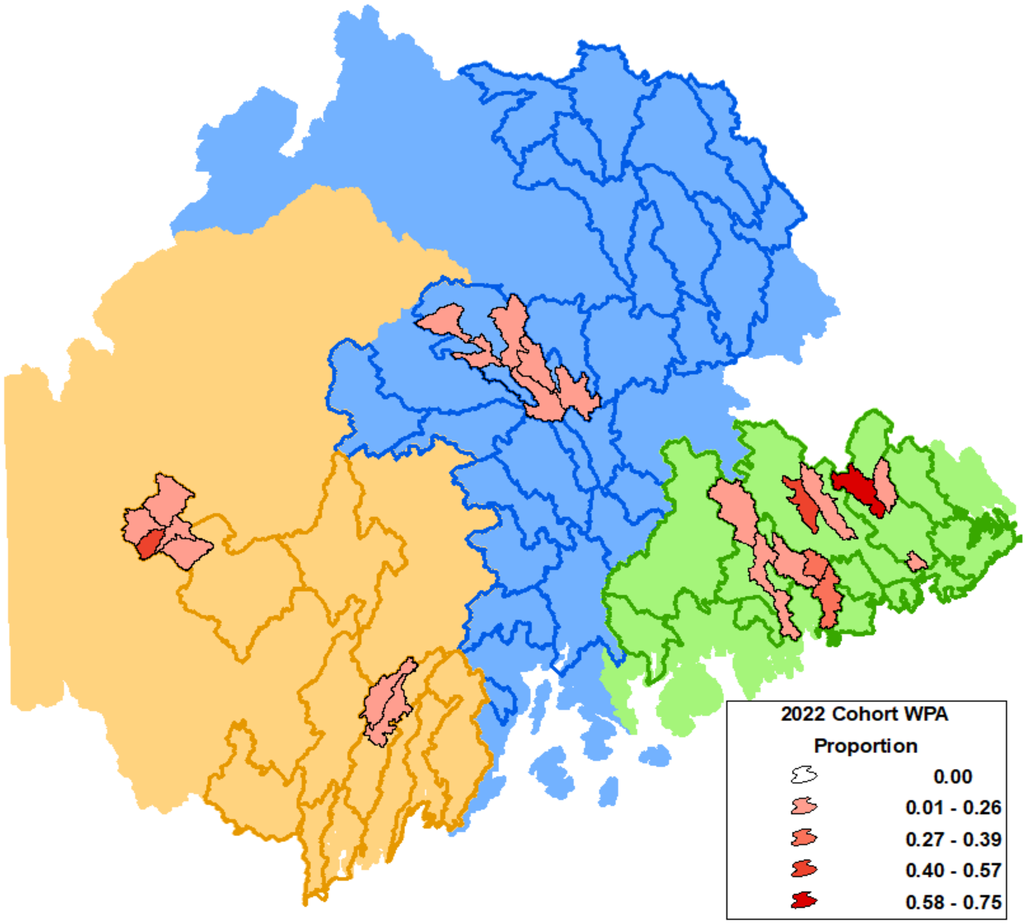

Figure 2.4.1.1 Map highlighting wild production for the 2022 cohort in individual HUC 12 areas where redds were documented in autumn 2021 and redd dispersion was modeled to indicate occupancy (fish present or absent). For example, for 100 units of habitat, if the distribution model predicted fish in 15 units – proportion occupancy would be 0.15.

2.4.2 Freshwater Cohorts and Hatchery Production Units

An important element of GOM DPS Atlantic salmon populations is their dependence on conservation hatcheries (Legault 2005). Since most US salmon are products of stocking, it is important to understand the magnitude, types, and spatial distribution of these inputs to understand juvenile spatial structure throughout Critical Habitat. Atlantic salmon hatcheries are operated by the U.S. Fish and Wildlife Service (USFWS) and the Downeast Salmon Federation (DSF). All egg takes occur at USFWS facilities operating as conservation hatcheries that collect fish from remnant local stocks within the GOM DPS and produce products to stock back into their natal rivers. In some cases, donor populations are used to stock vacant critical habitat in the GOM DPS range to re-establish production. For example, the Sandy River in the MMB SHRU has received donor stocking from the Penobscot and Dennys Rivers populations. From a management perspective, rebuilding Atlantic salmon populations will require increasing natural production of smolts in all available Critical Habitat (Recovery Plan). This management is focused on best use of hatchery production to optimally maintain population diversity, habitat occupancy, and effective population sizes. Examining the spatial contributions of multiple cohorts provides insights into likely gaps in freshwater production and where they occur on the landscape. This will provide an information base to further examine fish dispersal, optimal production areas, and site-specific stocking targets. Ultimately, these data should inform targeted management at a more refined spatial scale than an entire watershed and facilitate sub-drainage (HUC12) management.

The goal of this spatial analysis is to visualize and assess freshwater production at a HUC-12 level. This composite of freshwater production comes from a GIS Analysis of wild production from redds combined with naturally reared production resulting from spatially explicit stocking data for egg-planted, fry stocked, or parr stocked juveniles. This freshwater production yields both wild and naturally reared smolts that are an important conservation tool because these supplementation methods are designed to minimize selection for hatchery traits at the juvenile stage. Analyses show that these wild and naturally reared smolts typically have a higher (4-7 times) marine survival rate than hatchery reared smolts. The numbers of hatchery fish released, and eggs planted in the GOM DPS are presented in Section 5. The focus here is on the distribution of these fish throughout critical habitat and providing insights on densities relative to optimizing habitat use.

For this assessment, we modeled the occupied freshwater production habitat in December. This summary was based on production from both natural redds (WPA) and geo-referenced stocking locations. For this analysis, we assume that 3 cohorts of fish comprise the overall freshwater population. Numerically most juveniles would be age-0 (2021 cohort). By biomass, age-1 (2020 cohort) fish would dominate as they comprise most of the pre-smolt population and would be the second most abundant age class. Finally, a smaller number of age-2 (2019 cohort) fish would make up the balance of the river population. Occupancy was estimated by geospatial documentation of both WPA and egg planting and juvenile stocking for each cohort through November 2021. All input data were georeferenced and the Atkinson-Kocik occupancy model was used to document dispersal rates (Working Paper in Progress). We are continuing to develop these methods and metrics. As noted above, the spatial extent of WPA assumed an upstream distribution of juveniles of 0.5 km upstream and 1 km downstream (including tributary streams). Similar dispersions were calculated for all hatchery products as well. These hatchery production areas are Egg Planted Production Areas (EPA) that are based on point positions of artificial redds and similar diffusion models as WPA. For Fry or Parr stocked production areas (FPA or PPA), these areas are based on linear distances stocked and a similar diffusion model from both the upstream stocking point and downstream end of the reach. By combining all these production areas, we can estimate both occupancy and the amount of vacant CH (vacant CH = total CH – WPA – EPA- FPA-PPA). These values should be considered minimal occupancy areas because: not all redds are counted, assumptions on dispersion while well supported in literature and local data, need additional study, and weighting of redd survey areas needs further refinement Figure 2.4.1.2.

By organizing these data spatially, the Stock Assessment Team is providing a resource to further refine occupancy by targeting areas to conduct juvenile assessments and to further refine density and dispersion measures. Until there is significantly more wild production and/or greatly increased hatchery that would allow complete use of all HUC12 units in critical habitat, it is important to look at juvenile production spatially to examine effort and approaches to supplementation to maximize smolt production. This can be accomplished by considering production density at a HUC12 level and projecting climate impacts on habitats and distinct individual populations. The next steps of spatial stock assessment will work towards integrating density based on historic electrofishing and other sources. Independent efforts to look at climate resilience could then be merged with this spatial assessment to better manage Atlantic salmon habitat, hatchery supplementation, and passage priorities to support salmon conservation now and in the future.

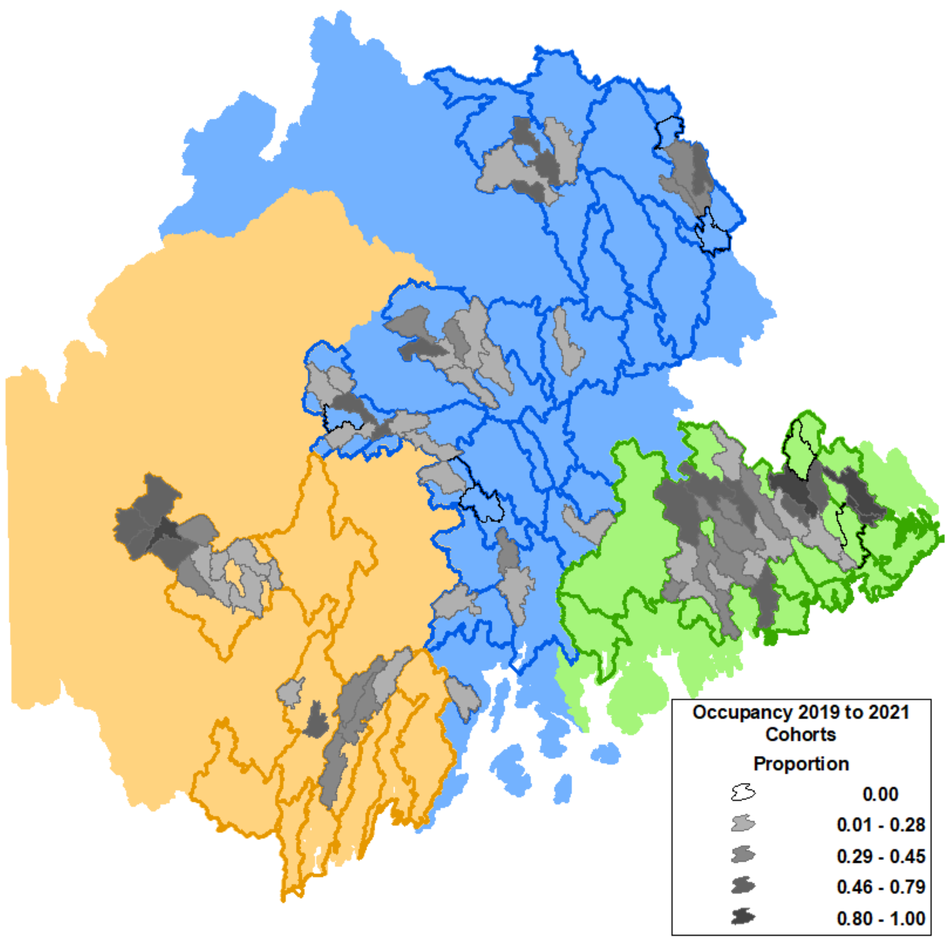

Figure 2.4.1.2 Map highlighting the relative proportion of river habitat occupied (see figure legend) the last 3 years of cohorts at a HUC-12 watershed summary level. Production is a synthesis of modeled distributions from spawning surveys of Atlantic salmon in the autumn preceding the cohort year and the cohort year of egg planting and fry and parr stocking.

2.5 Genetic Diversity

As part of the Atlantic salmon recovery program, maintenance of genetic diversity is a critical component of the process. Genetic diversity for the Atlantic salmon program is monitored through assessment of collected broodstock from the wild, which represent both individuals from natural reproduction and stocked individuals from the hatchery. Identification of origin (hatchery or wild) is determined through genetic parentage analysis. Therefore, estimates of these two groups combined represent the total genetic diversity present in the various populations monitored. At publication time, updated diversity data were not available for the 2019 (coastal rivers) and 2021 (Penobscot) cohorts.

Effective population size (N_e) is defined as the size of an ideal population (N) that will result in the same amount of genetic drift as the actual population being considered. Many factors can influence N_e, such as sex ratios, generation time (Ryman et al. 1981), overlapping generations (Waples 2002), reproductive variance (Ryman and Laikre 1991), and gene flow (Wainwright and Waples 1998). Applied to conservation planning, the concept of Ne has been used to identify minimal targets necessary to maintain adequate genetic variance for adaptive evolution in quantitative traits (Franklin and Frankham 1980), or as the lower limit for a wildlife population to be genetically viable (Soulé 1987). Estimation of N_e in Atlantic salmon is complicated by a complex life history that includes overlapping generations, precocious male parr, and repeat spawning (Palstra et al. 2009). Effective population size is measured on a per generation basis, so counting the number of adults spawning annually is only a portion of the total N_e for a population. In Atlantic salmon, Palstra et al. (2009) identified a range of N_e to N ratios from 0.03 to 0.71, depending on life history and demographic characteristics of populations. Assuming a N_e to N ratio of 0.2 for recovery planning, the N_e for a GOM DPS of Atlantic salmon population should be approximately equal to the average annual spawner escapement, assuming a generation length of 5 years. Although precocious male parr can reproduce and therefore be included in estimates of the number of adult spawners, Palstra et al. (2009) determined that reproduction by male Atlantic salmon parr makes a limited contribution to the overall Ne for the population.

For the GOMDPS our diversity goals are to 1) monitor genetic diversity of each of broodstock; 2) screen for non-DPS origin fish in the broodstock (including commercial aquaculture escapees) and 3) evaluate diversity to help inform hatchery practices, stocking activities and other recovery activities. Of 8 extant stocks, 7 are in the conservation hatchery program. The Penobscot River is supported by capture of returning sea-run adult broodstock at Milford Dam, which are transported to Craig Brook National Fish Hatchery for spawning. A domestic broodstock, maintained at Green Lake National Fish Hatchery, also supports production in the Penobscot River, and is created annually by offspring from the spawned sea-run adults at Craig Brook National Fish Hatchery. Six other populations have river-specific broodstocks, maintained by parr-based broodstocks, comprising offspring resulting from natural reproduction which may occur, or primarily recapture of stocked fry.

2.5.1 Allelic Diversity

A total of 18 variables, microsatellite loci, are used to characterize genetic diversity for all individuals considered for use in broodstocks (Figure 2.5.1). Loci analyzed were *Ssa197*, *Ssa171*, *Ssa202*, *Ssa85* (O'Reilly et al. 1996), *Ssa14*, *Ssa289* (McConnell et al. 1995), *SSOSL25, SSOSL85*, *SSOSL311*, *SSOSL438* (Slettan et al. 1995, 1996), and *SSLEEN82* (GenBank accession number U86706), *SsaA86*, *SsaD157*, *SsaD237*, *SsaD486*, (King et al 2005), *Sp2201*, *Sp2216*, and *SsspG7* (Paterson et al. 2004). Individuals characterized represent either parr collected for broodstock purposes (Dennys, East Machias, Machias, Narraguagus, Pleasant, and Sheepscot rivers), or adults returning to the Penobscot River and collected for broodstock at USFWS Craig Brook National Fish Hatchery. Individuals represent those to be used for broodstock purposes following screening of any individuals to be removed based on screening to remove potential aquaculture origin individuals, or landlocked Atlantic salmon. Annual characterization allows for comparison of allelic diversity between broodstocks, and over time. A longer time series allows for comparison of allelic diversity from the mid 1990's, but with a subset of 11 of the 18 loci. For this report, evaluating allelic diversity based on 18 loci, between 2008 and 2018 collection years (or from 2008 to 2020 in the case of the Penobscot broodstock), the average number of alleles per locus ranged from 10.69 alleles per locus for the Pleasant River to 13.44 alleles per locus for the Penobscot River.

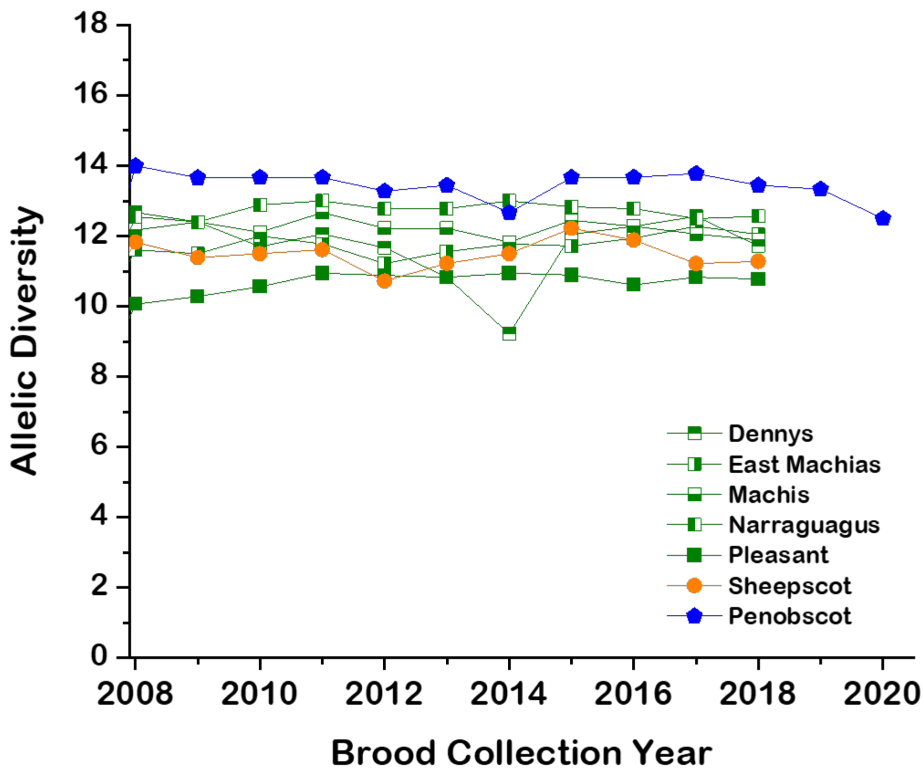

Figure 2.5.1.1. Allelic diversity time series for GOM DPS salmon populations, measured from 18 microsatellite loci. purposes (DE- Dennys, EM-East Machias, MA- Machias, NA-Narraguagus, PN-Penobscot, PL-Pleasant, SH-Sheepscot populations).

2.5.2 Observed and Expected Heterozygosity

Observed and expected heterozygosity is estimated for each broodstock. For the 2018 collection year parr broodstock and 2020 collection year Penobscot adult returns, average estimates starting in 2008 of expected heterozygosity based on 18 microsatellite loci ranged from 0.67 in the East Machias to 0.688 for the Penobscot broodstock. Observed heterozygosity estimates based on 18 loci ranged from 0.676 in the Machias to 0.707 in the Penobscot broodstock.

2.5.3 Effective Population Size

Estimates of effective population size, based on 18 loci, vary both within broodstocks over time, and between broodstocks. Estimates are obtained using the linkage disequilibrium method which incorporates bias correction found in Ne Estimator (V2.01, Do et al. 2013). Estimates are based on the minimum allele frequency of 0.010, and confidence intervals are generated by the jackknife option. Parr-based broodstocks typically incorporate a single year class, thereby not violating assumptions for effective population size estimates of overlapping generations. Within the parr-based broodstocks, the lowest N_e from the 2018 collection year was estimated for the Dennys broodstock (N_e =44.6, 36.6-54.5 95% CI), and the highest was observed in the Narraguagus broodstock (N_e =137.6 (110.4-176.0 95% CI). N_e estimates fluctuate annually, so beginning with 2008, average N_e across the parr-based broodstocks ranges from N_e=69.1 in the Dennys to N_e =143.6 in the Narraguagus. Within the Penobscot River, adult broodstocks typically include three to four year classes (including grilse). N_e estimates for the Penobscot since 2008 have ranged from maximum N_e =546.5 (465.8-650.7 95% CI) in 2017 to the low N_e =287.6 in 2009 (265.7-312.0 95% CI), with an average N_e =417.3. The N_e estimate for the 2020 return the broodstock N_e = 417.9 (302.3-644.2 95% CI).

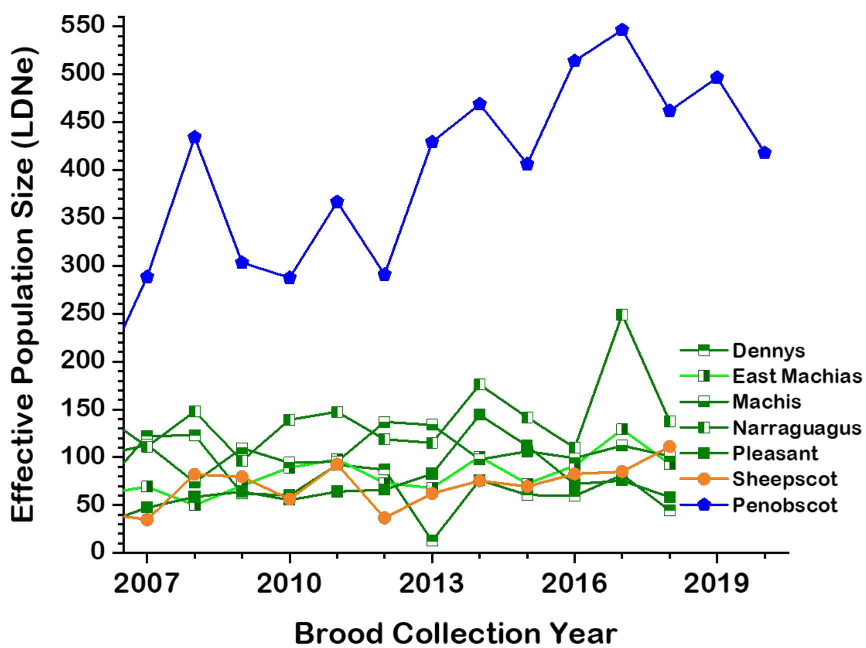

Figure 2.5.1.2. Time series of effective population size for seven GOM DPS distinct individual populations. Estimates for the parr-based broodstock populations approximate the number of breeders, since estimates are obtained from primarily a single cohort, and are sampled as juveniles (parr), from each river. Estimates of effective population size for the Penobscot broodstock are obtained from returning adults in a given year to the Penobscot River, and represent multiple cohorts (DE- Dennys, EM- East Machias, MA- Machias, NA-Narraguagus, PN-Penobscot, PL-Pleasant, SH-Sheepscot populations).

2.5.4 Inbreeding Coefficient

Inbreeding coefficients are an estimate of the fixation index. Estimates in the 2018 parr collection year ranged from -0.007 in the Dennys River to -0.044 in the Sheepscot River. The 2020 collection year for the Penobscot had an estimated inbreeding coefficient of -0.028.

2.5.5 Summary

Maintenance of genetic diversity within Maine Atlantic salmon populations is an important component of restoration. Past population bottlenecks, the potential for inbreeding, and low effective population sizes that have been sustained for multiple generations contribute to concerns for loss of diversity. Contemporary management of hatchery broodstocks, which consists of most of the Atlantic salmon currently maintained by the population, works to monitor estimates of diversity and implement spawning and broodstock collection practices that contributed to maintenance of diversity. Overall, genetic diversity as measured by allelic variability has been maintained since the start of consistent genetic monitoring in the mid 1990's, although there are concerns about slightly lower estimates of allelic diversity in the Sheepscot and Pleasant relative to the other broodstocks. Implementation of pedigree lines in the past to retain representatives of all hatchery produced families helped to limit loss of diversity resulting from a genetic bottleneck in the Pleasant River, along with active management to limit loss of diversity through stocking and broodstock collection practices. However, low sustained estimates of effective population size in the six parr-based broodstocks should continue to be monitored, as it indicates that populations are at a risk for loss of genetic diversity.

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3 Long Island Sound

3.1 Long Island Sound: Connecticut River

The Connecticut River Atlantic Salmon Restoration Program formally ceased in 2013 and in 2014 the new Atlantic Salmon Legacy Program was initiated by the Connecticut Department of Energy and Environmental Protection (CTDEEP). The Connecticut River Atlantic Salmon Commission (CRASC) maintained an Atlantic Salmon Sub-committee to deal with lingering issues of salmon throughout the watershed. Partner agencies other than the CTDEEP focused on operating fish passage facilities to allow upstream and downstream migrants to continue to access habitat but no further field work was conducted by other agencies. CRASC and its partners continued to work on other diadromous fish restoration. The following is a summary of work on Atlantic salmon.

3.1.1 Adult Returns

Four sea-run Atlantic salmon adults were observed returning to the Connecticut River watershed. Three were observed by video passing up the Rainbow Fishway on the Farmington River and not handled. One was observed by an experienced salmon biologist while snorkeling below the Leesville Fishway on the Salmon River and not handled. Last year, no adult salmon returned.

3.1.2 Hatchery Operations

A total of 650,646 green eggs was produced. Only the Kensington State Fish Hatchery (KSFH) in CT maintained domestic broodstock. Contributing broodstock included 123 females and 123 males. Both males and females were a mix of 3+ and 4+ year old fish but some 2+ males were also used. Those eggs will be used for fry stocking for the Connecticut Legacy Program including the Salmon-in-Schools program.

3.1.3 Stocking

3.1.3.1 Juvenile Atlantic Salmon Releases

A total of **33,585 j**uvenile Atlantic Salmon was stocked into the Connecticut River watershed, all in Connecticut. Selected stream reaches in the Farmington River were stocked with fed fry. Stocking was conducted out of KSFH. This was the fewest fry stocked in recent years due to a malfunction of the water chiller that resulted in mass mortality of eggs. Due to the low number of available eggs, the Tripp Streamside Incubation Facility (TSIF), which has received and hatched eggs in the past, was not provided eggs. The Salmon River normally receives fry from the TSIF but it was not stocked in 2021. In addition, unfed fry were stocked in various approved locations within the Salmon and Farmington rivers by schools participating in the Salmon in Schools programs, in which they incubate eggs for educational purposes and stock surviving fry. No estimate of the number of fry released is available due to complications resulting from the COVID pandemic.

3.1.3.2 Surplus Adult Salmon Releases

Domestic broodstock surplus to program needs from the KSFH were stocked into the Shetucket and Naugatuck rivers and two selected lakes in Connecticut to create sport fishing opportunities outside the Connecticut River basin.

3.1.4 Juvenile Population Status

3.1.4.1 Smolt Monitoring

No videography monitoring of the smolt migration at the viewing window at the Rainbow Dam Fishway (Farmington River) occurred in 2021 due to staff shortages.

3.1.4.2 Index Station Electrofishing Surveys

No electrofishing surveys of juvenile salmon populations were conducted in 2021.

3.1.5 Fish Passage

3.1.5.1 Hydropower Relicensing-

Similar to the past several years, State and federal resource agencies continued to spend considerable time on FERC-related processes for the re-licensings of four mainstem dams and one pumped storage facility. This includes requesting and reviewing the results of numerous studies of fish population, habitat, and fish passage and discussions of a possible Settlement Agreement. During 2021, the Parties once again entered into Settlement Agreement talks, which have proceeded in a confidential manner. At the time of this report, an Agreement has been signed by the Parties in respect to recreation and an Agreement in respect to flow and fish passage is expected to be signed very soon. No details about these agreements are available. Since no salmon are stocked upstream of the Holyoke Dam, such agreements have little relevance to Atlantic salmon.

3.1.5.2 Fish Passage Monitoring-

Salmonsoft® computer software was again used with lighting and video cameras to monitor passage at Turners Falls, Vernon, Bellows Falls, Wilder, Rainbow and Moulson Pond fishways. The software captures and stores video frames only when there is movement in the observation window, which greatly decreases review time while allowing 24h/d passage and monitoring. Many diadromous fish species were observed and counted using this technology but salmon were observed only at the Rainbow Fishway.

3.1.5.3 New Fishways-

A new fishway was completed during 2021 at the Upper Collinsville Dam Fishway on the Farmington River in the town of Canton, CT. This fishway is a license requirement as part of a FERC license issued to Canton Hydro, LLC. It will benefit Atlantic salmon since the Legacy program stocks fry upstream of this dam and smolts migrate downstream. A Denil fishway and counting facility and a downstream passage facility were designed and approved by the CTDEEP and the USFWS. It was hoped that it would be operational during the 2021 fish passage season but that did not occur due to construction delays. Although the fishway is now completed, the crest gates on the spillway (part of the hydro project) have not been installed. The fishway cannot be operated until the pond level is raised by the crest gates and it is not clear if that will happen prior to the 2022 fish passage season.

3.1.5.4 Dam Removals-

No dams in the basin were removed in 2021 but planning continued for some projects that hopefully will be implemented and reported in the future.

3.1.5.4 Culvert Fish Passage Projects-

No information is available for 2021.

3.1.6 Genetics

The genetics program previously developed for the Connecticut River program has been terminated. Best accepted broodstock management practices are attempted at the KSFH.

3.1.7 General Program Information

The use of salmon egg incubators in schools as a tool to teach about salmon continued in Connecticut. The Connecticut River Salmon Association, in cooperation with CTDEEP, maintained its Salmon-in-Schools program, providing 8,000 eggs for 40 tanks in 32 schools in Connecticut.

A total of 800 0+ parr from KSFH were provided to Dr. Steve McCormick of the Silvio Conte Anadromous Research Center in Turners Falls, MA to support Atlantic Salmon research.

3.1.8 Migratory Fish Habitat Enhancement and Conservation

There were several stream restoration projects throughout the basin but since most of them no longer impact Atlantic salmon habitat, they will not be listed here.

3.2 Long Island Sound: Pawcatuck River

Although a small portion of the watershed lies in Connecticut, all activities involving Atlantic Salmon have been conducted solely by Rhode Island Department of Environmental Management (RIDEM) within the state of Rhode Island. RIDEM still continues minimal efforts with salmon. The following is a summary of available information.

3.2.1 Adult Returns

No adult salmon were known to have returned to the river.

3.2.2 Hatchery Operations

RIDEM's Lafayette Trout Hatchery produced 6,000 eggs from its Sebago Lake broodstock. All of the eggs were used to support the Salmon-in-the-Classroom program.

3.2.3 Stocking

A total of 3,200 fry were stocked into the watershed by participating schools in the Salmon-in-the-Classroom program.

3.2.4 Juvenile Population Status

There is no report of any electrofishing surveying being conducted in 2021.

3.2.5 Fish Passage

No additional work in 2021.

3.2.6 Genetics

No genetics program relative to the broodstock program was reported.

3.2.7 General Program Information

The Salmon in the Classroom program continues to grow with 16 schools participating in the 2020-21 season, totaling 16 tanks (Number of tanks in 2020 = 40).

3.2.8 Migratory Fish Habitat Enhancement and Conservation

No special fishway or dam removal projects were reported.

4 Central New England

4.1 Merrimack River

4.1.1 Adult Returns

A total of four sea-run Atlantic salmon was counted in the Merrimack River at the Essex Dam fishway, Lawrence, MA. None of these fish were handled, sampled nor transported to the Nashua National Fish Hatchery (NNFH), NH. Instead all fish were allowed to continue to migrate up the river. There were no subsequent reports or observations of them.

The origin of these fish is unknown, with several possibilities of origin. The most likely are these fish could have been products of natural spawning in the Merrimack by previously released adult salmon or strays from nearby rivers in Maine. No age or other data could be collected because they were not handled, but some presumptive data based upon past experience from this river were entered into the database to account for all returning fish.

4.1.2 Hatchery Operations

Atlantic salmon were not spawned at NNFH in 2020. The final year of spawning Merrimack strain salmon at NNFH occurred in the fall of 2018. There were no salmon broodstock nor juvenile salmon on station in 2020 that were designated for use in the Merrimack River.

4.1.3 Juvenile Population Status

No parr assessment was conducted in the watershed.

4.1.4 General Program

The USFWS and state partners previously terminated the program. There was no salmon program or activities in 2020.

Atlantic salmon Broodstock Sport Fishery

The last of the broodstock designated for a sport fishery were stocked in December of 2019 (total of 1,117). No fish were stocked in 2020.

Adopt-A-Salmon Family

This program was not active in 2020.

4.2 Saco River

4.2.1 Adult Returns

Brookfield Renewable Energy Partners operated three fish passage-monitoring facilities on the Saco River. The Cataract fish lift, located on the East Channel in Saco and the Denil fishway-sorting facility located on the West Channel in Saco and Biddeford, operated from 1 May to 31 October 2020. Only visual observations were recorded at the East Channel of Cataract. Three adults were observed to pass this facility. Four Atlantic salmon were captured, at a third passage facility upriver at Skelton Dam, which operated from 8 May to 31 October 2020. A total of six Atlantic salmon returned to the Saco River for the 2020 trapping season. However, the count could exceed six due to the possibility of adults ascending Cataract without passing through one of the counting facilities.

4.2.2 Hatchery Operations

Egg Collection

The Saco Salmon Restoration Alliance & Hatchery (SSRA) has ceased receiving eggs from Nashua National Fish Hatchery. The remaining broodstock (52) from Nashua were transferred and spawned at the University of New England (UNE). In the fall of 2020, the UNE staff spawned 18 adult salmon and transferred the eggs to the SSRA Hatchery. The eggs will be used to supplement the Saco River as well as support the Salmon in Schools Program.

Broodstock Collections

In October, 156 naturally reared and wild parr were taken from Swan Pond Stream, a tributary to the Saco River.

4.2.3 Stocking

Juvenile Atlantic salmon Releases

In 2020, the SSRA planted 24,000 eyed-eggs in two tributaries, Swan Pond Stream and Cooks Brook to the Saco River.

Adult Salmon Releases

In February 49 retired broodstock adult Atlantic salmon were stocked into the Saco River below the lowermost mainstem dam on the Saco River.

4.2.4 Juvenile Population Status

Index Station Electrofishing Surveys

MDMR did not conduct any electrofishing surveys in the Saco River watershed in 2020.

Smolt Monitoring

There was no smolt monitoring in 2020.

Tagging

No salmon outplanted into the Saco were tagged or marked in 2020.

4.2.5 Fish Passage

No changes were made to any passage facilities on the Saco River in 2020.

4.2.6 Genetics

All adult returns captured at Skelton Dam are tissue sampled. Samples are preserved and kept at MDMR in Augusta. Currently no plans have been made to characterize them genetically.

4.2.7 General Program Information

In 2019 the SSRA began a partnership with the UNE. The partnership relies on the UNE to rear broodstock and assist the SSRAH with spawning. UNE is holding the last Merrimack River broodstock adults which were spawned in the fall of 2020.

In addition, to maintain a source of broodstock the SSRA will collect parr. The parr will be taken annually from the Saco River drainage and be reared until spring in the SSRA hatchery and then transferred to the UNE. In the Fall of 2020, 156 parr were collected from two tributaries to the Saco River.

4.2.8 Migratory Fish Habitat Enhancement and Conservation
No habitat enhancement or conservation projects directed solely towards Atlantic salmon were conducted in the watershed during 2020.

5 Gulf of Maine

5.1 Summary
Documented adult Atlantic salmon returns to rivers in the geographic area of the Gulf of Maine Distinct Population Segment (73 FR 51415-51436 - NMFS 2009) in 2021 was 676. Returns are the sum of counts at fishways and weirs (591) and estimates from redd surveys (85). No fish returned "to the rod" because angling for Atlantic salmon is closed statewide. Counts were obtained at fishway trapping facilities on the Androscoggin, Narraguagus, Penobscot, Kennebec, and Union rivers.

Escapement to these same rivers in 2021 was 529 (Table 5.1). Escapement to the Gulf of Maine (GOM) Distinct Population Segment (DPS) area equals releases at traps and free swimming individuals (estimated from redd counts) plus released pre-spawn captive broodstock (adults used as hatchery broodstock are not included) and recaptured downstream telemetry fish.

Naturally reared growth rates to the DPS has varied since 1990 although the rate has been somewhat consistent since 1997 with a mean of 0.89, (Figure 5.1). Most of these were 2SW salmon that emigrated as 2-year-old smolt, thus, cohort replacement rates are calculated assuming a five-year lifespan. To show sustained improvement, population growth is observed for at least two generations (10 years). The 10-year geometric mean naturally reared growth rate for the period 2012 to 2021 is 0.96 (0.57 – 1.61) for the DPS. Dividing this further by Salmon Habitat Recovery Unit (SHRU), Merrymeeting Bay was 1.40 (0.89 – 2.18) saw the largest growth rate, Penobscot Bay was 0.97 (0.47 – 2.01) and Downeast Coastal was 0.81 (0.51 – 1.30). This indicates that the DPS has been hovering right around replacement. It's likely that consistent stocking rates have helped maintain the replacement rate and variations are due to marine survival. Naturally reared returns are still well below 500 (Fig. 5.2). For more detail on population growth rates, see Section 2.3 above.

Table 5.1. Table of 2021 sea-run returns versus escapement for drainages with trapping facilities and drainages using the redds based estimate. Narraguagus returns are included in the redd estimate total.

Drainage	Returns	Brood Stock	DOA	Escapement	Captive Pre-Spawn	Sea-run Pre-Spawn	Total Escapement
Androscoggin	5	0	0	5	0	0	5
Kennebec	25	0	0	25	0	0	25
Narraguagus	--	--	--	--	--	--	--
Penobscot	561	147	1	413	0	1	414
Union	0	0	0	0	0	0	0
Redds Estimate	85	N/A	N/A	85	0	0	85
	676	147	1	528	0	1	529

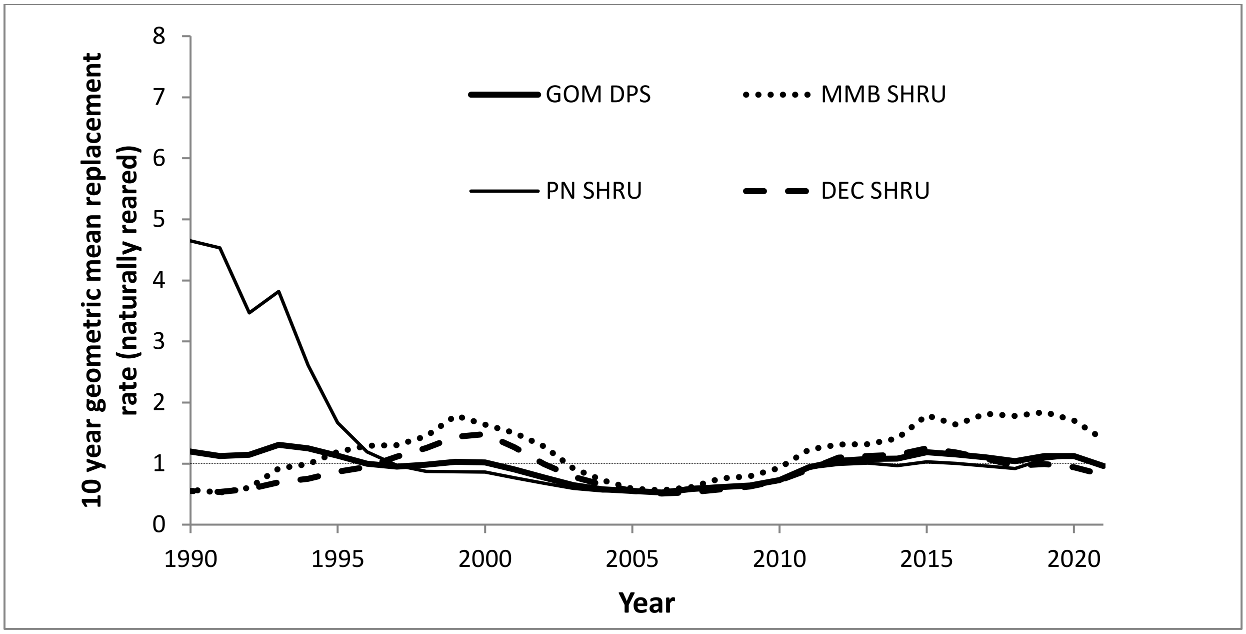

Figure 5.1. Ten-year geometric mean of replacement rate for returning naturally reared Atlantic salmon in the Gulf of Maine Distinct Population Segment and the three Salmon Habitat Recovery Units.

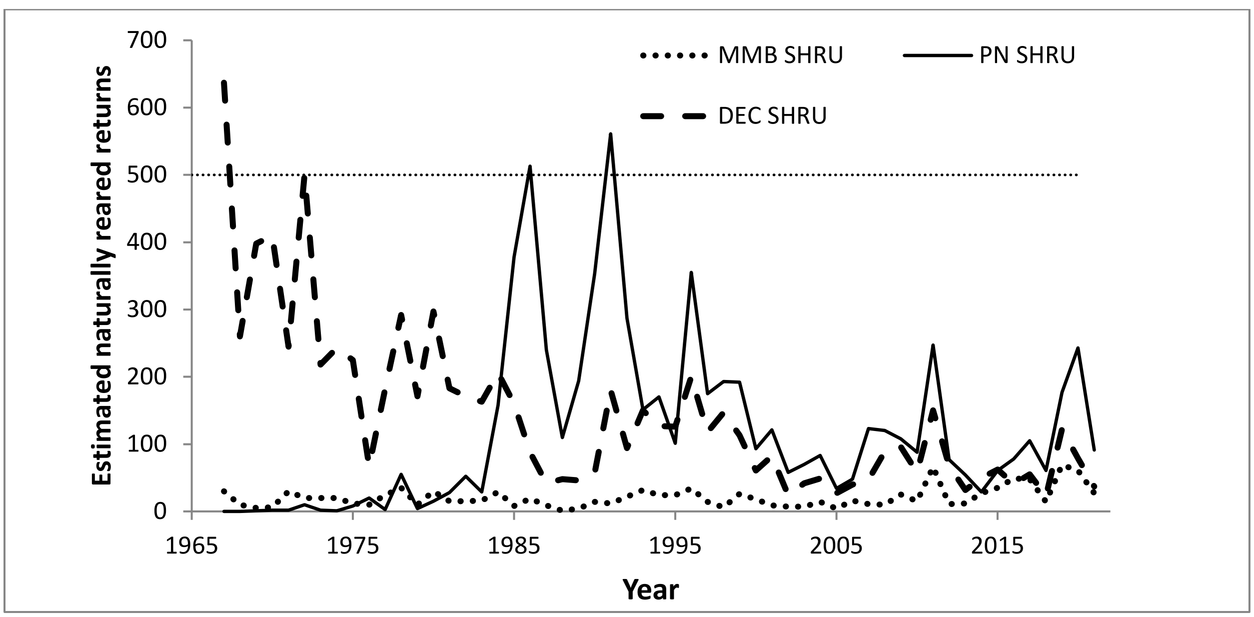

Figure 5.2 Estimated Naturally Reared Returns to the Gulf of Maine 1965 to 2021. Naturally reared refers to the egg, fry, and 0+parr life stages.

5.2 Adult returns and escapement

5.2.1 Merrymeeting Bay

5.2.1.1 Androscoggin River

The Brunswick fishway trap was operated from 30 April to 15 November 2021 (Table 5.1.1) by a combination of MDMR and Brookfield Renewable Partners (BRP) staff. Five adult Atlantic salmon were passed at the Brunswick fishway trap. These consisted of 4 (80.0%) hatchery reared grilse (1SW) and 1 (20.0%) naturally reared 2SW adult.

Occasionally an adult Atlantic salmon will pass undetected through the fishway at Brunswick during maintenance/cleaning, so a minimal redd count effort was conducted. Two small sections of the Little River where redds have been documented in past years were surveyed for redd presence, totaling 1.0 river kilometers covered.

5.2.1.2 Kennebec River

The Lockwood Dam fish lift was operated by BRP staff from 1 May to 31 October 2021. Twenty-three adult Atlantic salmon were captured at the lift (Table 5.1.1). In addition, due to the dam's configuration, adults occasionally need to be rescued from a set of ledges in the bypass canal. In July one additional salmon was captured in the bypass channel and trucked upstream. An electrofishing crew sampling below Lockwood captured one salmon that was released below Lockwood bringing the total returns to the Kennebec River to 25. Biological data were collected from the 23 lift captured returning Atlantic salmon in accordance with Maine Marine Resources (MDMR) protocols, and the presence of marks and tags were recorded. The other two were prorated for origin and age. Of the 25 returning Atlantic salmon, 17 (68%) were 2SW, 8 (32%) were grilse (1SW). Four of the returning grilse (16%) were of hatchery origin.

Spawning surveys were limited to the Sandy River, Togus Stream and Bond Brook. Nine redds were observed in the Sandy River and none in Bond Brook or Togus Stream. A total of 73.37 river kilometers were surveyed which contained 21.25% of the spawning habitat in the Kennebec River drainage. Sandy River surveys covered 66.11 river kilometers and 59% of the spawning habitat. Togus Stream surveys covered 100% of the spawning habitat and the Bond Brook surveyed covered 86.3% of the spawning habitat.

Sebasticook River at Benton Falls fish lift facility was operated by MDMR staff from 01 May to 31 October 2021. No Atlantic salmon were captured (Table 5.1.1).

5.2.1.3 Sheepscot River

There were 7 redds observed in the Sheepscot River; five were observed in the mainstem and two were observed in the West Branch. The 7 redds were likely from sea-run adults. A total of 30.43 river kilometers were surveyed which contained 80.29% of the spawning habitat in the drainage. The Redds Based Returns model estimate was 11 (95% 4 to 29).

5.2.2 Penobscot Bay

5.2.2.1 Penobscot River

The fish lift at the Milford Hydro-Project, owned by BRP, was operated daily by MDMR staff from 15 April through 15 November. The fish lift was also used to collect adult sea-run Atlantic salmon broodstock for the U.S. Fish and Wildlife Service (USFWS). In addition to the Milford fish lift, BRP operated a fish lift daily at the Orono Hydro project. The counts of salmon collected at that facility are included in the Penobscot River totals.

A total of 561 sea-run Atlantic salmon returned to the Penobscot River (Table 5.1.1). Scale samples were collected from 222 salmon captured in the Penobscot River and analyzed to characterize the age and origin structure of the run. In addition, video monitoring is conducted at the Milford Dam to aide in counts when environmental conditions warrant reduced handling, i.e. warm water temperatures. The origins of the video counted and trapped Atlantic salmon that were not scale sampled were prorated based on the observed proportions, considering the size, presence of tags or marks observed and dorsal fin deformity. Of returning salmon, 7 were 3SW (1%), 343 were age 2SW (61%), 207 were age 1SW (37%), and 4 were repeat spawners (<1%). Hatchery origin returns were 84% (470) of the returning salmon and the remaining 16% (91) were naturally reared origin. No aquaculture suspects were captured.

Spawner surveys in the Penobscot were limited to the Piscataquis River, Cove Brook and the Ducktrap River. In the Ducktrap 37.81% of spawning habitat and 0.89 of river km were surveyed. No redds were observed. In Cove Brook, 50.48% of spawning habitat and 1.54 river km were surveyed. There were no redds observed in Cove Brook. In the Piscataquis Drainage a total 26.4 river km and 11.77% of the spawning habitat were surveyed. Twelve redds were observed in the East Branch (4) and West Branch (3) Pleasant River and 5 in Schoodic Brook (Table 5.1.2)

5.2.3 Downeast Coastal

5.2.3.1 Dennys River

There were no redds observed in the Dennys River in 2021. Surveys covered 85.25% of the habitat and 34.25 km of stream.

5.2.3.2 East Machias River

Eighteen redds were counted during the 2021 redd surveys covering 98.28% (40.39 km) of known spawning habitat. This was the fifth cohort of adults to return from fall parr out planted as part of the project by the Downeast Salmon Federation (DSF) to raise and release fall parr. There were 211,559 fall parr (2017) associated with the 2SW adult cohort. Based on the Redds Based Returns model, estimated escapement was 19 (95% 7 to 51).

5.2.3.3 Machias River

A total of 13 redds were counted in 2021. Surveys covered 60% of the habitat and 53.96 km of stream. Based on the Redds Based Returns model estimated escapement was 16 (95% 6 to 42).

5.2.3.4 Pleasant River

There were 11 redds recorded in 2021. Surveys covered 87.72% of the habitat and 19.8 km of stream. Based on the Redds Based Returns model estimated escapement was 14 (95% 5 to 38).

5.2.3.5 Narraguagus River

The Narraguagus Trap located at the Cherryfield ice control dam was operated from 1 April to 28 October 2021. Returns to the fishway trap (21) were much lower than 2020 (108). This is likely due to the ending of smolt stocking with the 2019 cohort and the large 1SW return that made up the majority of the 2020 returns. The majority of 2SW salmon returns are attributed to hatchery smolt released in 2019. Redd surveys accounted for 27 redds with surveys covering 90.71% and 70.25 km of known spawning habitat. The Redds Based Return model was used to determine returns to the Narraguagus instead of trap count. Based on the Redds Based Returns model the estimated return was 25 (95% 9 to 65). Breakdowns of returns were prorated as follows: Hatchery origin salmon returns were, 2 (8%) 1SW and 17 (68%) 2SW. For Naturally reared salmon returns were, 3 (12%) 1SW and 3 (12%) 2SW adults.

5.2.3.6 Union River

The fish trap at Ellsworth Dam on the Union River is operated by the dam owners, BRP, under protocols established by the DMR. The trap was operated from 1 May to 31 October 2021. No salmon were captured although four aquaculture escapes were captured and released downstream. These fish were reported by BRP to various agencies. Tissues collected were sent to the Lamar Fish Health Lab and to Cooke Aquaculture for genetic analysis. Only the last three captured had tissues analyzed since trapping staff released the first fish without collecting a sample. All fish were tagged with a Floy tag prior to release. Of the three fish that were tissue sampled, they were traced to rearing sites located off Black Island in Frenchman’s Bay (adjacent to Mount Desert Island). Per the MDMR protocol for capture of aquaculture suspects the usual practice is to remove a confirmed aquaculture origin salmon from the river and euthanize it, but BRP was not authorized to make this decision or perform this act. Therefore, fish were released before MDMR staff could have had an opportunity to investigate since BRP has no way to hold salmon in the interim.

Table 5.1.1. Returns to the Gulf of Maine in 2021. Counts are from traps at dams or redds based estimates. Age and origins are prorated based on observed catches at traps, cohort specific catches at smolt traps or historical age ratios.

			Hatchery					Naturally Reared					Totals		
SHRU	Drainage	Method	1SW	2SW	3SW	4SW	Repeat	1SW	2SW	3SW	4SW	Repeat	H	W	Total
Downeast Coastal	Dennys	Redd Estimate											0	0	0
	East Machias	Redd Estimate	3	15					1				18	1	19
	Machias	Redd Estimate						3	13				0	16	16
	Pleasant	Redd Estimate						3	11				0	14	14
	Narraguagus	Trap	2	17				3	3				19	6	25
	Union	Trap											0	0	0
Penobscot Bay	Penobscot	Trap	194	270	5		1	13	73	2		3	470	91	561
	Kenduskeag	Redd Estimate													0
	Souadabscook	Not surveyed													N/A
	Cove Brook	Redd Estimate											0	0	0
	Duck Trap	Redd Estimate											0	0	0
Merry-meeting Bay	Sheepscot	Redd Estimate	1	5				1	4				6	5	11
	Kennebec	Trap	4					4	17				4	21	25
	Androscoggin	Trap	4						1				4	1	5
		Totals	208	307	5	0	1	27	123	2	0	3	521	155	676

Table 5.1.2. Results of redd surveys by SHRU, Drainage and Stream for 2021. Effort is shown by both total kilometers surveyed and the proportion of the spawning habitat surveyed for Drainage and individual stream.

SHRU	Drainage	Drainage Total	% Drainage Spawn Habitat Surveyed	Drainage Total KM surveyed	Stream Name	Redds	% Stream Spawn Habitat Surveyed	Stream Total KM surveyed
Downeast Coastal	Dennys	0	85.25	34.89	Cathance Stream	0	66.67	15.14
					Dennys River	0	85.27	19.75
	East Machias	18	98.28	40.39	Beaverdam Stream	0	100	4.29
					Chase Mill Stream	4	100	2.13
					Creamer Brook	0	40	0.37
					East Machias River	11	98.85	15.91
					Northern Stream	1	100	13.73
					Seavey Stream	0	100	3.96
	Machias	13	59.99	53.96	Crooked River	0	59.87	2.57
					Holmes Brook	0	100	0.86
					Machias River	9	51.57	8.72
					Mopang Stream	0	47.84	11.32
					New Stream	0	91.69	1.1
					Old Stream	4	79.95	18.39
					West Branch Machias River	0	93.29	11
	Narraguagus	27	90.71	70.25	Narraguagus River	27	98.27	66.35
					West Branch Brook	0	100	3.9
	Pleasant	11	84.65	22.7	Eastern Little River	0	80	3.99

SHRU	Drainage	Drainage Total	% Drainage Spawn Habitat Surveyed	Drainage Total KM surveyed	Stream Name	Redds	% Stream Spawn Habitat Surveyed	Stream Total KM surveyed
					Pleasant River	11	84.68	18.71
Merrymeeting Bay	Lower Kennebec	9	21.25	73.37	Bond Brook	0	86.26	3.46
					Orbeton Stream	3	90.57	12.31
					Perham Stream	0	61.27	1.24
					Sandy River	4	58.13	47.57
					South Branch Sandy River	2	100	4.99
					Togus Stream	0	100	3.8
	Sheepscot	7	80.29	30.43	Sheepscot River	5	86.86	27.54
					West Branch Sheepscot River	2	59.94	2.89
Penobscot	Ducktrap	0	37.81	0.89	Ducktrap River	0	37.81	0.89
	Penobscot	0	0.51	1.54	Cove Brook	0	50.48	1.54
	Piscataquis	12	11.77	26.4	East Branch Pleasant River	4	15.37	1.06
					Piscataquis River	0	8.99	6.81
					Pleasant River	0	15.32	7.69
					Schoodic	5	100	0.69
					West Branch Piscataquis River	0	36.36	1.06
					West Branch Pleasant River	3	84.28	9.78

5.2.3.7 Redd Based Returns to Small Coastal Rivers

Estimated returns to Maine are based on the total number of returning salmon to traps (Androscoggin, Kennebec, Penobscot, Union and Narraguagus Rivers) and spawner surveys. For small coastal rivers without traps, capture data from the Pleasant, Narraguagus and Union River traps are used to predict returns in the Cove Brook, Dennys River, Ducktrap River, East Machias, Kenduskeag Stream, Machias River, Pleasant River, and the Sheepscot River based on observed redd counts. Estimated returns based on redd counts are computed using the equation: lnAdults = 1.1986 +0.6098(lnRedds).

A total of 76 redds were surveyed across all SHRU's. The predicted redds based estimate of returns for 2021 is 85 adults (95% CI 32 to 223) (Table 5.1.3). Total Redd numbers across the GOM DPS have decreased from 2019 surveys but are like other years in the past decade (Figure 5.1.1.). This trend was also observed across individual drainages (Figure 5.1.2).

Table 5.1.3. Redds based regression estimates and confidence intervals of total Atlantic salmon escapement to Cove Brook, Dennys, Ducktrap, East Machias, Kenduskeag, Machias, Pleasant, Sheepscot and Souadabscook Rivers for 2021.

Drainage	**Total Spawn Habitat**	**Surveyed Habitat**	**Surveyed Redds**	**Predicted Returns**	**L95**	**U95**
Cove Brook	7.27	3.67	0	0	NA	NA
Dennys	238.51	203.34	0	0	NA	NA
Ducktrap River	42.87	16.21	0	0	NA	NA
East Machias	58.92	57.91	18	19	7	51
Machias	449.77	269.84	13	16	6	42
Narraguagus	265.82	241.12	27	25	9	65
Pleasant	141.41	119.7	11	14	5	38
Sheepscot	325.36	261.22	7	11	4	29
Total	1,573.70	1,189.22	76	85	32	223

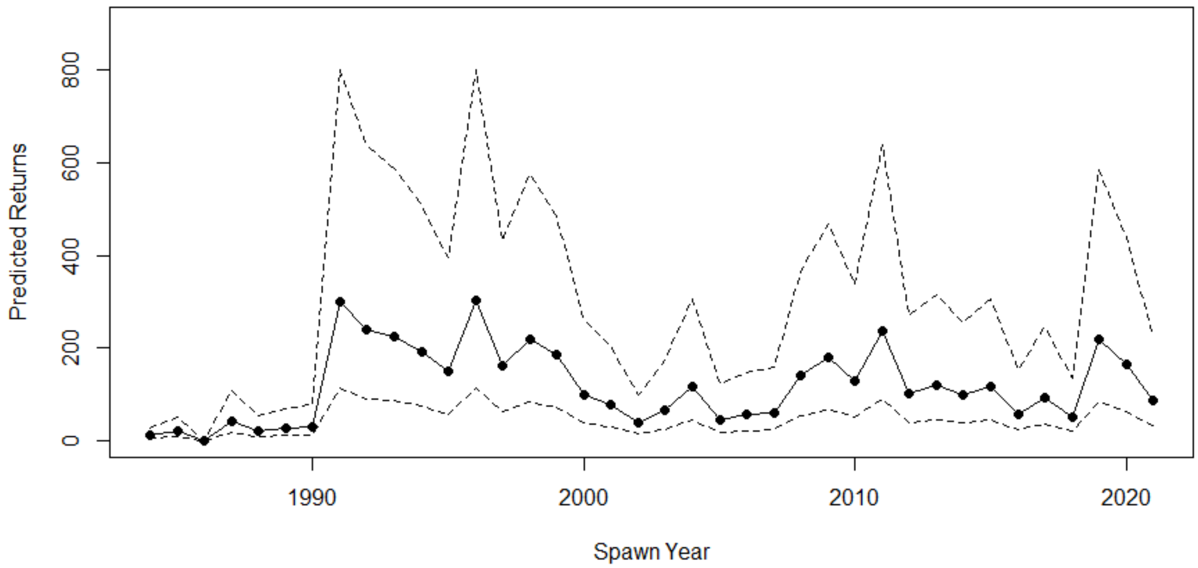

Figure 5.1.1. Annual total redds based returns estimate for Cove Brook, Dennys, Ducktrap, East Machias, Kenduskeag, Machias, Pleasant, Sheepscot and Souadabscook Rivers through 1984 – 2021.

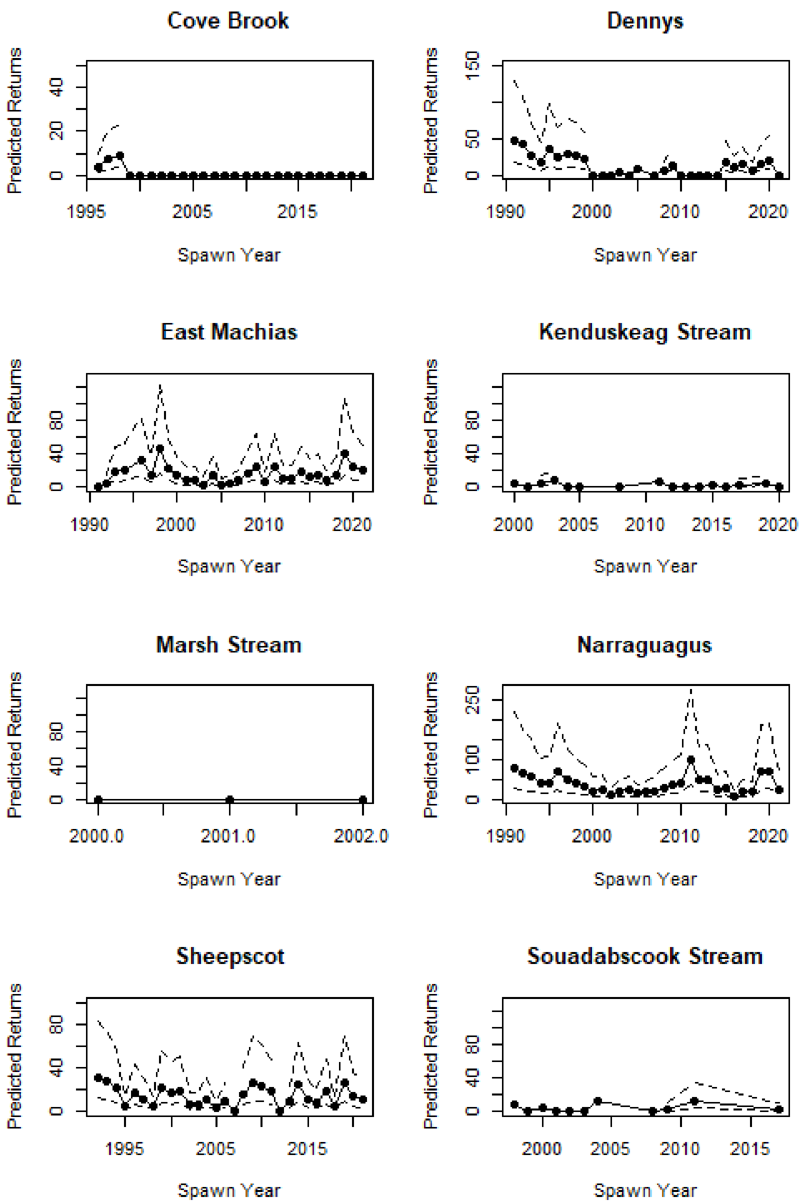

Figure 5.1.2. Individual annual redds based estimate of adult returns to managed drainages in the Gulf of Maine DPS 1984 - 2021.

5.3 Juvenile Population Status

Understanding the spatial variability of juvenile Atlantic salmon provides information on habitat quality and habitat productivity that is a crucial step towards the recovery of Atlantic salmon. This factor was recognized in the listing of Atlantic Salmon (74 FR 29345; June 19, 2009) and in the designation of Critical Habitat (74 FR 29300; June 19, 2009), when the number of habitat units in each SHRU was prorated, based on a habitat quality score and expressed in terms of functional units. One of the best resources that we have to evaluate habitat quality is to measure juvenile abundance and distribution and smolt production.

5.3.1 Juvenile abundance estimates

5.3.1.1 Introduction

MDMR conducts single pass catch per 100m^2 electrofishing surveys (Bateman et al. 2005; Stevens et al. 2010) at sites that are divided into three groups, GRTS, Wild Production (WPAs) and Project sites. GRTS sites are sites derived using the Geographic Randomized Tessellation Stratification (GRTS) technique (Stevens and Olsen 2004). WPAs are sites based on locations of redds in years that coincide with the current year's cohort for 0+ parr and are used to evaluate spawning success. Project sites are selected to answer specific questions of juvenile salmon response to stock enhancement changes, habitat alterations or other questions. GRTS sites will be sampled annually, WPAs and Project sites will change from year to year as defined by redd distribution or research needs.

Sampling locations are divided among the three SHRUs within the GOM. Streams that are included in the sampling design, referred to as management drainages, are streams that are currently managed for Atlantic salmon. This means that there is active restoration work that involves at minimum stock enhancement work or monitoring i.e. spawner surveys (Table 5.2.1). Additionally, the Sandy River and the Narraguagus River have been identified as Life Cycle Management Stations (LCMS) and these drainages receive the greatest focus for GRTS sites.

Table 5.2.1. Currently Managed Streams. Rearing habitat from the Wright et al. 2008 Species Distribution and Habitat Model.

SHRU	Name	Drainage Area (hectares)	Rearing Habitat (100 m^2)	Drainage length (km)
DEC	Dennys	33,836.20	2,098.00	121.33
DEC	East Machias	80,797.25	6,951.00	238.03
DEC	Machias	129,072.74	19,602.00	537.91
DEC	Narraguagus	63,496.33	7,180.00	203.01
DEC	Pleasant	32,845.72	2,580.00	90.89
MMB	Sandy River	153,567.46	36,790.78	1,567.79
MMB	Sheepscot River	64,980.85	6,751.00	163.66
PEN	Cove Brook	14,147.18	218.00	8.05
PEN	East Branch Penobscot	289,561.27	35,246.00	448.63
PEN	Kenduskeag	49,542.19	6,705.00	58.36
PEN	Piscataquis	377,853.45	56,598.73	488.50

5.3.1.2 Results

A total of 189 sites were surveyed between August 1st and October 15th, 2021 using single pass electrofishing survey techniques across all three SHRU's. Of these, 110 sites were either GRTS selected sites or index sites used to track status and trends. Additional electrofishing efforts were used to evaluate spawner success for hatchery products (WPA), habitat improvements and parr brood stock collections (Projects). A list of survey types for each drainage is presented in Table 5.2.2.

Table 5.2.2 Summary of electrofishing efforts within the Gulf of Maine DPS in 2021.

SHRU	Drainage	0+ PARR STUDY	Brood-stock	Egg Planting	Fish Exclusion	GRTS	Index	PALS	Upper NG Index	Wild Spawning	Totals
DEC	Dennys		2							3	5
DEC	East Machias	8	4								12
DEC	Machias		6	1							7
DEC	Narraguagus		4			12			5		21
DEC	Pleasant		3							3	6
MMB	Lower Androscoggin						2				2
MMB	Lower Kennebec			7	1	30	4			6	48
MMB	Sheepscot		14	5	1		12	4		2	38
PNB	Ducktrap					3					3
PNB	Penobscot					9					9
PNB	Piscataquis					33	5				38
	Totals	**8**	**33**	**13**	**2**	**87**	**23**	**4**	**5**	**14**	**189**

Mean parr densities for GRTS and Index sites are shown in Table 5.2.3. Parr abundance across management reaches was similar with the exception of the Piscataquis River ($p = 0.0203$) which had a greater mean CPUA (Figure 5.2.2).

Table 5.2.3. Summary of Single-pass Catch per 100m^2 results for index and GRTS selected sites across sampled drainages for 2021. Bold text signifies a significant difference at $p < 0.05$.

SHRU	MGMTREACH	Year	n	Mean	SD	Low 95	Up 95
Downeast Coastal	East Machias	2021	9	4.4	1.6	3.3	5.4
Downeast Coastal	Narraguagus	2021	13	1.0	1.5	0.2	1.8
Merrymeeting Bay	Middle Sandy River	2021	12	1.1	1.7	0.1	2.0
Merrymeeting Bay	Sheepscot	2021	22	0.4	0.6	0.2	0.7
Merrymeeting Bay	Upper Sandy River	2021	28	0.6	0.7	0.3	0.9
Penobscot	Ducktrap	2021	2	1.0	1.4	0.0	2.9
Penobscot	**Piscataquis**	**2021**	**27**	**5.8**	**5.3**	**3.8**	**7.9**

Across both GRTS and Index sites, electrofishing survey sites are divided into stream width classes. There are four: A = 0 to 6 meters, B = 6 to 12 m, C = 12 to 18 m and D = > 18 m. Results of an ANOVA using Catch per minute (CPUE) across width classes (Figure 5.2.3.) showed that abundance within A class stream reaches was significantly greater than the other width classes combined (p = p = <2.00E-16). Second, the B class stream reaches are more productive than C and D class reaches (Table 5.2.4). However, looking at mean fork lengths (mm) across width classes (Figure 5.2.4), parr measured from A class sites were smaller (p = <2.00E-16) than those from the other width class reaches combined (Table 5.2.5).

This has implications on stock enhancement decisions when considering how and where to use limited resources of available fish. Larger parr should have higher overwinter survival (Close and Anderson 1992) so balancing higher abundance with better growth needs to be prioritized. It is unknown how habitat characteristics contribute to this observation but it can be guessed that water temperature and habitat complexity play a role (Johnston et al. 2004; Finstad et al. 2007). Use of the GRTS methods has helped to identify some of these relationships. Ongoing habitat rehabilitation projects as described below help with increasing complexity and access to thermal refuges. Tying these findings related to juvenile abundance surveys to habitat data to develop tools to identify optimal scenarios for stocking or habitat protections is currently being pursued by the Maine Atlantic Salmon combined group; NOAA, USFWS, MDMR, PIN, and NGOs.

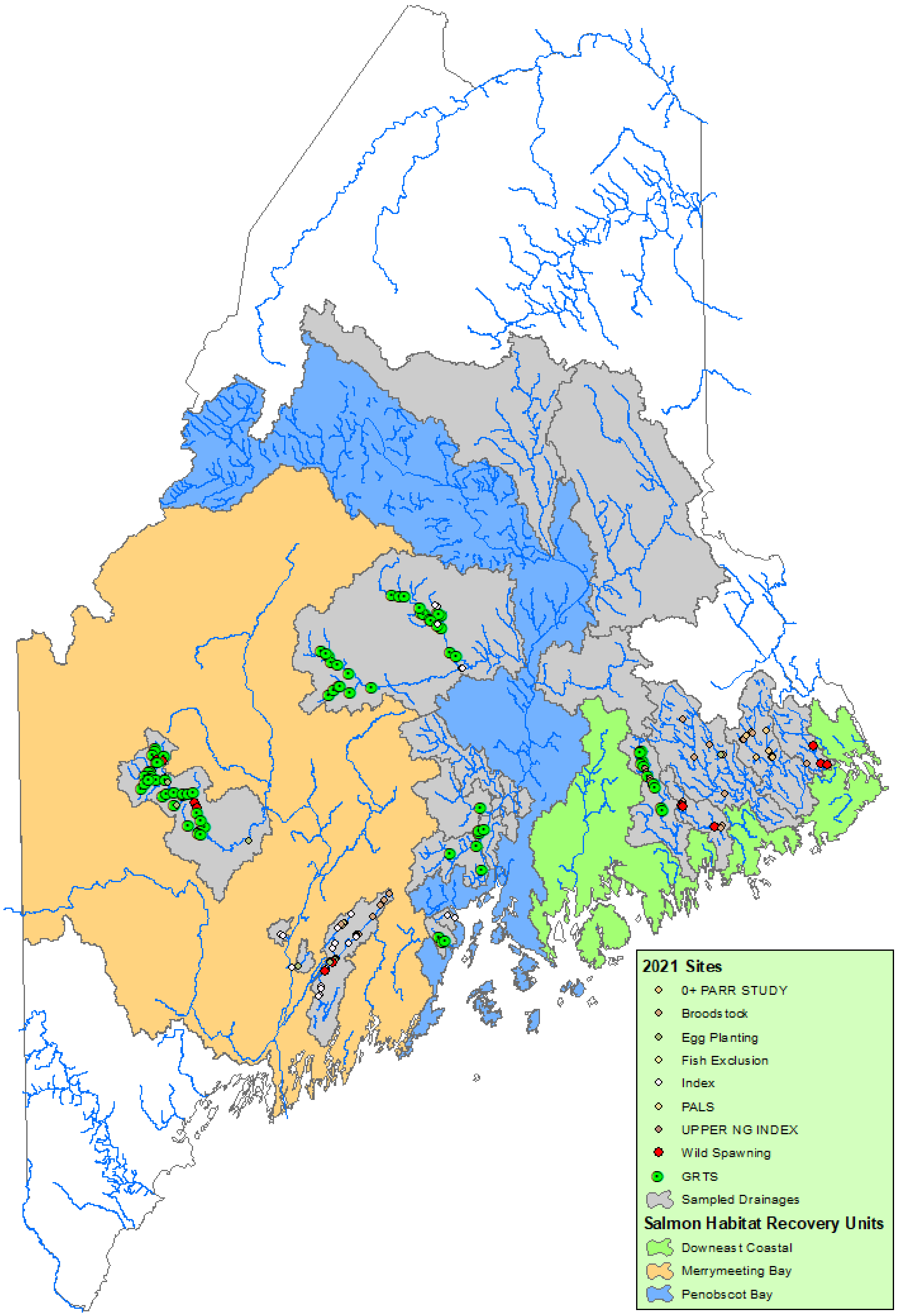

Figure 5.2.1. Location of sites (189) surveyed in 2021 for juvenile abundance and distribution estimates within the Gulf of Maine Distinct Population Segment of Atlantic Salmon.

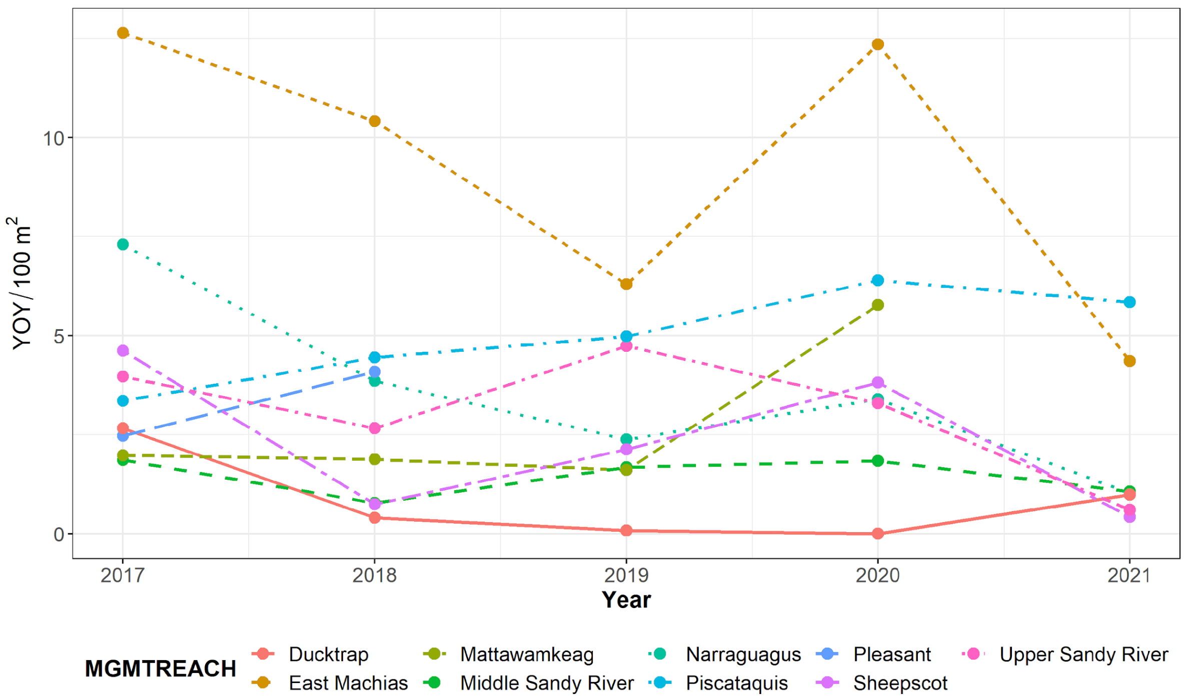

Figure 5.2.2. Mean Catch per 100m^2 by drainage 2017 to 2021 for index sites across managed drainages within the GOM DPS.

Table 5.2.4. Mean catch per 100 m^2 for large parr across width classes. A = 1-6m, B = 6-12m, C = 12-18m, C = >18m stream width. Bold letter indicates significant ($p < 0.05$) difference based Tukey multiple comparisons of means.

Width Class	n	Mean	SD	Low 95	Up 95
A	163	6.4	7.3	5.2	7.5
B	311	4.0	4.6	3.5	4.5
C	117	2.4	3.7	1.7	3.0
D	105	1.3	2.0	0.9	1.6

Results of ANOVA

	Df	Sum Sq	Mean Sq	F-value	Pr(>F)
Width Class	3	2003.0	667.7	26.8	<2e-16
Residuals	692	17245.0	24.9		

Tukey multiple comparisons of means, 95% family-wise confidence level

Width Class	difference	lower	upper	p adj
B-A	-2.388	-3.63128	-1.1449761	0.000006
C-A	-4.013	-5.57113	-2.4556029	0.000000
D-A	-5.105	-6.71406	-3.4965641	0.000000
C-B	-1.625	-3.01954	-0.2309335	0.014734
D-B	-2.717	-4.16823	-1.26614	0.000010
D-C	-1.092	-2.82016	0.6362679	0.363950

Table 5.2.5. Mean fork length (mm) for large parr across width classes. A = 1-6m, B = 6-12m, C = 12-18m, C = >18m stream width. **Bold** letter indicates significant (p<0.05) difference based Tukey multiple comparisons of means.

Width Class	n	Mean	SD	Low 95	Up 95
A	980	109.3	16.9	108.2	110.3
B	707	118.6	19.5	117.2	120.1
C	204	119.9	19.0	117.3	122.5
D	266	115.7	20.4	113.3	118.2
Results of ANOVA					
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Width Class	3	45031.0	15010.0	44.2	2.00E-16
Residuals	2153	731990.0	340.0		

Tukey multiple comparisons of means, 95% family-wise confidence level.

Width Class	difference	lower	upper	p adj
B-A	9.357436	7.0182	11.69667	**0**
C-A	10.679752	7.031483	14.32802	**0**
D-A	6.451719	3.174207	9.729231	**2.7E-06**
C-B	1.322316	-2.44536	5.089992	0.803592
D-B	-2.905717	-6.31564	0.504209	0.126045
D-C	-4.228033	-8.64	0.183933	0.065983

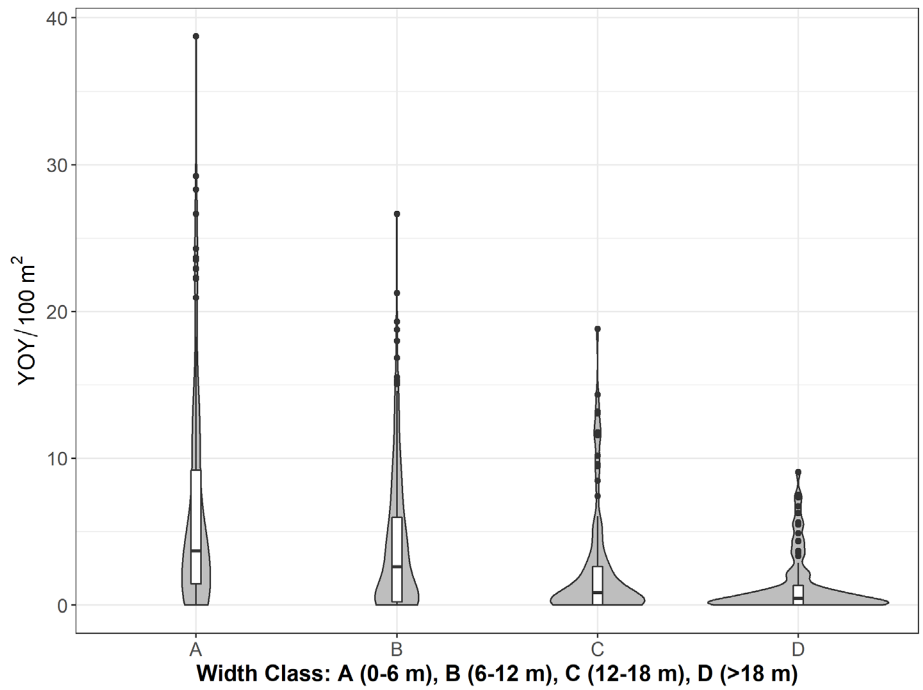

Figure 5.2.4. Violin plots showing relative abundance as catch per 100m^2 for large parr across four width classes.

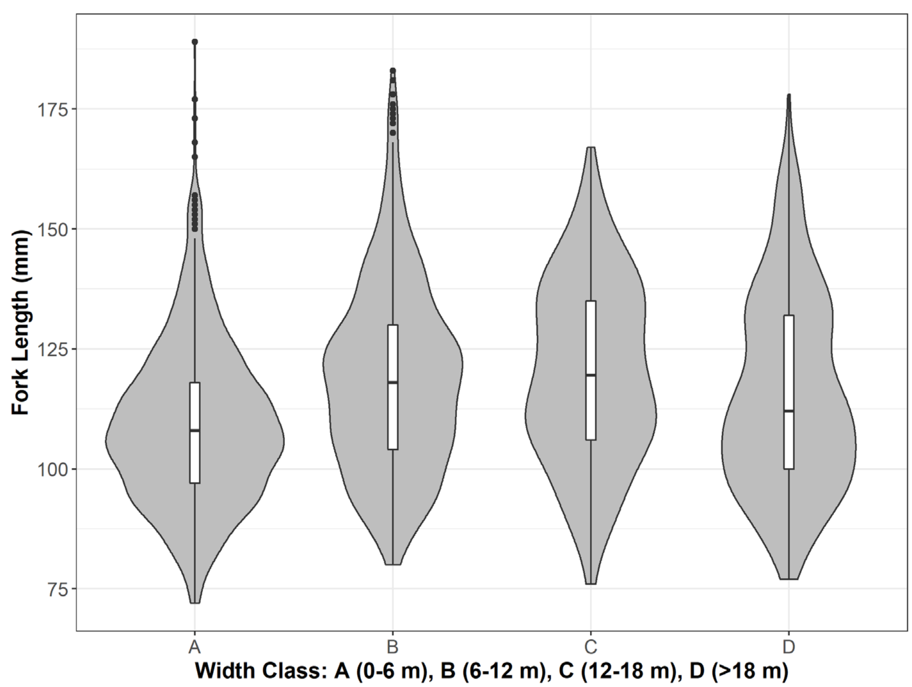

Figure 5.2.4. Violin plots showing fork length (mm) for large parr across four width classes.

5.3.2 Smolt Abundance

The following is a summary of activities intended to obtain smolt population estimates based on mark-recapture techniques at several sites within the GOM. A more detailed report on smolt population dynamics is included in the Smolt Update Working Paper.

MDMR enumerated smolt populations using Rotary Screw Traps (RSTs) in several Maine rivers. These include the Narraguagus River (in partnership with Project SHARE), Sandy River, and the East Machias River (in partnership with DSF). A total of 2,622 smolts were unique captures at all sites between 10 April and 11 June 2021 (Table 5.2.6).

MDMR scientists calculated population estimates using Darroch Analysis with Rank Reduction (DARR) 2.0.2 for program R (Bjorkstedt 2005; R Core Team 2018) for each RST site (Figures 5.2.5 and 5.2.6; Table 5.2.7).

Population estimates for each river/site were based on a one-site mark-recapture design. Two sites were operated on the Narraguagus River in 2021. Long-term monitoring continued at the lower river site at Little Falls. The total population estimate (± standard error (SE) for all smolts exiting the Narraguagus River (hatchery 0+ parr origin and naturally reared origin) was 1,431 (± 93). The naturally reared smolt population estimate was 1,426 (± 92). The hatchery population was not estimated due to low captures and low recapture rate. Additionally, production was evaluated in the upper Narraguagus River at Route 9. The naturally reared smolt population emigrating from the upper watershed was estimated at 1,276 (± 186). The population estimate for naturally reared smolts exiting the Sandy River was 13,229 (± 1,294). The total population estimate for all smolts exiting the East Machias River (hatchery 0+ parr origin and naturally reared origin) was 881 (± 167). The hatchery population estimate was calculated 792 ±SE 156. The naturally reared population estimate was not calculated due to low captures and low recapture rate. Further details on age, origin, and other data are presented in the Smolt Update Working Paper.

Table 5.2.6 Atlantic salmon smolt trap deployments, total captures, and capture timing by origin in Maine rivers, 2021.

River	Site	Dates Deployed		Origin	Total Capture	First Capture	Median Capture Date	Last Capture
East Machias	Jacksonville Bridge	11-Apr	1-Jun	H	154	17-Apr	10-May	28-May
				W	14	2-May	12-May	28-May
Narraguagus	Little Falls	13-Apr	27-May	H	4	18-Apr	23-Apr	7-May
				W	533	20-Apr	6-May	26-May
	Route 9	10-Apr	26-May	H	-	-	-	-
				W	342	12-Apr	1-May	24-May
Sandy	Lane Road	12-Apr	11-Jun	H	-	-	-	-
				W	1,574	14-Apr	8-May	6-Jun
				Total	2,622			

Table 5.2.7. Maximum likelihood mark-recapture population estimates ±SE for naturally reared and hatchery origin Atlantic salmon smolts emigrating from Maine rivers, 2021.

River	Site	Origin	Population Estimate
East Machias	Jacksonville Bridge	Hatchery (parr)	792 ± 156
		Naturally reared	n/a
		Both	881 ± 167
Narraguagus	Little Falls	Hatchery (parr)	n/a
		Naturally reared	1,426 ± 92
		Both	1,431 ± 93
	Route 9	Naturally reared	1,276 ± 186
Sandy	Lane Road	Naturally reared	13,229 ± 1,294

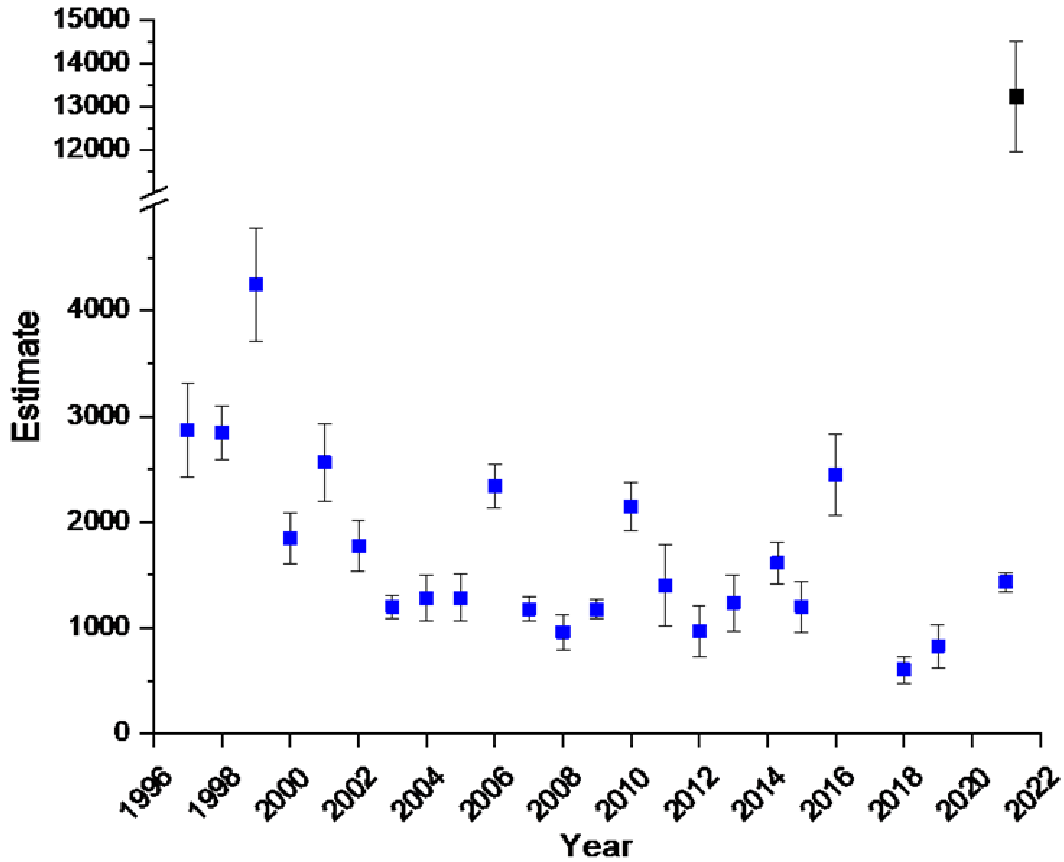

Figure 5.2.6. Population Estimates (± Standard Error) of emigrating naturally-reared smolts in the Narraguagus (no estimate in 2016, 2017 and 2020) and Sandy rivers, Maine, 1997-2021, using DARR 2.0.2.

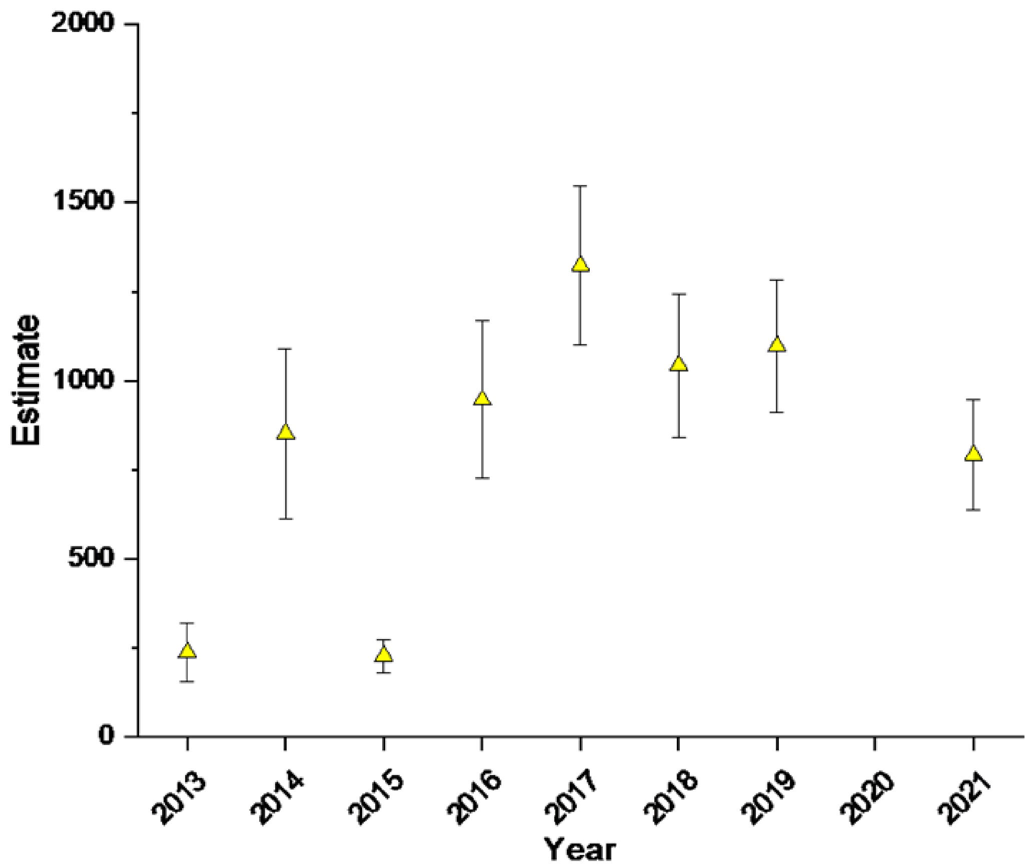

Figure 5.2.7. Population Estimates (± Standard Error) of emigrating hatchery-origin smolts stocked as fall parr in the East Machias River, Maine (2013-2019 and 2021), using DARR 2.0.2.

5.4 Fish Passage and Migratory Fish Habitat Enhancement and Conservation

5.4.1 Habitat Assessment

5.4.1.1 Quantitative Habitat Surveys

MDMR staff conducted a habitat survey in upper Lemon Stream located in the Merrymeeting Bay SHRU. Staff surveyed from the Greenwood Brook Road crossing in the town of Industry to the Anson Road in the town of Starks. An adjacent survey in Lemon Stream was completed below a small hydro-electric dam in 2018. Approximately 146 units of spawning habitat and 657 units of rearing habitat was documented. Data has been geo-referenced and will be appended to the current habitat geo-database. An updated GIS dataset will be issued in March 2022. Survey data will be utilized to establish broodstock requirements and direct habitat and/or connectivity improvements.

5.4.1.2 Thermal Refugia Surveys

With an anticipated increase of adults returning to the lower Kennebec River starting in 2021 as a response to smolt stocking (stocked in 2020), MDMR collected thermal profile data from Waterville to Augusta to find potential areas of thermal refugia for returning adults. In 2020 MDMR crews conducted an adult Atlantic salmon thermal refugia survey (thermal profile) on the mainstem Kennebec River that had yet to be geo-processed (See USASAC report 2021). Methods, equipment, and data processing were adopted from Vaccaro and Maloy 2006. Two crews surveyed the river each day of sampling – each on opposite sides of the river in a canoe. Sampling took two days – the first from Waterville to Sidney, then next from Sidney to Augusta. Resulting GPS and Solinst logger data was paired, and data points were labeled as warming, steady or cooling but the magnitude of each are only noted in the attribute table. Geoprocessing was completed in March 2021.

The thermal profile started at river kilometer 101.71 and ended at river kilometer 72.40, covering approximately 29 river kilometers. However, there was a small data gap in Sidney of approximately 3.74 river kilometers due to equipment malfunctions (Figure 5.3.1).

Within the Waterville to Sidney section of river, 29 areas of cooling temperatures were identified on river left (RL) and eight areas on river right (RR). Notable sections include river kilometers 101.07 - 97.60 on RR and river kilometers 94.65 - 93.83 on RL for the vast lengths of the cooling sections. The quickest cooling section on RL was located at the confluence of an unnamed tributary at river kilometer 96.43 with a decrease in temperature of -0.13°C/second. The coldest temperature documented in this section was also documented here at 16.46°C. On the RR side, the mouth of Messalonskee Stream showed the greatest temperature decrease of -0.12 °C/ second. The coldest documented temperature in this section was 22.12°C at river kilometer 98.92, just upstream of the Messalonskee Stream confluence. This section of cool water was no surprise as radio tagged adult salmon have been documented here frequently in the past.

In the Sidney to Augusta section, 48 areas of cooling were identified on RL and 28 on RR. Notable sections include river kilometers 75.44-74.58 on RR and river kilometers 72.76 - 72.41 on RL for the vast lengths of the cooling sections. The quickest cooling section on RL was located at the confluence of an unnamed tributary at river kilometer 77.82 with a decrease in temperature of -0.151°C/second. The coldest temperature documented in this section was 17.28°C and at the same location. On the RR side, approximately 1.5 kilometers upstream of the route 3 bridge at river kilometer 76.26, the greatest decrease in temperature was documented for this section at -0.11 °C/ second. The coldest documented temperature in this section was 18.79°C at river kilometer 83.15, which is located at the base of 4 small unnamed tributaries.

The results of these surveys will allow MDMR to key into specific areas in the lower Kennebec for protection of returning adult Atlantic salmon.

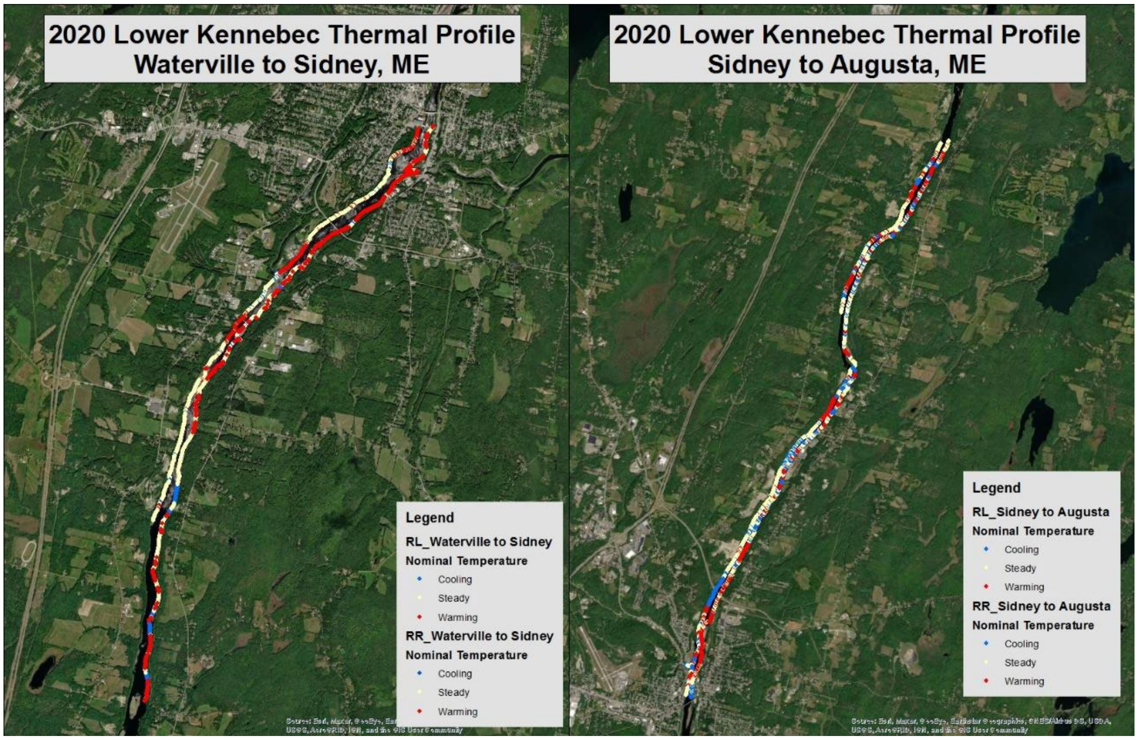

Figure 5.3.1. Warming, cooling and steady temperatures documented by a thermal profile of two sections of the lower Kennebec River. Two crews collected data each sampling day – one on each side of the river. Thermal regimes will inform MDMR scientists of potential thermal refugia for returning adult Atlantic salmon.

5.4.1.3 Habitat Connectivity

Numerous studies have identified how stream barriers can disrupt ecological processes, including hydrology, passage of large woody debris, and movement of organisms. Thousands of barriers that block the movement of diadromous fish, other aquatic and terrestrial species, sediment, nutrients, and coarse wood exist in Maine streams. These barriers include dams and road-stream crossings. All dams interrupt stream systems but are highly variable in their effects on the physical, biological, and chemical characteristics of rivers. Improperly sized and placed culverts can drastically alter physical and ecological stream conditions. Undersized culverts can restrict stream flows, cause scouring and erosion and restrict animal passage. Perched culverts usually scour the stream bottom at the downstream end and can eliminate or restrict animal passage. Culverts that are too small or have been difficult to maintain or install are also at increased risk of catastrophic failure during larger than average storm events. Emergency replacements are more dangerous, costlier economically and more environmentally damaging than replacements installed before disaster.

Highlighted Connectivity Projects: In 2021, 33 aquatic connectivity projects were completed across the GOM DPS (Table 5.3.1; Figures 5.3.2 and 5.3.3) with the primary goal of restoring aquatic organism connectivity and ecological stream processes by allowing the natural flow of materials (water, wood, sediment). A total of 147.1 km of streams were made accessible because of these projects. These efforts were made possible due to strong partnerships between ASF, DSF, Maine DMR, Houlton Band of Maliseets, Maine Rivers, Maine DOT, NRCS, TNC, AMC, Piscataquis County, Project SHARE, US National Park Service, Maine Forest Service, NOAA Fisheries, USFWS, municipalities, lake associations, towns, and numerous private landowners.

Figure 5.3.2. Curry Brook upstream of crossing, before (left) and after (right) culvert replacement using a wood deck bridge, Dennys River watershed, Maine 2021. (photo credit: Chris Federico – Project SHARE)

Figure 5.3.3. Cummings Brook crossing, before (left) and after (right) culvert replacement, Sandy River watershed, Maine 2021. (photo credit: Bill Bennett – USFWS-GOMCP)

5.4.1.4 Habitat Complexity and Suitability

5.4.1.4.1 Upper Narraguagus Focus Area Restoration: 2021 Field Season Summary

Project SHARE has identified the Upper Narraguagus sub-watershed as a high priority focus area for salmonid habitat restoration. Other native fish species include Eastern brook trout (identified in steep decline throughout its range by the Eastern Brook Trout Joint Venture), American eel, alewife, shad, and sea lamprey will also be positively affected.

In collaboration with state and federal agencies, landowners, and nonprofit organizations, Project SHARE has developed a habitat restoration program with principal focus on the five Downeast Maine Atlantic salmon watersheds. The group has identified threats to habitat connectivity and function along with opportunities to restore cold-water refugia and rearing habitat. Cooperatively, projects have been done to mitigate those threats and/or restored connectivity and natural stream function. Watershed-scale threat assessments of the Narraguagus River have documented summer water temperatures in mainstem river reaches above sublethal stress levels, approaching acute lethal levels. Remnant dams and the associated legacy reservoirs are identified as heat sinks contributing to warmer temperatures. Undersized culverts at road/stream crossings present stream connectivity threats and are barriers to upstream cold-water refugia.

Climate change predictions present threats in addition to legacy effects of past land use. Stream temperatures are expected to rise in most rivers; the threat to salmon recovery is high where temperatures are near sub-lethal or lethal thresholds for salmon (Beechie et al. 2013). Average air temperatures across the Northeast have risen 0.83˚ C since 1970, with winter temperatures rising most rapidly, 2.2˚ C between 1970 and 2000 (Frumhoff et al. 2007). However, increased water temperature is not the only threat associated with climate change. Precipitation and timing of significant aquatic events (intense rain, ice-out, spring flooding, and drought, among them) are “master variables” that influence freshwater ecosystems and are predicted to change, according to all climate model predictions. Jacobson et al. 2009 provide a preliminary assessment summarizing impacts to Maine’s freshwater ecosystems, predicting a wetter future, with more winter precipitation in the form of rain and increased precipitation intensity. Although it is not possible to predict specific changes at a given location, several 100- to 500-year precipitation events have occurred in recent years.

Climate change will affect the inputs of water to aquatic systems in Maine, and temperature changes will affect freezing dates and evaporation rates, with earlier spring runoff and decreased snow depth. Stream gauges in Maine show a shift in peak flows to earlier in spring, with lower flows later in the season. New England lake ice-out dates have advanced by up to two weeks since the 1800s. Water levels and temperatures cue migration of sea-run fish such as alewives, shad, and Atlantic salmon into our rivers, and the arrival or concentration of birds that feed on these fish. Lower summer flows will reduce aquatic habitats like cold-water holding pools and spawning beds. This complex interplay of climate effects, restoration opportunities, and potential salmonid responses poses a considerable challenge for effectively restoring salmon populations in a changing climate (Beechie et al. 2013). However, past land use practices often have degraded habitats to a greater degree than that predicted from climate change, presenting substantial opportunities to improve salmon habitats more than enough to compensate for expected climate change over the next several decades (Battin et al. 2007).

Process-based habitat restoration provides a holistic approach to river restoration practices that better addresses primary causes of ecosystem degradation (Roni et al. 2008). Historically, habitat restoration actions focused on site-specific habitat characteristics designed to meet perceived “good” habitat conditions (Beechie et al. 2010). These actions favored engineering solutions that created artificial and Unnaturally static habitats and attempted to control processes and dynamics rather than restore them. By contrast, efforts to reestablish system processes promote recovery of habitat and biological diversity. Process restoration focuses on critical drivers and functions that are how the ecosystem and the target species within it can be better able to adapt to future events, such as those predicted associated with climate change.

Project SHARE is collaborating on this project with a team of scientists in a 5- to 7-year applied science project taking a holistic, natural process-based approach to river and stream restoration in an 80-square-mile area in Hancock and Washington Counties. The vision, from the perspective of restoration of Atlantic salmon as an endangered species, is to restore the return of spawning adult Atlantic salmon from the sea to the Upper Narraguagus River subwatershed to escapement levels that are self-sustaining. The work is guided by a team of scientists and restoration actions will be based on the four principles of process-based restoration of river systems:

- Restoration actions should address the root causes of degradation.
- Actions should be consistent with the physical and biological potential of the site.
- Actions should be at a scale commensurate with environmental problems; and
- Actions should have clearly articulated expectations for ecosystem dynamics.

This project, a collaboration with the NMFS, USFWS, University of Maine, MDMR, Boston College, Connecticut College, and the Canadian Rivers Institute, will test the hypothesis that reconnecting river and stream habitat, improving habitat suitability, and reintroducing salmon to unoccupied habitat, will increase the number of salmon smolts leaving the sub-watershed in-route to the ocean.

In 2021, SHARE completed habitat enhancement projects in several locations in the upper Narraguagus watershed. In Township 39, another treatment of self-placing wood was added to West Branch Brook, a tributary of the upper Narraguagus River (Table 5.3.2). This treatment involved using a gas-powered winch to place 28 commercially harvested red pine trees into the brook near the top of the surveyed salmon habitat. The intent is for the trees to wash downstream during the fall and spring floods before hanging up and becoming key logs (i.e. self-placing). This is the third year of this treatment and will be evaluated in the spring of 2022 for effectiveness.

Further downstream of West Branch Brook, at the 30-00-0 Rd bridge, another load of the same red pine had been delivered in 2020 in preparation for 2021. Most of these logs were pulled off the bank and up the stream to begin manually building wood jams. The dry red-pine logs were maneuvered around using log-lifters and peaveys to construct seven jams (Figure 5.3.4). Most of these are channel spanning and use the banks and the weight of other logs to help anchor them in place. Over 700 feet of biodegradable 3/8” sisal rope was used to lash all of the structures together. The post driving gear was then hauled in to secure the structures with posts. These Post-Assisted Log Structures (PALS) have an average footprint of 229.6 ft^2 with an average of 32.7 posts securing them. An additional 28 logs were spread out over the river-right floodplain to help breakup flood water and keep ice from scouring off woody vegetation.

Fifty-seven trees were also added to the Bracey Ford-31-00-0 Rd reach in the mainstem using a Griphoist (Figure 5.3.5). Some of the trees were felled to form large wood jams but most felled either individually or in pairs. Felling trees in this manor anchors them to the bank and increases their effective size.

Table 5.3.2. Large wood additions implemented by Project SHARE in support of the Upper Narraguagus Watershed Restoration Project, Narraguagus River, Maine (2021).

River Reach/Tributary	Addition Type	Large Wood Pieces Added	Habitat Units ($100m^2$) Treated
Narraguagus Mainstem	Griphoist – Individual Trees	57	58.0
Narraguagus Mainstem	Mechanical*	14	22.6
West Branch Brook	Self-placing Wood	28	13.0
West Branch Brook	Post-Assisted Log Structures	55	12.0
West Branch Brook	Floodplain Wood	12	n/a

SHARE also continued working on the Route 9 Narraguagus Project in 2021. The overall goal of this project is to provide all the habitat types that Atlantic salmon need, increase mainstem water depth, increase stream dynamics, and show persistence of installed structures. To accomplish this a series of restoration actions will be completed including placing 10 in-stream boulder clusters, excavating 3 off-channel groundwater-fed pools, re-opening 2 remnant side channels, constructing 3 engineered log jams, and building a new wooded floodplain (Figure 5.3.6).

A little less than half of the work has been completed to date. In 2020, two of the boulder clusters were placed while completing exploratory geotechnical work. In 2021, two more of the boulder clusters were placed along with excavating the off-channel pools (Figure 5.3.7) and opening one of the side-channels (Figure 5.3.8). The pools were constructed in a small groundwater-fed stream that flows into the mainstem just downstream of the project area. The middle pool (B2) is situated at the confluence of the groundwater stream and the side channel that we re-opened (Figure 5.3.9). Late in the year construction materials were sourced from local landowners/managers and staged near the project area. Over 220 pine trees were harvested with their roots intact, 1,250 yd^3 of stone fill was hauled, and truckloads of commercially harvested pine pulp was purchased for use as construction materials in 2022.

SHARE anticipates completion of the Route 9 Narraguagus Project in 2022. Engineered log jams will be constructed along with the placement of the remaining 6 boulder clusters, construction of the wooded floodplain, and opening the second side channel. Bob Gubernick, geologist with U.S. Forest Service, will be flying in to aid in project oversight as he has worked on many of these types of projects. To say

SHARE and all their restoration partners are excited for this project is an understatement. It has been a long time in the making and we are already thinking about where we can do a similar project next.

Figure 5.3.4. Constructed log jam with crew lashing the logs together, West Branch Brook, Maine (2021). (photo credit: Chris Federico, Project SHARE)

Figure 5.3.*5*. Preparing a tree for felling (left) and a completed wood jam (right) during a Griphoist wood addition, Narraguagus River, Maine (2021). (photo credit: Chris Federico, Project SHARE)

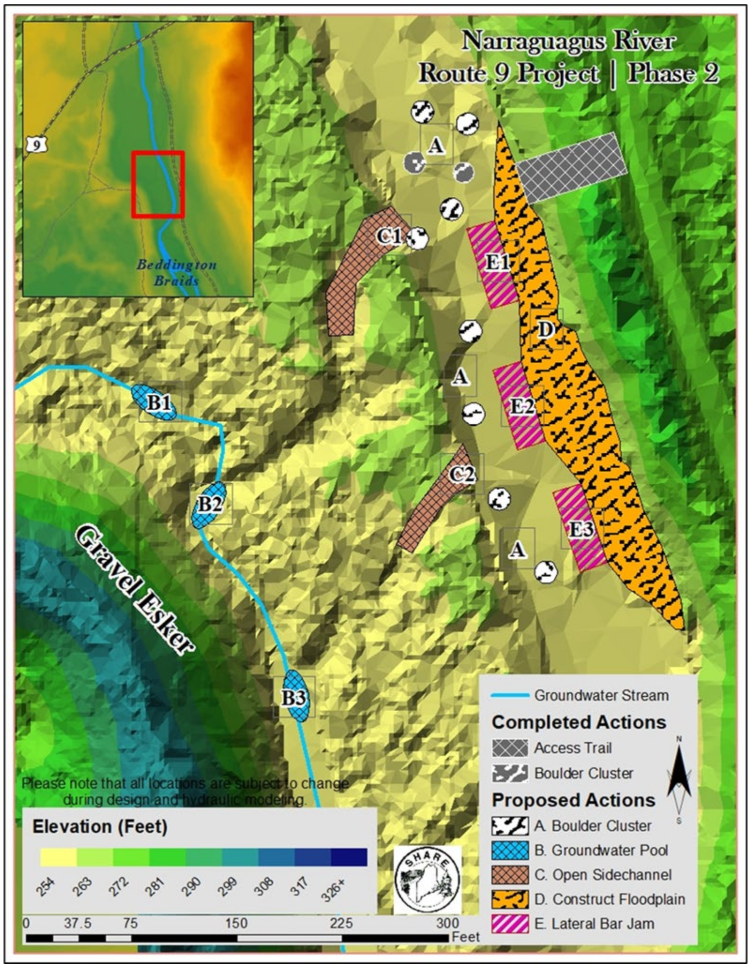

Figure 5.3.6. Map overview of the Route 9 Narraguagus Project, Narraguagus River, Maine (2021). (credit: Chris Federico, Project SHARE)

Figure 5.3.7. Groundwater Pool B2 during construction (left above) and after completion (right), Narraguagus River, Maine (2021). (credit: Chris Federico, Project SHARE)

Figure 5.3.8. Side channel A being reopened (top), after excavation (middle), and during first activation (bottom), Narraguagus River, Maine (2021). (credit: Chris Federico, Project SHARE)

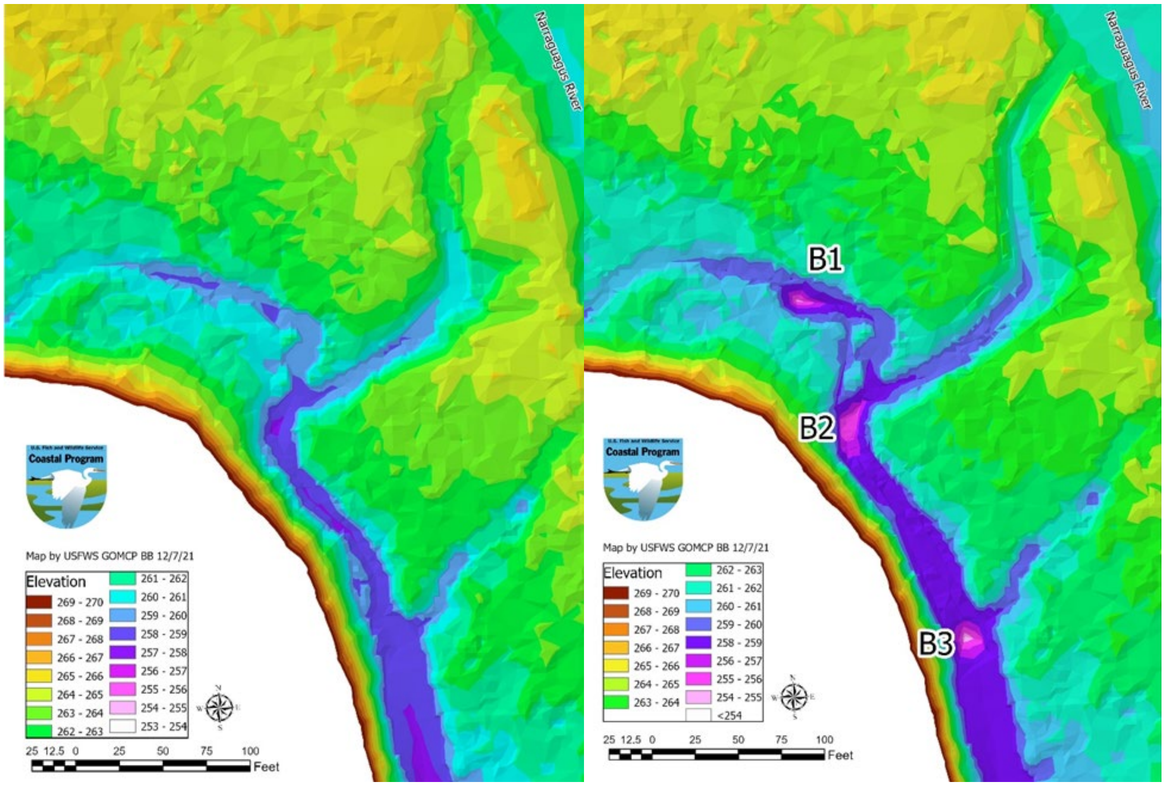

Figure 5.3.9. Digital elevation model representing pre- (left) and post- (right) construction conditions, Narraguagus River, Maine (2021). (credit: Bill Bennett, USFWS-GOMCP)

5.4.1.5 Water Quality

The Downeast Salmon Federation, in collaboration with the Maine Department of Environmental Protection (DEP), continued their multi-year effort which began in 2017 in the East Machias River watershed to investigate the efficacy of using clam shells to lime streams that have been impacted by acid rain. The goal of the project is to increase macroinvertebrate abundance and diversity, and to increase juvenile salmon abundance. Each summer starting in 2019, clam shells have been spread along the bottom of Richardson Brook, as well as along the banks to capture high flow events (i.e., rainfall and snow melt, when episodic acidity is expected). Since the addition of shells in 2020, the pH at the treated site has been 0.4 Units higher than during baseline conditions, as well as remaining higher than the upstream control site. No other statistically significant changes have been observed in any measured parameter (including calcium, exchangeable aluminum, macroinvertebrates, etc.). Despite the increase in pH, periodic stressful conditions are still occurring in Richardson Brook, including low pH (minimum of 4.75), low calcium (minimum of 1.4 mg/L), and high exchangeable aluminum (maximum of 44 ug/l). Further data analysis is required to determine the extent of seasonal and yearly variations, as well as any impacts to biological communities. As clam shells are added to the target area, monitoring efforts will continue until at least 2023 to determine the efficacy of using this approach to mitigate acidity.

Figure 5.3.10. Clam shells spread in and along the banks of Richardson Brook, TWP 19 ED BPP, Maine, 2021. (photo credit: Tanya Rucosky, DSF)

5.5 Hatchery Operations

As a result of the ongoing Covid-19 pandemic, which began in the spring of 2020, operations at the federal hatcheries have remained altered to ensure the health and safety of hatchery personnel. This includes the use of personal protective equipment (PPE), physical distancing of personnel during hatchery and field operations and limiting access to the hatchery. Modifications to field operations such as egg distribution, stocking and broodstock collection undertaken in 2020 continued in 2021.

Hatchery operations described below are arranged seasonally, progressing from egg transfers of 2020 eggs through juvenile stocking, adult broodstock collection, disease sampling, juvenile broodstock collection and 2021 spawning.

5.5.1 Egg Transfers

Craig Brook National Fish Hatchery (CBNFH) and Green Lake National Fish Hatchery (GLNFH) transferred 3.34M eyed eggs in 2021 to MDMR, Downeast Salmon Federation (DSF) and the Fish Friends educational program (Table 5.4.1.). Eyed eggs from each population were allocated to include egg planting, fry stocking [from the hatchery of origin], 0+ parr production, smolt production, and private rearing. Equal aliquots from each family of eyed eggs, when practical, were included in each transfer to ensure equal genetic representation in all life stages.

Table 5.4.1. Eyed egg transfers from Craig Brook National Fish Hatchery (CBNFH) and Green Lake National Fish Hatchery (GLNFH) in 2021. MDMR = Maine Department of Marine Resources, DSF = Downeast Salmon Federation, FF = Fish Friends, educational program. *Egg numbers rounded to the nearest 1,000.

Originating Entity	Strain	Rearing History	Receiving Entity	Purpose	Number*
CBNFH	Dennys	Captive/domestic	MDMR	Egg planting	43,000
CBNFH	East Machias	Captive/domestic	DSF	Private rearing	507,000
CBNFH	Machias	Captive/domestic	MDMR	Egg planting	40,000
CBNFH	Machias	Captive/domestic	GLNFH	Smolt production	21,000
CBNFH	Narraguagus	Captive/domestic	DSF	Private rearing	210,000
CBNFH	Penobscot	Sea-run	GLNFH	Smolt production	830,000
CBNFH	Pleasant	Captive/domestic	DSF	Private rearing	155,000
CBNFH	Pleasant	Captive/domestic	MDMR	Egg planting	178,000
CBNFH	Sheepscot	Captive/domestic	MDMR	Egg planting	264,000
CBNFH	Sheepscot	Captive/domestic	GLNFH	0+ parr production	21,000
GLNFH	Penobscot	Captive/domestic	MDMR	Egg planting	1,066,000
GLNFH	Penobscot	Captive/domestic	FF	Education	7,000

5.5.2 Juvenile Stocking and Transfers

CBNFH, GLNFH, Nashua National Fish Hatchery (NNFH), two DSF hatcheries (Pleasant River Hatchery and Peter Gray Hatchery) and the Fish Friends program released 4.49M juveniles (eyed eggs, fry, parr, and smolts) throughout the GOM DPS (Table 5.4.2). Stocking operations are a collaborative effort between MDMR and hatchery management.

As noted in the summary of egg transfer activities, efforts were made to ensure equal distribution of genetic material (families) in all juvenile life stages released in the GOM DPS. Particular attention was paid to stocking fry [or planting eggs] of as many families as feasible into high production habitat areas. In turn, those areas will be targeted for future captive parr broodstock collections the following year [two years post egg-planting]. These actions ensured the broad distribution of genetic material throughout varying habitat conditions.

In addition to the release of juvenile Atlantic salmon into habitat, transfers of smolts and age 0+ parr were made from GLNFH to University of Maine (UMO) researchers, the Center for Cooperative

Aquaculture Research (CCAR)[1], NNFH and an educational rearing aquarium at the Bangor Wastewater Treatment Plant (BWWTP).

Table 5.4.2. Juvenile stocking and transfers of Gulf of Maine Distinct Population Segment populations in 2021. CBNFH = Craig Brook National Fish Hatchery, GLNFH = Green Lake National Fish Hatchery, NNFH = Nashua National Fish Hatchery, DSF = Downeast Salmon Federation, CCAR = Center for Collaborative Aquaculture Research, UMO = University of Maine, FF = Fish Friends, BWWTP = Bangor Wastewater Treatment Plant. *Juvenile numbers rounded to the nearest 1,000 for values exceeding 10,000.

Originating Entity	Receiving Drainage or Entity	Strain	Action	Parr	Smolt	Egg Eyed	Fry
FF	Androscoggin	Penobscot	Release	0	0	0	600
GLNFH	BWWTP	Penobscot	Transfer	8	0	0	0
GLNFH	CCAR	Penobscot	Transfer	0	5,300	0	0
GLNFH	CCAR	Machias	Transfer	0	900	0	0
CBNFH	Dennys	Dennys	Release	0	0	43,000	313,000
DSF/CBNFH	East Machias	East Machias	Release	172,000	0	0	19,000
NNFH/GLNFH/FF	Kennebec	Penobscot	Release	0	100,000	759,000	1,800
GLNFH/CBNFH	Machias	Machias	Release	17,000	0	40,000	290,000
DSF/CBNFH	Narraguagus	Narraguagus	Release	113,000	0	283,000	280,000
GLNFH	NNFH	Penobscot	Transfer	108,000	0	0	0
FF	Passagassawakeag	Penobscot	Release	0	0	0	1,600
GLNFH/CBNFH/FF	Penobscot	Penobscot	Release	112,000	620,000	306,000	240,000
DSF/CBNFH	Pleasant	Pleasant	Release	0	0	178,000	165,000
GLNFH/CBNFH/FF	Sheepscot	Sheepscot	Release	19,000	0	264,000	28,000
GLNFH	UMO	Penobscot	Transfer	0	100	0	0
FF	Union	Penobscot	Release	0	0	0	1,000

5.5.3 Broodstock

5.5.3.1 Penobscot Domestic Broodstock

Four cohorts of domestic broodstock are maintained at GLNFH: juvenile (age 0+ to age 1), sub-adult (age two) and adult (ages three and four). The combined total of domestic broodstock reared at any given time is approximately 3,600 salmon. GLNFH annually receives Penobscot sea-run eyed eggs CBNFH for smolt production; eggs consist of equal aliquots from each mated pair of Penobscot broodstock. As fry are moved from GLNFH's inside rearing tanks to the outside rearing pools, equal aliquots from each family are combined to populate each pool. This practice allows for representatives of each sea-run family to be in each pool. To create a domestic broodstock cohort, 960 age 0+ parr are randomly selected from one outside rearing pool. Sixty fish are lethally sampled for fish health monitoring. Nine-

[1] The Center for Collaborative Aquaculture Research (CCAR), operated by the University of Maine, is rearing Machias and Penobscot origin smolts for future use in the Salmon for Maine Rivers Program.

hundred brood are reared based on rearing and incubation capacity at GLNFH and the desire to spawn 1:1.

Future brood are tagged in early-December of their second year with passive integrated transponder (PIT) tags and a fin clip is collected for genetic analysis. Following tagging, future brood are transferred to the broodstock holding area and classified as broodstock.

Eyed eggs from age three females are reserved for egg planting in the Sandy River drainage, a tributary to the upper Kennebec River, by MDMR. In the event of a shortfall of Penobscot sea-run eyed eggs, eyed eggs from age four domestic females are allocated to smolt production in a manner that captures the genetic variability of that cohort to produce a full complement of Penobscot River smolts.

5.5.3.2 Penobscot Sea-run Broodstock

Penobscot sea-run adults collected for broodstock represent multiple life stages (grilse, multi-sea winter, repeat spawners) of both hatchery and natural origin adults returning annually to the Penobscot River. Collection protocols established in 2020, in response to the Covid-19 pandemic, were continued in 2021. In addition, the collection target of 400 (200 females, 170 males and 30 grilse), established in 2020, was maintained in 2021. The foundation of this decision is based on recovery objectives outlined in the Recovery Plan to minimize the number Atlantic salmon being removed from the river and promote locally adapted stocks. The collection of 400 adults for broodstock will provide enough eggs to produce 650,000 age 1 smolts and ±100,000 age 0+ parr for release into the Penobscot River as well as ±100,000 age 0+ parr for transfer to NNFH, to be released into the Kennebec River.

CBNFH capped the number of broodstock per day at 40 to facilitate disease sample processing [see *Infectious Salmonid Anemia Monitoring* below], although the highest number of fish captured in a single day did not exceed 20. No collections were made on weekends or holidays. In 2021, broodstock collections were initiated on May 18th. Following 40 individual trips to the trap, collections concluded on July 26th with 147 adults collected. Of the 147 adults collected two were removed prior to acceptance into the broodstock population [see *Infectious Salmonid Anemia Monitoring* below] and three died of natural causes prior to spawning leaving [see *General Disease Monitoring* below].

Adults were tagged with PIT tags, sampled for genetics and scales, weighed, and measured at the hatchery. MDMR and CBNFH biologists collaborated on data collection methods that met the needs of both agencies as well as shared resources such as tags, tagging needles and other materials. In 2021 notable injuries were photographed.

As described in (Piper et al. 1982) each fish species has a characteristic range of condition factors depending on growth over time. The condition factor (C) is the ratio of a fish's weight to its length cubed. CBNFH and GLNFH use a C of 0.00035 for Atlantic salmon. Individual weights and lengths have been collected at CBNFH from sea-run adults as part of the broodstock program since 2012 and a declining trend in C is apparent (Figure 5.4.1).

5.5.3.3 Condition Factor of Penobscot River Sea-Run Adults

Declines in condition factor (C) have been observed in Atlantic salmon adults and post-smolts on both sides of the Atlantic. These declines may be influenced by poor feed availability (Utne et al. 2021), climate change (Todd et al. 2012; Calado et al. 2021), sea-lice infestation (Susdorf et al. 2018) or potential genetic factors (Bacon et al. 2009).

Data collected on individual adults is feasible due to the trapping facility at Milford and the sea-run broodstock program. In rivers lacking trapping facilities and adequate staff it is impossible to determine whether this trend is repeated in other DPS populations. The decline in C is correlated with a decline in the fecundity of sea-run Atlantic salmon at CBNFH over the same temporal period [see *Egg Production* below]. Should a similar decline in C and fecundity in other DPS populations exist it could affect occupancy and WPA models.

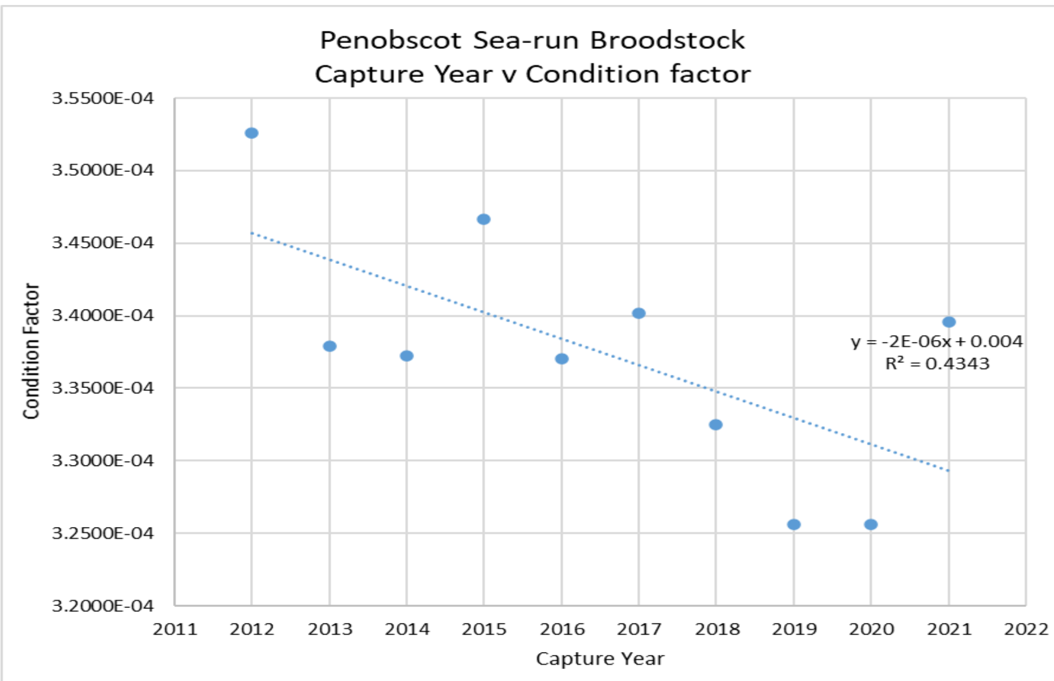

Figure 5.4.1. Condition factor (C) of sea-run Atlantic salmon sampled at Craig Brook National Fish Hatchery from 2012 through 2021.

5.5.3.4 Infectious Salmonid Anemia Monitoring

Infectious Salmonid Anemia (ISA) is an orthomyxovirus first reported among Norwegian salmon farms in the mid-1980's and first reported in the United States in 2000 (Bouchard et al. 2001). ISA is extremely infectious and may result in high mortalities in aquaculture settings. Due to the proximity of aquaculture installations to Maine rivers, sea-run adults from the Penobscot River are monitored for the disease prior to being accepted as broodstock.

Sea-run adults are isolated in a screening facility at CBNFH to undergo ISA sampling. Blood samples are analyzed using Polymerase Chain Reaction (PCR) testing at the Service's Lamar Fish Health Center (LFHC). Adults which pass the PCR test are accepted into the sea-run broodstock program and transferred to the holding area for future spawning.

In the event of a positive or suspect ISA result, additional tests are conducted on the affected individual. If diagnosed with the non-pathogenic strain (HPRO), the affected individual is released to the Penobscot

River at a location above the Milford dam. Any adults initially isolated in the same room with the HPRO individual, are allowed to join the general hatchery population.

The risk of releasing HPRO positive fish back to the river is negligible as the virus is extant in the population (John Coll, personal communication). The aim of releasing the affected individual is to avoid breeding it in a hatchery setting.

In 2021 one individual was diagnosed, via PCR, for HPRO and released to the Penobscot River.

In the event a positive diagnosis for a pathogenic strain of ISA is detected, the affected individual is euthanized. Samples of blood and tissue are collected and sent to the LFHC and the U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS). Any adults held in the same isolation room as the affected fish are isolated for an additional 28 days and then resampled.

In 2021, one individual was diagnosed, via PCR, for pathogenic ISA.   The individual did not demonstrate any clinical signs of ISA prior to being euthanized. APHIS confirmed the presence of a pathogenic ISA genome (HPR6 and HPR8) in whole blood samples, blood preserved in RNAlater™, blood diluted in Hanks Balanced Salt Solution (HBSS) and a homogenate of kidney, heart and spleen tissue. The cohort of the affected individual was quarantined for 28 days and then resampled. No additional positive results were found, and the fish were allowed to join the broodstock population.

5.5.3.5 Captive Parr Broodstock

Prior to 2018, captive broodstock targets were based on the number of broodstock required to seed available fry habitat with the equal of 240 eggs per habitat unit (100 m^2). Parr broodstock capture targets increased in the mid-2000's in response to either losses in genetic diversity or from a desire to stock additional juveniles (Table 5.4.3.). An additional number of parr, over the established target, were often collected to account for any losses prior to their first spawn at age three. The number of 'extra' parr was not established and often led to dramatic increases in broodstock population size, leading to increases in biomass, excess egg production and gravid broodstock releases.

In 2018, CBNFH equalized the number of age 1+ parr collected for the six captive broodstock populations (Dennys, East Machias, Machias, Narraguagus, Pleasant, and Sheepscot). Parr collection targets for all populations are 200 individuals with up to 15 extra parr to mitigate against potential losses (up to 1,290 total). This cohort size was derived by using broodstock maturation estimates, broodstock needs to maintain 1:1 spawning protocols, rearing space at the facility and biomass considerations. Collection targets may be adjusted for individual rivers based on genetic analysis.

Table 5.4.3. Captive broodstock collection target by population and year.

	Parr Targets by Year		
Populations:	<2006	2008-2017	>2018
Dennys	150	200	200 ± 15
East Machias	150	200	200 ± 15
Machias	250	300	200 ± 15
Narraguagus	250	300	200 ± 15
Pleasant	100	200	200 ± 15
Sheepscot	150	200	200 ± 15

Age 2 future broodstock, collected the prior year as age 1+ parr, are tagged with PIT tags and sampled for genetic characterization annually in June or July. Of the 1,282 age 1+ parr collected in 2020, 1,271 were tagged as age 2 future broodstock and will be genotyped prior to their first spawn in 2022.

The annual average size of each of the six captive broodstock populations is 675 individuals, representing five year classes. As fish mature and spawn they are released back to their natal river, so each broodstock population is diminished in numbers until the cohort is released at age five (Table 5.4.4.).

In 2021, parr collections totaled 1,249 from the six populations; each population had a minimum of 200 parr collected but some were unable to achieve the ± 15.

Table 5.4.4. Average number of captive broodstock, per age class, at Craig Brook National Fish Hatchery

Year of Capture Age 1+ Parr	Pre-broodstock Age 2	Broodstock Age 3	Broodstock Age 4	Broodstock Age 5
1,290	1,275	1,250	950	570

5.5.4 General Disease Prevention and Monitoring

CBNFH, GLNFH and NNFH adhere to facility-specific biosecurity plans and water treatments to prevent the introduction of disease to fish populations. Surface water sources for CBNFH and GLNFH are mechanically filtered and irradiated before use. Biosecurity measures include the annual fish health sampling, disinfection of eggs from other facilities, disinfection of equipment, the use of footbaths and keeping populations segregated.

Disease prevention is achieved through prophylactic formalin treatments on eggs, newly captured age 1+ parr and sea-run adults, and any fish that display clinical signs of illness or external parasites. Sea-run adults, once accepted into the broodstock population, are treated with a 25 part per million (ppm) 8-hour formalin flow-through treatment every four days to mitigate against Ich (*Ichthyophtirius multifiliis*).

Ich is a common external parasite seen in freshwater fish populations and can cause significant losses if left untreated.

Service hatcheries collaborate with LFHC and Kennebec River Biosciences for veterinarian services in the event of atypical or unusual disease events requiring either prescriptions or medicated feed.

In accordance with State of Maine aquatic health regulations and as a condition of each facility's National Discharge Elimination System Permit (NPDES) any incidence of disease, and the recommended course of treatment, is reported to the state environmental agency as well as other partners within 24 hours.

Disease monitoring at CBNFH, GLNFH and NNFH adheres to protocols established in the Service's Handbook of Aquatic Animal Health Procedures and Protocols, with some modification to accommodate the endangered status of Atlantic salmon.

The LFHC analyses samples collected from necropsied mortalities, reproductive fluids (ovarian fluid and milt), and lethal whole-body samples collected from each juvenile lot (60 each) prior to stocking. Collection of reproductive fluids is done in lieu of lethally sampling adult broodstock.

Atlantic salmon are screened for a suite of salmonid viruses and bacteria including, but not limited to, furunculosis (*Aeromonas salmonicida)*, enteric redmouth (*Yersinia ruckeri*)*,* bacterial kidney disease (*Renibacterium salmoninarum),* Infectious Hematopoietic Necrosis virus, Infectious Pancreatic Necrosis virus, Viral Hemorrhagic Septicemia virus and Infectious Salmonid Anemia virus.

No positive disease findings were made in 2021 except the two ISA diagnoses discussed above.

5.5.5 Spawning Activities and Egg Production

5.5.5.1 Spawning Activities

A total of 77 Penobscot sea-run origin females, 589 captive females, and 704 Penobscot-origin domestic females were spawned in November and December 2021 to provide eggs for egg planting, fry, parr and smolt production, domestic broodstock and educational programs.

Spawning protocols for Atlantic salmon broodstock at CBNFH and GLNFH prioritized first time spawners and utilized 1:1 paired matings.

5.5.5.2 Photoperiod Manipulation

Photoperiod manipulation is used at CBNFH to mitigate against the effects of warm water temperatures (>10°C), typically experienced in late October, on early egg and fry survival. The practice was first applied to Penobscot sea-run adult broodstock in response to an observed shift in spawn timing to earlier in October and decrease in egg quality and survival. Photoperiod manipulation entails providing 16 hours of artificial light beginning on June 20th for one month; ambient light is not restricted during this period. On or about July 20th the amount of artificial light is gradually reduced until the amount of ambient and artificial light is equalized in early November (Figure 5.4.2). Standard linear fluorescent tubes, delivering approximately 2900 lumens, are used in the Screening Building and Swedish pools.

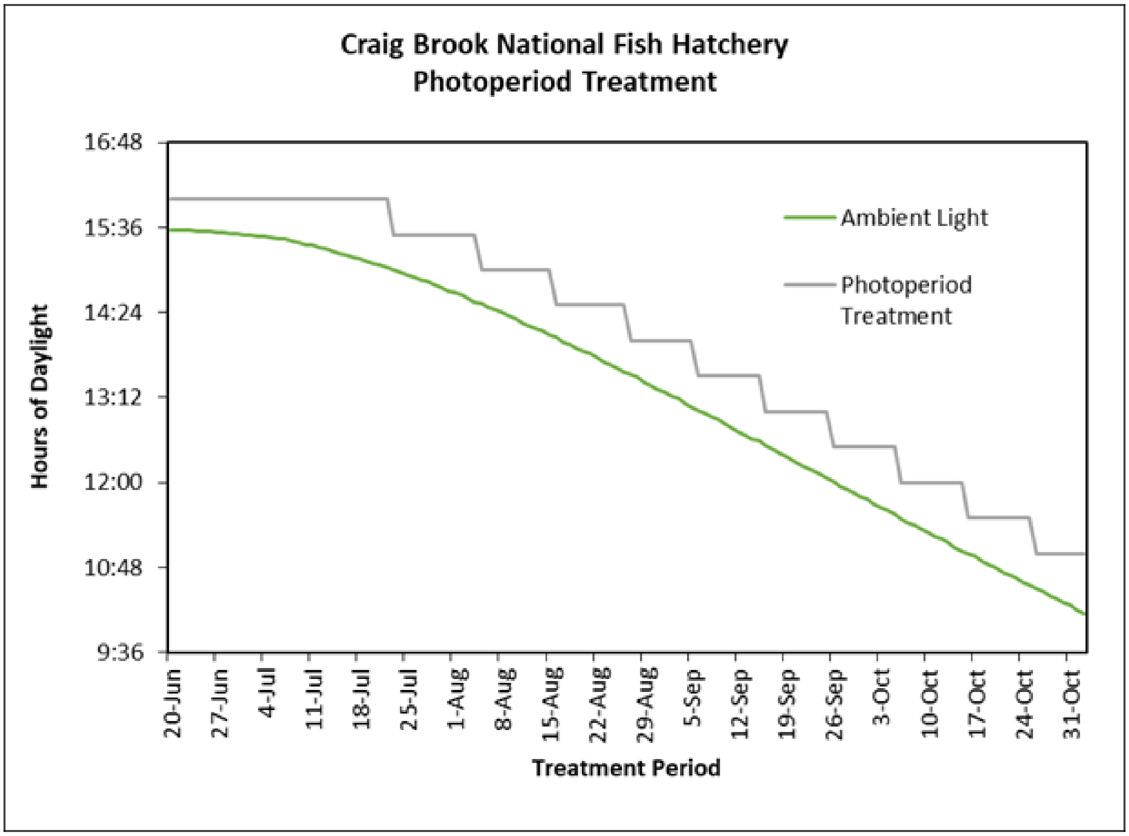

Figure 5.4.2. Number of hours of photoperiod treatment applied to adult broodstock at Craig Brook National Fish Hatchery annually from June 20th to November 3rd.

The use of photoperiod manipulation has successfully delayed spawning of sea-run broodstock by approximately 10 days (Figure 5.4.3) and allowed eggs to be collected and incubated in more favorable water temperatures (<10°C).

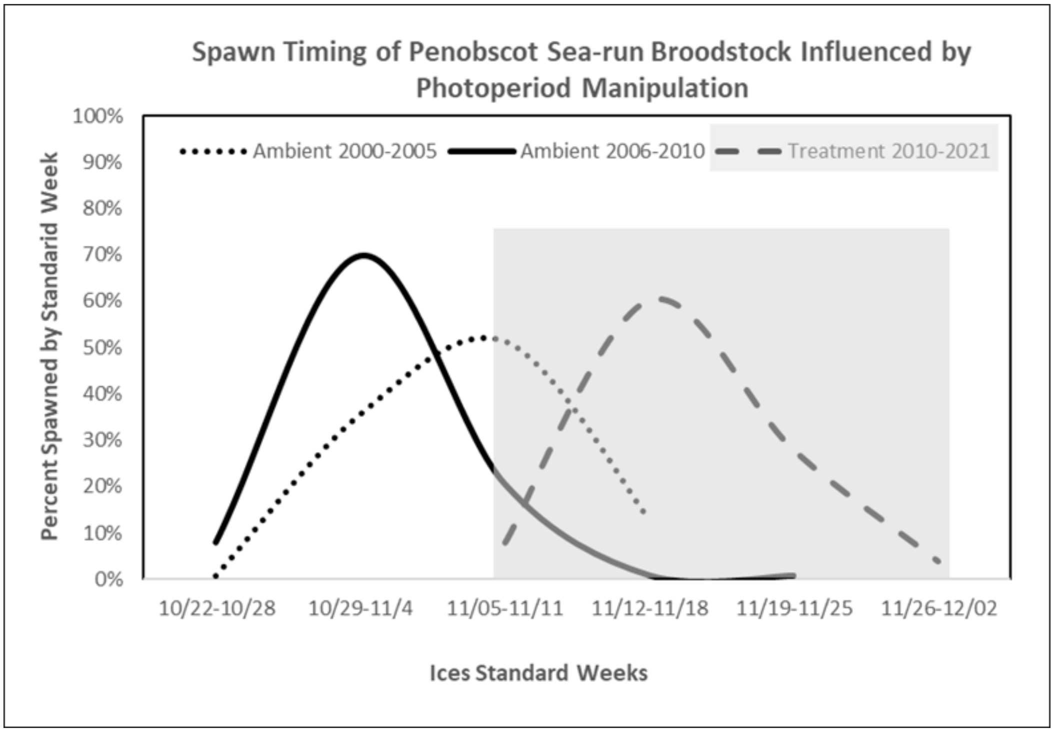

Figure 5.4.3. Shift in spawn timing of Penobscot Sea-run Broodstock at Craig Brook National Fish Hatchery after initiating photoperiod manipulation in 2010.

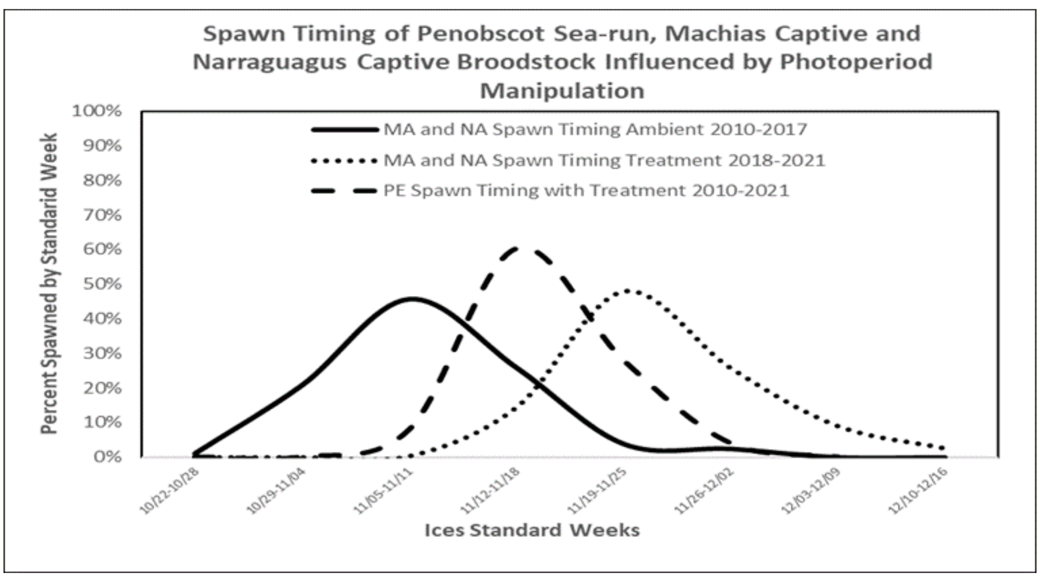

Figure 5.4.4. Spawn timing of Machias (MA) and Narraguagus (NA) captive broodstock, compared with Penobscot (PE) sea-run broodstock, as influenced by photoperiod treatment using 2900 lumen versus 7500 lumen lighting.

In 2018, the practice was extended to the Machias and Narraguagus broodstocks. New LED (light emitting diode) lighting was installed, delivering approximately 7200 lumens, in the Machias and Narraguagus broodstock modules. The use of higher intensity lighting delayed spawning for the

Machias and Narraguagus broodstocks approximately an additional week beyond the Penobscot sea-runs even though the same treatment applied for the same period of time (Figure 5.4.4). In 2019, some of the lights in those two modules were turned off which shifted spawning ahead slightly to be more in line with the Penobscot brood.

In 2020, the practice was extended to the remaining captive broodstocks. New LED lighting, delivering approximately 5700 lumens, was installed in the remaining broodstock modules. This level of light, delivered over the same time period, performed similarly to the standard fluorescent lights used for Penobscot brood area. Not only does the practice delay spawning towards more favorable water temperature conditions, but it also allows greater flexibility during the spring release season when river conditions and road accessibility can affect fry stocking activities.

5.5.5.3 Mate Matcher Software

CBNFH and GLNFH use "Mate Matcher", a proprietary software program for real-time pairing of mating individuals through optimization of all possible pairings for minimization of genetic relatedness. The software uses broodstock inventory and genotype data to calculate the proportion of shared alleles, which is the count of identical alleles shared by individuals selected for spawning; the lower the shared proportion, the less likely the individuals share common ancestry (Coombs and Nislow 2019). The software then creates data records for each successful pairing including the PIT tag identification of each male and female, their relatedness value, a unique family number and other pertinent information. CBNFH uses the optimization feature of the software for all spawning, and it is anticipated within the next five years GLNFH will also begin optimizing pairing between age three females and age four males.

5.5.5.4 Egg Production

Sea-run, captive and domestic broodstock spawned in 2021 at CBNFH and GLNFH produced 4,614,477 green eggs for the Maine program: 488,680 eggs from Penobscot sea-run broodstock; 1,656,921 eggs from domestic broodstock; 2,468,876 eggs from captive broodstock populations.

Egg production from CBNFH and GLNFH contribute towards river-of-origin and out-of-basin egg planting, fry production, educational programs, private rearing (fry and parr production), parr and smolt production.

As described in Figure 5.4.1., a decline in the C of Penobscot sea-run broodstock has been observed over the past ten years. Over the same time period a decline in the fecundity (eggs per female) has also been observed, although not closely correlated with the change in C (Figures 5.4.6. and 5.4.7.).

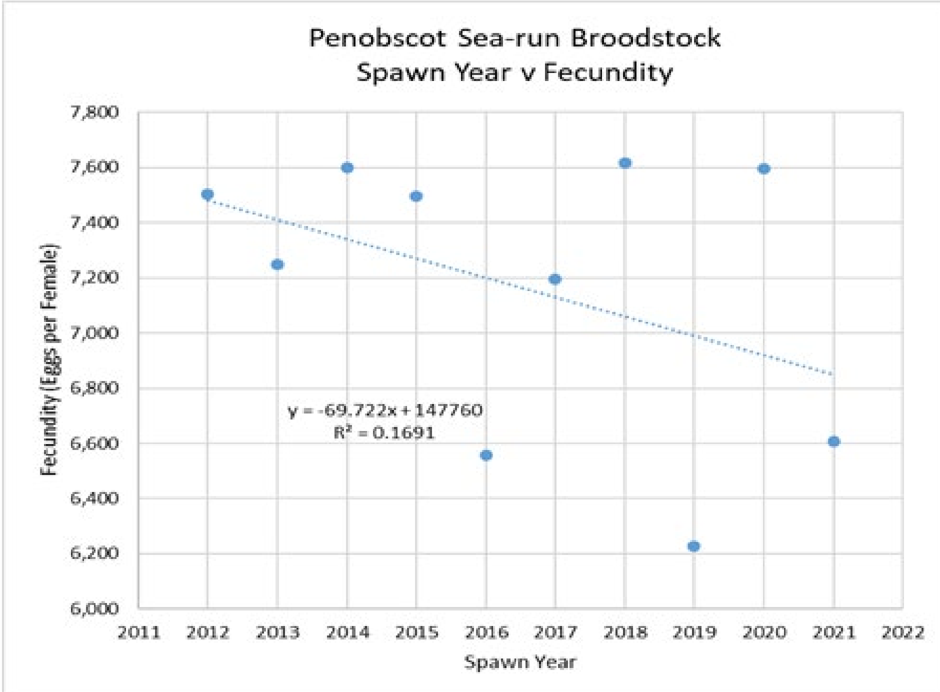

Figure 5.4.6. Observed decline in Penobscot sea-run broodstock fecundity from 2012 through 2021.

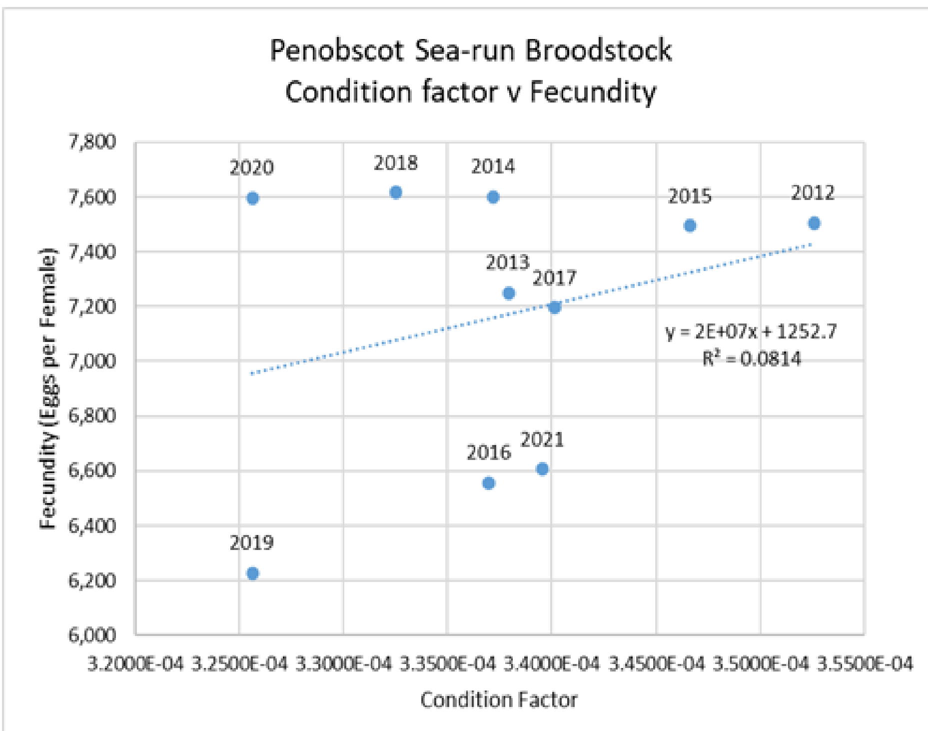

Figure 5.4.7. Relationship of Penobscot sea-run broodstock condition factor and fecundity from 2012 through 2021.

5.5.5.5 Adult Stocking

A total of 2,212 adults were stocked into GOM drainages (Table 5.4.5). All adult releases were of post-spawned spent broodstock except for one Penobscot sea-run adult released back to the river following a diagnosis of non-pathogenic ISA (see *Infectious Salmonid Anemia Monitoring)*.

CBNFH releases spent age three and four broodstock while retaining a small cohort to spawn in future years as needed. The entire age five year class is released following their final spawn. GLNFH releases spent age three broodstock at the entire age four year class following spawning. All Penobscot sea-run broodstock are released post-spawning.

Spent broodstock are released to the rivers-of-origin within a week or two following spawning. All broodstock are PIT tagged and have either a double upper caudal fin punch or a double adipose punch to identify them. Releases of spent broodstock are coordinated with MDMR biologists, as well as state and federal game wardens.

Table 5.4.5. Adult broodstock released pre- and post-spawn from Craig Brook and Green Lake National Fish Hatcheries in 2021.

Originating Entity	Receiving Drainage	Strain	Pre/Post Spawn	Lot	Number Stocked
CBNFH	Dennys	Dennys	Post-Spawn	Captive/Domestic	196
CBNFH	East Machias	East Machias	Post-Spawn	Captive/Domestic	218
CBNFH	Machias	Machias	Post-Spawn	Captive/Domestic	181
CBNFH	Narraguagus	Narraguagus	Post-Spawn	Captive/Domestic	171
GLNFH	Penobscot	Penobscot	Post-Spawn	Captive/Domestic	905
CBNFH	Penobscot	Penobscot	Pre-Spawn	Sea-run	1
CBNFH	Penobscot	Penobscot	Post-Spawn	Sea-run	141
CBNFH	Pleasant	Pleasant	Post-Spawn	Captive/Domestic	212
CBNFH	Sheepscot	Sheepscot	Post-Spawn	Captive/Domestic	187

5.6 General Program Information

5.6.1.1 GOM DPS Recovery Plan

The Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon has been completed by the USFWS and NOAA in close collaboration with MDMR and the Penobscot Indian Nation and was released on February 12th, 2019. This document is available at: https://www.fisheries.noaa.gov/action/final-atlantic-salmon-recovery-plan?utm_medium=email&utm_source=govdelivery

A new format for integrating communication and restoration efforts was put in place in 2019. This is called the Collaborative Management Strategy (CMS) and is composed of both upward and outward components. The CMS replaces the previous Atlantic Salmon Framework. At its base, the CMS has three SHRU specific coordinating committees that are charged with development of recommended recovery actions that are tailored to each SHRU. Above these committees is the Implementation Team (IT) which is made up of the SHRU team chairs and the Management Board. This is the interface between on the ground managers and upper level decision makers. Finally, the Management board is the group of agency leads representing FWS, NOAA, MDMR and the PIN.

One task undertaken by the SHRU Coordinating Committees has been the development of SHRU specific work plans. Draft 5-year SHRU based recovery plans and stock enhancement plans are currently under consideration by the management board. Recognizing that each SHRU has different priorities in the lens of triaging threats to Atlantic salmon recovery, this process provides detailed actions in a list format for agencies and NGOs to reference.

5.7 References

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6 Outer Bay of Fundy

The rivers in this group are boundary waters with Canada. Further, the majority of the area for both watersheds is in Canada. As such, the Department of Fisheries and Oceans conducts assessments and reports status of stock information to ICES and NASCO. Any data reported is limited to the Aroostook River (St. John) and the St. Croix Rivers.

6.1 Adult Returns

The Tinker fishway trap on the Aroostook River was operated by Algonquin Power Company from 2 July to 29 October 2021. One Atlantic salmon was captured and released upstream in 2021. The salmon was a hatchery origin 2SW male.

6.2 Hatchery Operations

Stocking

No juvenile life stages were stocked.

Adult Salmon Releases

No adults were stocked.

6.3 Juvenile Population Status

Electrofishing Surveys

There were no population assessments in the Aroostook River watershed.

Smolt Monitoring

No smolt monitoring was conducted for the Aroostook River program.

6.4 Tagging

No tagging occurred in the Aroostook River program.

6.5 Fish Passage

No projects or updates.

6.6 Genetics

No tissue samples were collected.

6.7 General Program Information

There were 550,123 river herring and 40 American shad passed at the Milltown dam fishway on the St. Croix. Also, the Milltown dam is scheduled to be removed in 2022.

7 Emerging Issues in US Salmon and Terms of Reference

7.1 Summary

This section provides an overview of information presented or developed at the meeting that identifies emerging issues or new science or management activities important to Atlantic salmon in New England. To be proactive to requests from ICES and NASCO, this section is developed to report on and bring into focus emerging issues and terms of reference beyond the scope of standard stock assessment updates that are typically included in other sections. This section reviews select working papers, ensuing discussions, and ad-hoc topics to provide information on discussions and decisions made by the USASAC.

7.2 Scale Archiving and Inventory Update

The USASAC noted that the lack of dedicated resources and capacity has delayed an effort to better archive and inventory historic scale samples throughout New England. In 2017, a general inventory was conducted by New England fishery agencies participating in USASAC. We found that much information is currently contained in databases such as the Maine program's Adult Trap and Bioscale Databases. However, storage details and the condition of fish scales has not been adequately summarized. The USASAC supports continued efforts of an ad-hoc committee to work towards identifying funding sources and drafting a proposal to add capacity to inventory and archive historic scale samples throughout New England.

In 2021, the USASAC was briefed on activities and updates made by S. Gephard (DEEEP, Ret) and R. Haas-Castro (NOAA) regarding the archiving and inventory update. S. Gephard presented these materials which included: Visits to MDMR offices in Jonesboro and Augusta in August of 2021 to inventory the Maine collections. At this time, all scale samples known to have been stored at the Bangor office had been recently transferred to the Augusta office. Collections were inventoried by box or storage unit (e.g. file cabinet). All samples remain in those two locations according to the wishes of the MDMR. In December of 2021, all available salmon scale collections at the Springfield, VT, office of VTFW were acquired and brought to Gephard's home in Deep River, CT, for inventory and repackaging prior to transporting them to NOAA-Fisheries storage space in Cohasset, MA. All inventory data and supplementary information were entered into an Excel spreadsheet with various pertinent information (agency, location, sample type, life stage, year, location, box descriptions, number of samples per box, disposition, and comments).

A constructive discussion ensued with some urgency expressed to identify existing biomineral inventories across agencies and throughout the historical range of Atlantic salmon in the USA. With the geography of assessments shrinking and storage facilities limited, the urgency of understanding what there is for inventory (data and samples) and how it is presently stored was the focus of much of the discussion. The ad hoc group will continue with inventory and archiving activities and provide further reporting in 2022 to be reported in the TOR for 2023.

7.3 Juvenile Assessment Update

Over the past twenty years juvenile abundance efforts have been determined based on individual studies or larger scale basin wide estimates. Sampling locations were often picked based on likelihood of a successful catch or proximity to a road at a time when equipment was heavy and cumbersome. The use of multiple-pass depletion methods were used to estimate juvenile salmon production. While providing a closer estimate of the true population size with error around the estimates, these methods take more time to perform and reduce the number of locations a field crew can sample in a season. Additionally, these methods increase the risk of electrofishing injuries. More recently the use of a single pass Catch per Unit Effort has been adopted. The main advantages single-pass has over multiple-pass methods is it reduces injuries, and more sites can be surveyed in each time frame and over a larger geographical area within a drainage.

With the ability to sample more locations managers can examine the spatial distribution and abundance of salmon across the drainages and regions. However, to do this objectively can be an additional challenge. The method outlined by (Stevens and Olsen, 2004) has been applied to select biological sampling locations based on a Generalized Random – Tessellation Design (GRTS) for a linear resource. Besides removing objectiveness from sampling site selection, use of this selection method can allow for other spatial relationships to be examined such as temperature, physical stream habitat variables, water quality, and land uses, all which could be used in development of a species distribution and habitat model (SDHM).

An update was provided by E. Atkinson on the progress of Generalized Random - Tessellation Stratified (GRTS; Stevens and Olsen) sampling from 2021. Plans for 2022 include continuing the use of GRTS By breaking down sampling needs to cover long term trends (GRTS Index), wild production (WPA) and project based sampling (Project), a strong base of data will exist for current and future management needs. Future work within GRTS selected site could include specific habitat monitoring or long term water temperature monitoring. These data can be paired with site biological data to inform SDHM's that would aid in optimizing rearing strategies and habitat restoration projects across the Maine DPS. An update on 2022 sampling activities will be provided in 2023 TOR reporting.

7.4 Naturally Reared Smolt Definitions - ICES vs. Recovery Plan Reporting

The USASAC added fish stocked as age-0 parr (Oct/Nov) to other life stages stocked in year-0 (fry stocking, egg planting and wild reproduction) within the definition of naturally reared as outlined in the recovery plan. It was decided within reporting of smolts that origin groups will be continued to be broken out into two unique origin categories for fall parr (ambient and/or accelerated). This would allow summarizing these fish into separate groups as needed by ICES or recovery plan needed as naturally reared or hatchery fish. Ambient (stream reared) parr are smaller in size and growth patterns observed in wild, egg, or fry stocked fish, whereas the accelerated parr (hatchery reared) have characteristics of larger size and growth similar to hatchery smolts. Parr are loosely defined as "naturally reared" according to the recovery status, but breaking out biometrics, abundance and population estimates, is important to managers and their restoration actions.

The USASAC discussed the best method of incorporating the different categories into USASAC databases. It was agreed to work on the specifics during the intercession and revisit at the summer meeting. For summary calculations (smolt pro-ration or stocking totals) this effort is straightforward. For longer integrated calculations such as replacement rates, this would require updating some database fields going back a decade or more for repeatability and standard comparisons.

Finally, to aid field biologists and project managers in more accurately identifying origins, continued evaluation and implementation of a hatchery marking program to distinguish hatchery from wild stocks should continue to be a priority. Such a program would aid in the evaluation of the recovery criteria (USFWS and NMFS 2018) and management of recovery efforts. Hatchery marking programs have been identified as a need in the hatchery review (SEI 2007) and *The Williamsburg Resolution* (NASCO 2003).

Emerging Issues

7.5 Need for Accurate and Consistent Reporting on Habitat Connectivity gains

The USASAC discussed increasing needs for accurate reporting of habitat accessibility data at the international and domestic level. These goals are reported annually in the U.S. Annual Progress Report to NASCO where the US needs to report on restoring connectivity to 15,000 units of salmon habitat by 2024 through improved fish passage. This objective can be achieved by removing dams, installing fishways, removing culverts, decommissioning roads, and upgrading road-stream crossings. Collecting this information is important but capacity and the reporting and synthesis infrastructure needed to do this are limited. Additionally, at the national level, a database is needed to report on progress towards attainment of the habitat metric in the recovery plan. The final recovery plan states that a minimum of 30,000 units of accessible (as defined in the recovery plan) and suitable habitat must be obtained before delisting is considered. The determination of suitable habitats are left to the discretion of scientists and managers. The Committee discussed this issue and because habitat actions have been part of this report further work here was considered appropriate for synthesis review. However, the USASAC does not have the capacity to build or manage the database needed. This is an essential need for reporting at international and domestic levels. What USASAC can offer is a forum where the group could review developing systems on best available information annually.

Citations:

NASCO. 2003. Resolution by the Parties to the Convention for the Conservation of Salmon in the North Atlantic Ocean, The Williamsburg Resolution. Adopted at the Twentieth Annual Meeting of North Atlantic Salmon Conservation Organization in June 2003, as amended.

SEI. 2007. Review of Atlantic Salmon Hatchery Protocols, Production, and Product Assessment. Sustainable Ecosystems Institute, Portland Oregon.

U.S. Fish and Wildlife Service and NMFS. 2018. Recovery plan for the Gulf of Maine Distinct Population Segment of Atlantic salmon (*Salmo salar*). 74 pp.

7.6 Draft Terms of Reference for 2023 Meeting

The purpose of this section is to outline terms of reference identified at the USASAC annual meeting in March 2020. These draft Terms of Reference are meant to be revisited during our summer 2020 teleconference and intersessional work. These draft TOR will be integrated with requests and needs that emerge from the ICES WGNAS (March 2020); NASCO Meetings (June 2020), and the Maine Collaborative Management Strategy Annual Report (April 2020) to develop Final 2022 TOR and an agenda for the 2023 USASAC Meeting.

In **support of North American Commission to NASCO**, we anticipate reporting on the following with respect to Atlantic salmon in the United States

Describe the key events of the annual fisheries bycatch (targeted fisheries are closed) and aquaculture production

Update age-specific stock conservation limits based on new information as available including updating the time-series of the number of river stocks with established CL's by jurisdiction.

Describe the status of the stocks including updating the time-series of trends in the number of river stocks meeting CL's by jurisdiction.

Update framework of indicators – what it is, how it works, what the US has contributed in the past

Compilation of Tag releases

In **support of the Maine Cooperative Management Strategy Implementation Team**, we anticipate reporting on the following with respect to Atlantic salmon in the Gulf of Maine DPS.

Status of US Populations for the Gulf of Maine DPS at SHRU level including:
Adult Returns Estimate (Hatchery and Naturally Reared)
Freshwater Production Summaries – Smolts and pre-smolt production CPUE
Marine Survival – hatchery index Penobscot and naturally-reared Narraguagus
Diversity Metric
Hatchery production
Connectivity
Distribution - occupancy maps and data

Scale Archiving - Continue efforts to foster retention of all US Atlantic salmon scales, tissue, and associated databases for future analysis by seeking funding and capacity to both complete the task and secure long-term storage. Progress on inventory activities.

Juvenile Assessment Update. Develop a synthesis document that describes both the long-term index sites through 2012 (Sweka) and new Generalized Random - Tessellation Stratified (GRTS; Stevens and Olsen 2004) design (2013-2017) (Atkinson) for Maine. From this foundation, document lessons learned and the best path forward for monitoring juvenile production status and trends in one index river system in each SHRU. From this foundational work, develop a list of research needs for historic data related to time-series and climate (for Furey), approaches for index rivers, and complementary efforts that address specific restoration questions (e.g. dispersion from artificial redds, fry vs. parr etc.). -

Biological characteristics of US Atlantic salmon - To better inform international stock assessment activities, there is opportunity to provide more detailed population dynamics information for US populations within ICES WGNAS assessment models given the development of expected adoption of the new Life Cycle Modeling (LCM) approach. The new LCM has the ability to incorporate detailed information on age-specific adult abundance, estimates of annual escapement, estimates of annual smolt ages, estimates of annual fecundities, estimate of sea age-specific sex distribution of adult returns etc. The LCM has yet to be formally benchmarked and accepted by ICES as the official assessment model for the WGNAS, but this is expected to occur in 2024. In support of this, the USASAC will work towards developing these time series data-streams to be available for use within the LCM.

Conservation Limits - Continue refinement of Conservation Limits especially within the Gulf of Maine DPS. Review and update the number of rivers with conservation limits and the monitored time series.

Connectivity Reporting - Pursuant to accurate reporting of habitat accessibility gains, the U.S. Atlantic Salmon Assessment Committee agreed to review protocols and database structures as they are developed and recommend any necessary changes to data management in support of domestic or international management needs.