2016 ANNUAL REPORT & MEETING

Lake Superior State University's
Aquatic Research Laboratory
&
Michigan Department of
Natural Resources

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2016 Annual ARL-MDNR Meeting Agenda

9:30 am – 2:30 PM
June 2, 2016
Anchor Room, Cisler Center, LSSU

9:30-9:35	Welcome and introductions – Kevin Kapuscinski & Ashley Moerke
9:35-10:00	Hatchery operations – Roger Greil
	ATS planned stocking 2015
	ATS rearing 2013-2015
	ATS brood stock netting report 2015
10:00-10:15	ATS Health update 2014-2016 – Jun Li
	Production and brood stock health inspection
	BKD results (MSU and LSSU)
	Thiamine results
10:15-10:35	Fish Disease Lab updates – Jun
	Health status of migrating and resident fishes in three tributaries of Whitefish Bay, Lake Superior
	Effects of dietary β-glucan derived from algae on growth performance, disease resistance and immune response in Atlantic Salmon juveniles
10:35-10:40	Larval fish sampling in the St. Marys and Carp rivers – Jake Larsen
10:40-11:10	MDNR Update - Hatchery activities – Randy Espinoza
11:10-11:25	Roxbury Pond overview – Cory Kovacs
11:25-11:35	Introduction of MI Sea Grant Extension Educator, Elliot Nelson
11:35-12:20	Lunch break (lunch provided)
12:20-12:25	Fishery internships update – Kevin
12:25-1:50	Research Activities (5-10 min each)
	Superior AquaSystems and aquaculture challenge – Barbara Evans
	Egg mortality in the sensitive stage - Jonathan Edwards
	Olfaction development in hatchery fish –Trevor Pitcher (Windsor)
	Cisco and Muskellunge projects – Kevin
	Didymosphenia geminata in the SMR – Ashley & Megan Kelly
	Little Rapids restoration and GLCW monitoring updates – Ashley
	Fish migration project– Frank Zomer
1:50-2:00	Updates on ARL/LSSU facilities and events
	Hunt Creek Field Station Update – Barbara
	30th Anniversary Atlantic Salmon celebration, June 3 – all invited
2:00-2:30	Other business
10:00-11:00 pm	Atlantic Salmon Release at the lab – all invited

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ACKNOWLEDGMENTS

We are extremely grateful to Cloverland Electric Cooperative for providing space within their facility and electricity, which are essential to our hatchery operations. We are also appreciative of Lighthouse.net for graciously providing broadband internet service for broadcasting our fishcam (http://www.lssu.edu/arl/fishcam.php). The Michigan Department of Natural Resources supplies the feed necessary to sustain our hatchery operation, funds all disease testing, and provides expertise and additional supplies as needed. We also acknowledge the numerous student employees, volunteers, and donors that contribute to the success of the Aquatic Research Laboratory.

HATCHERY OPERATIONS

Stocking & Disease Testing

A total of 29,880 age-1 and 7,680 age-0 Atlantic Salmon (*Salmo salar*) that were reared at Lake Superior State University's Aquatic Research Laboratory (ARL) were stocked into Michigan waters in 2015 (Table 1). Age-1 fish (lot P-ATS-LL-W-13-SM-LS-LS) received a right pectoral fin clip, averaged 164 mm in total length, and were stocked into the St. Marys River on 2 June 2015. Survival of these age-1 fish was about 86% from the eyed-egg stage until the time of stocking, similar to the survival rate observed for the previous five year classes. Age-0 fish (lot P-ATS-LL-W-14-SM-LS-LS) did not receive a fin clip, averaged 102 mm in total length, and were transported and stocked into Torch Lake (Antrim County) by Michigan Department of Natural Resources (MDNR) personnel on 27 October 2015. Sixty age-1 fish and sixty age-0 fish were tested for the presence of *Aeromonas salmonicida*, Bacterial Kidney Disease (BKD), Infectious Hematopoietic Necrosis Virus, Infectious Pancreatic Necrosis Virus, Viral Hemorrhagic Septicemia Virus, and *Yersinia ruckeri* by Michigan State University (MSU) personnel prior to stocking; age-0 fish were also tested for *Myxobolus cerebralis*. All fish tested negative for pathogens (Appendices 1 & 2).

Table 1. Number and mean total length of age-1 Atlantic Salmon stocked during 1987-2015. Stocking typically occurred between mid-May and mid-June of each year.

Year	# stocked	Mean total length
1987	19,000	189
1988	12,751	196
1989	19,966	170
1990	31,702	131
1991	8,367	127
1992	8,048	179
1993	47,716	191
1994	20,350	174
1995	29,060	185
1996	33,756	183
1997	43,373	150
1998	41,721	142
1999	49,818	181
2000	46,220	179
2001	35,909	172
2002	29,313	154
2003	54,743	180
2004	24,811	211[a]
2005	29,665	201[a]
2006	38,032	186
2007	20,437	178
2008	29,373	186
2009	28,400	185
2010	26,301	184
2011	31,100	200
2012	35,230	189
2013	35,000	196
2014	40,908	181
2015	29,880	164

[a] Fish were held until August because they were treated for Bacterial Kidney Disease and furunculosis

Sub-adult Rearing and Use for Education and Research

A total of 38,839 age-0 Atlantic Salmon were moved into fry raceways in early March of 2015 at the time of early feeding and reared in heated water until June. About 35,000 age-0 Atlantic Salmon survived through early June of 2015, at which time they were transferred into large raceways and reared in ambient river water. On average, these fish grew about 128 mm in total length during March-November 2015 (Table 2). A total of 36,798 age-1 Atlantic Salmon were fin clipped in May 2016 and will be stocked into the St. Marys River on 2 June 2016.

Table 2. Biweekly rearing data of age-0 Atlantic Salmon reared in heated water in 2015 (lot: P-ATS-LL-W-14-SM-LS-LS). The number of fish initially moved into fry raceways was 38,839.

Mid date of biweekly summary	Ending # of fish[a]	Mean temp (°C)	Mean length (mm)	Mean biomass (kg)	TUGR (mm/C)	FCR	Biweekly mortality (%)	Mean density (kg/m^3)	Flow (L/min)
3-Mar	38,417	10.51	26.17	6.39	0.021	0.84	1.09	5.42	39
17-Mar	37,164	10.20	28.40	8.13	0.010	2.91	3.26	6.89	66
31-Mar	35,995	8.86	30.25	9.59	0.019	2.06	3.15	5.45	88
14-Apr	35,713	8.15	33.00	12.35	0.028	1.53	0.78	7.02	117
28-Apr	35,456	8.08	36.65	17.05	0.036	1.27	0.72	9.69	117
12-May	35,161	8.36	41.25	24.54	0.044	1.23	0.83	13.12	125
26-May	35,056	9.06	46.7	36.09	0.046	0.90	0.30	19.30	125
9-Jun	34,981	8.98	52.95	53.50	0.053	0.74	0.21	28.61	125
23-Jun	34,897	9.83	60.05	79.40	0.054	0.58	0.24	8.50	311
7-Jul	34,663	12.22	68.2	118.05	0.051	0.79	0.67	6.32	934
21-Jul	34,581	15.56	76.85	171.58	0.039	1.37	0.24	6.76	1,693
4-Aug	34,501	17.46	86.0	244.05	0.040	1.31	0.23	9.61	1,693
18-Aug	34,435	17.41	96.1	345.89	0.043	1.08	0.19	13.62	1,270
1-Sep	34,312	18.39	106.8	481.50	0.043	1.28	0.36	12.38	2,592
15-Sep	34,196	18.52	118.15	660.11	0.045	1.06	0.34	16.98	2,592
29-Sep	34,133	16.79	130.2	894.72	0.053	0.74	0.18	23.01	2,592
13-Oct	34,110	13.07	142.8	1,196.45	0.070	0.64	0.07	30.77[b]	2,592
27-Oct	34,091	9.53	154.6	1,538.03	0.081	0.53	0.06	39.56[b]	2,592

[a] Number of fish estimated by batch weight method

[b] High densities were because fish were combined in raceways to accommodate brood stock collection

An additional 10,337 age-0 Atlantic Salmon were moved into fry raceways on 9 June of 2015 and reared in ambient water; feeding began on 19 June 2015. About 8,804 fry survived through early July of 2015, at which time they were transferred into large raceways. On average, these fish grew about 72.65 mm in total length during June-October 2015 (Table 3). A total of approximately 7,680 age-0 Atlantic Salmon were taken by MDNR personnel and stocked into Torch Lake on 27 October 2015.

Table 3. Biweekly rearing data of age-0 Atlantic Salmon reared in ambient water in 2015 (lot: P-ATS-LL-W-14-SM-LS-LS). The number of fish initially moved into fry raceways was 10,337.

Mid date of biweekly summary	Ending # of fish[a]	Mean temp (°C)	Mean length (mm)	Mean biomass (kg)	TUGR (mm/C)	FCR	Biweekly mortality (%)	Mean density (kg/m^3)	Flow (L/min)
30-Jun	10,218	9.86	25.00	1.572	0.009	5.03	1.15	4.91	11
14-July	8,804	13.26	31.32	2.773	0.063	0.89	13.84	8.66	16
28-July	8,157	15.56	42.32	6.488	0.048	1.00	7.35	6.83	63
11-Aug	8,097	17.47	52.50	12.28	0.040	0.90	0.74	3.63	113
25-Aug	7,971	18.65	62.05	20.50	0.035	0.80	1.55	6.07	169
08-Sep	7,937	18.39	71.20	31.88	0.034	1.25	0.42	4.91	212
22-Sep	7,854	18.53	80.05	44.61	0.035	1.35	1.04	7.02	318
06-Oct	7,775	16.79	88.80	60.97	0.037	1.01	1.00	9.61	423
20-Oct	7,717	13.07	97.65	81.22	0.048	0.82	0.75	12.8	423

[a] Number of fish estimated by batch weight method

Table 4. Summary data of 303 Atlantic Salmon used and sacrificed for education and research activities during May 2015-May 2016.

Date	Number	Size category	Use
20-May-15	13	Yearlings	Quality Assessment Dissection
21-May-15	12	Yearlings	Quality Assessment Dissection
22-May-15	2	Yearlings	Quality Assessment Dissection
29-June-15	120	Fry	Dr. Li-feeding study
14-Sep-15	60	Fall fingerlings	MSU-health inspection
18-Jan-16	5	Yearlings	Dr. Li-class
15-Mar-16	40	Fry	MSU-disease diagnosis
22-Mar-16	7	Yearlings	F&W Club- JKL dissection class
24-Mar-16	10	Fry	Dr. Kapuscinski-class
24-Mar-16	6	Yearlings	Dr. Kapuscinski-class
4-Apr-16	5	Yearlings	Dr. Li-class
18-Apr-16	3	Yearlings	Dr. Li-class
25-May-16	20	Yearlings	Quality Assessment Dissection

Broodstock Collection, Disease Testing, Gamete Collection, and Egg Treatments

Personnel from the ARL and MDNR collected returning adult Atlantic Salmon for broodstock on 29-31 October 2015. Fish were captured from the St. Marys River at the Cloverland Hydroelectric Plant using a gill net that covered the opening of the first inactive turbine tailrace on the east side of the closest active turbine. The gill net used was 15.2 m (50 ft) long, 3.4 m (10 ft) high, with a 10.2 cm (4 in) stretch mesh. The net was continuously observed until a fish became entangled in the net, at which time the net was lifted and the fish was immediately removed. Each fish was measured for length and weight, and examined to determine sex, maturity (ripe or unripe), presence of fin clips, tags, and Sea Lamprey (*Petromyzon marinus*) scars. After examination, Atlantic Salmon were retained for subsequent gamete collection in one of two raceways based on sex.

The net was fished on 29 October from 08:16-12:13 (3.97 hr), on 30 October from 13:20-16:34 (3.14 hr) and 31 October from 08:39 -14:48 (6.18 hr) for a total of 13.29 hr. A total of 348 Atlantic Salmon were collected; 105 on 29 October, 95 on 30 October, and 148 on 31 October. No species other than Atlantic Salmon were captured during broodstock netting in 2015. The catch rate of Atlantic Salmon was just over 26 fish per hr (Table 5). The 214 male fish captured averaged 60.92 mm in total length and 2.12 kg in weight, whereas the 134 females averaged 63.32 mm in total length and 2.82 kg in weight. Brood fish were age 2-5, with 54% of all fish captured being age-2 (Table 5). The average Fulton's condition factor *K* for all fish was 1.09 in 2015, and there was no discernable trend since record-keeping began in 1990 (Figure 1). Data on individual Atlantic Salmon used as broodstock are presented in Appendix 4. Eleven of the 348 fish (3.2%) were possibly reared by the MDNR based on the presence of eroded fins and double fin clips (3 possessed an adipose fin clip). About 21.6% of all Atlantic Salmon had at least one Sea Lamprey scar (Figure 2). The most common types of scars were Type B, stage IV (38.3%) and Type A stage IV (37.2%; Table 6).

Table 5. Summary data from gill-netting of Atlantic Salmon broodstock from 1990-1994 and 1998-2015.

Year	# of fish	Mean hr/d	# of d	Net length (m^2)	Mean # fish/hr	Mean # fish/d
1990	46	-	23	47	-	2
1991	65	6.5	23	47	0.43	2.83
1992	19	6.7	28	58	0.1	0.68
1993	11	2.5	18	56	0.24	0.61
1994	18	2.6	23	65	0.31	0.78
1998	87	2.6	17	47	1.98	5.12
1999	49	3	26	56	0.63	1.88
2000	105	2.8	18	47	2.0	5.83
2001	116	2.5	13	47	3.61	8.92
2002	104	2.7	13	56	2.94	8.0
2003	158	2.8	9	56	6.36	17.56
2004	196	3.1	14	56	4.5	14
2005	210	4.1	6	56	8.52	35
2006	111	2.7	6	56	6.83	18.5
2007	276	2.6	6	56	17.52	46
2008	172	2.8	4	47	15.4	43
2009	140	4.5	3	47	10.37	47
2010	212	4.8	3	47	14.78	70.67
2011	240	4.2	4	47	14.19	42.4
2012	313	2.0	6	47	26.21	52.17
2013	378	3.5	4	47	27.35	94.49
2014	225	2.9	2	47	38.79	112.5
2015	348	4.4	3	47	26.19	116.0

Table 6. Age of Atlantic Salmon captured in fall 2015 broodstock collection efforts. Fish with an adipose (AD) fin clip were reared and stocked by the MDNR.

Age	Type of clip	# of males	# of females	Total # of fish
	AD	1	2	3
2	LV	146	43	189
3	LP	54	56	110
4	RV	7	17	24
5	RP	2	12	8
	None/regenerated	4	4	8
	Grand total	214	134	348

Table 7. Classification of Sea Lamprey scars observed on Atlantic Salmon captured in 2015 broodstock collection efforts. Percentages are based on 75 fish that had scars (28 males and 47 females).

Gender	Scar type	Scar stage	# of scars	Percent
Male	A	I	1	1.9
	A	II	2	3.8
	A	III	0	0.0
	A	IV	11	20.8
	Subtotal		14	26.4
	B	I	5	9.4
	B	II	1	1.9
	B	III	0	0.0
	B	IV	7	13.2
	Subtotal		13	24.5
Female	A	I	4	7.5
	A	II	4	7.5
	A	III	1	1.9
	A	IV	24	45.3
	Subtotal		33	62.3
	B	I	2	3.8
	B	II	2	3.8
	B	III	1	1.9
	B	IV	29	54.7
	Subtotal		34	64.2
	Grand total of A		47	50.0
	Grand total of B		47	50.0

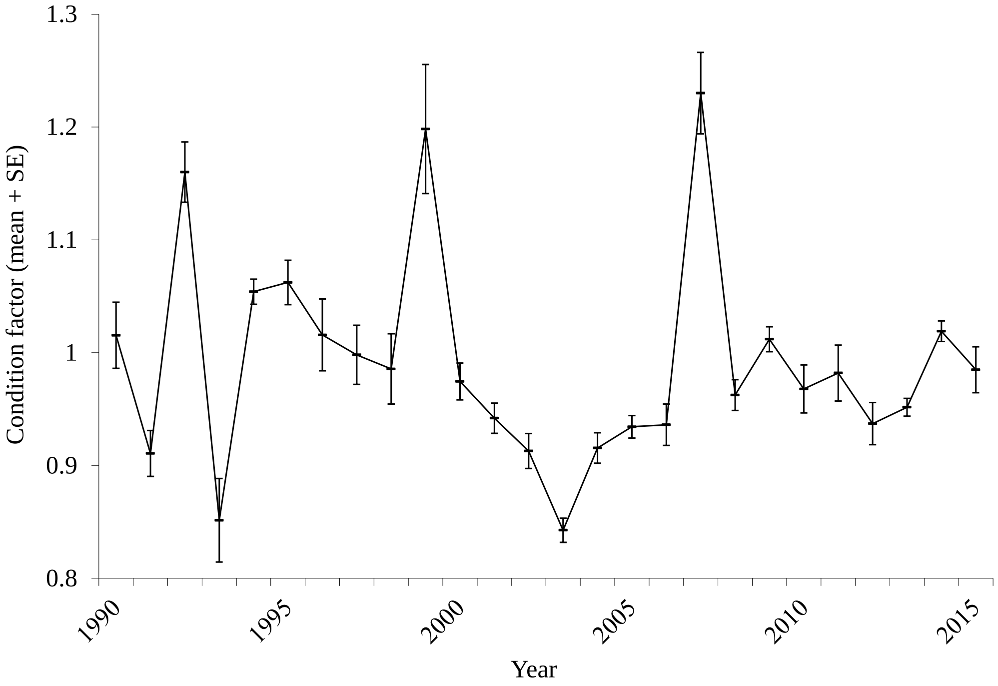


Figure 1. Annual mean (±SE) Fulton's condition factor *K* for Atlantic Salmon netted during 1990-2015.

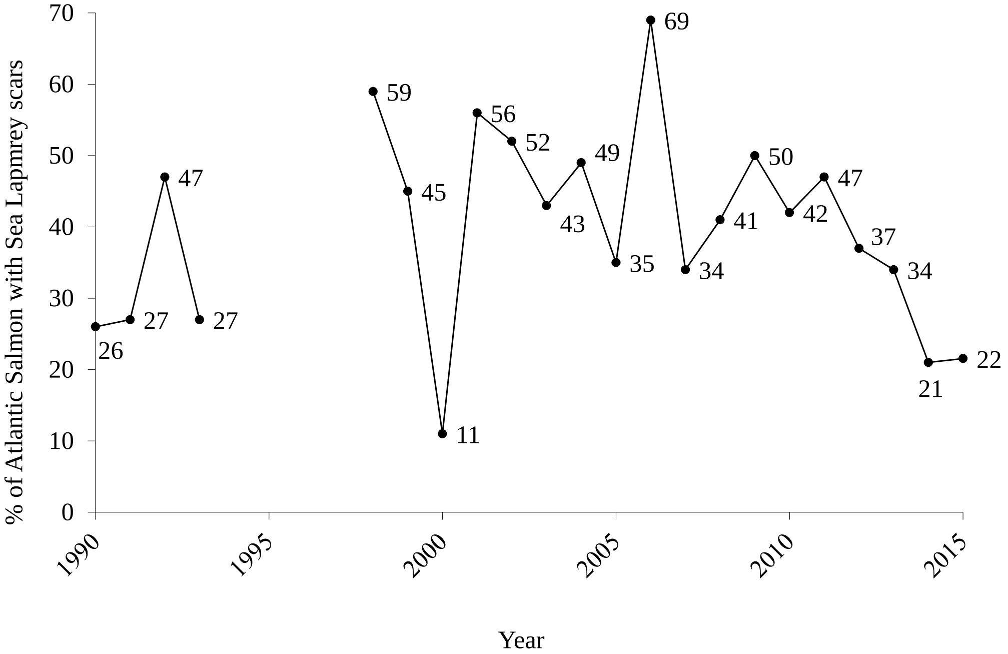


Figure 2. Percent of Atlantic Salmon broodstock that had at least one lamprey scar during 1990-1993 and 1998-2015.

Fish were held in raceways for at least one week prior to gamete collection, which occurred on 5, 9, 12, 16, and 19 November 2015. A 1 female: 1 male crossing scheme and the dry method were used during artificial spawning of 131 pairs of Atlantic Salmon. Fertilized eggs from each cross were isolated in buckets until testing for BKD was completed by LSSU's Fish Disease Laboratory (usually within 24 hr). Sperm from one male tested positive for BKD (Appendix 4), so the fertilized eggs from that cross were discarded. All other fertilized eggs were mixed together according to the date of collection and placed into egg trays. Personnel from MSU arrived on 17 November 2015 and completed a broodstock health inspection for the presence of *Aeromonas salmonicida*, BKD, Infectious Hematopoietic Necrosis Virus, Infectious Pancreatic Necrosis Virus, *Myxobolus cerebralis*, Viral Hemorrhagic Septicemia Virus, and *Yersinia ruckeri* on 60 adult fish that had been previously tested for BKD by LSSU. Five fish tested positive for *Aeromonas salmonicida* and four tested positive for BKD; all other tests were negative (Appendix 5). In addition, MSU personnel tested the gametes from these 60 broodstock fish for BKD, Infectious Hematopoietic Necrosis Virus, Infectious Pancreatic Necrosis Virus, *Oncorhynchus masu* Virus, and Viral Hemorrhagic Septicemia Virus; all fish tested negative (Appendix 5). The 293 adult Atlantic Salmon that were not sacrificed for disease testing were tagged with uniquely numbered Floy tags prior to release.

A total of 488,307 Atlantic Salmon eggs were collected, but only 482,772 eggs were used because one male's sperm tested positive for BKD in 2015 (Table 7). This year all eggs were counted by the Von Bayer method. All fertilized eggs were treated according to MDNR protocols, which included saline baths, erythromycin treatment, and iodine disinfectant. Dosages for each treatment are described in Appendix 6. Personnel from the Platte River State Hatchery picked up eggs on 28 December 2015 and on 01 January 2016, for a total of 368,449 eyed eggs.

After hatching, sac fry at the ARL were given a static bath of 2,000 ppm thiamine for ≥ 4 hr. We used one tote per egg tray of sac fry for the static bath. For each tote, 12 L of filtered river water was added and initial pH was measured. Next, 24 g of thiamine was added and mixed, and then pH was measured again. Initial pH readings ranged from 7.2 to 8.1, whereas pH ranged from 2.5 to 5.4 after thiamine was added. Baking soda was added to the thiamine bath (ranging from 55-70 g) to return pH to initial levels, and then oxygen stones were placed in the totes. Finally, sac fry from a single egg tray (about 2,500 fry per tray) were added to each tote, a lid was placed over them, and the fry were checked every hr. Thiamine treatments for eggs collected in 2015 occurred on 9, 10, 13, 15, 19, and 20 January 2016. The duration of static baths averaged 7.2 hr, and the sac fry appeared healthy after the treatments.

Table 7. Summary data of egg collection efforts in 2015.

Date	# of pairs	Mean # of eggs / fish	Total # eggs
5 Nov 15	23	3,236	74,432
9 Nov 15	22[a]	3,863	85,000
12 Nov 15	32	3,730	119,275
16 Nov 15	26	4,075	105,960
19 Nov 15	28	3,699	103,560
Grand total	131	3,728	488,307

[a] One pair tested positive for BKD, so 3,867 of the 85,000 eggs collected on 9 Nov 2015 were not used

Concentration of Thiamine in Eggs of Chinook and Coho Salmon

Concentrations of thiamine in eggs of 60 Chinook Salmon (*Oncorhynchus tshawytscha*) and 30 Coho Salmon (*O. kisutch*) collected by the MDNR in 2014 were quantified at the LSSU Fish Disease Lab by Dr. Jun Li and his students. The mean concentration of total thiamine in eggs was 5.91 nMol / g of egg (SE = 2.87, range = 2.54-12.45) for Coho Salmon and 4.03 nMol / g of egg (SE = 2.41, range = 1.33-7.93) for Chinook Salmon from SWR and 3.43 nMol / g of egg (SE = 1.08, range = 0.85-5.76) for Chinook Salmon from the Little Manistee River (Table 8). All eggs tested contained concentrations of thiamine above 1 nMol / g of egg except one (LMRW-CHS-15, 0.85 nMol / g of egg), so most were not considered at risk for Early Mortality Syndrome.

Table 8. Summary data from tests of concentrations of thiamine in eggs from 60 Chinook Salmon and 30 Coho Salmon collected by the MDNR in 2014.

Species, source		Total phosphorylated thiamine per gram egg (nMol / g)	Total nonphosphorylated thiamine per gram egg (nMol / g)	Total thiamine per gram egg (nMol / g)
Coho Salmon,	Mean	3.01	2.89	5.91
Platte River	SE	1.25	1.87	2.87
	Minimum	0.45	1.05	2.54
	Maximum	4.89	8.2	12.45
Chinook Salmon,	Mean	2.36	1.67	4.03
Swan River	SE	0.85	1.77	2.41
	Minimum	0.76	0.57	1.33
	Maximum	5.5	5.52	7.93
Chinook Salmon,	Mean	2.3	1.13	3.43
Little Manistee	SE	0.78	0.46	1.08
River	Minimum	0.26	0.59	0.85
	Maximum	4.1	2.72	5.76

RESEARCH ACTIVITIES

Grants & Contracts (LSSU PIs listed in **bold**)

Conservation of native fish communities in tributaries to the Great Lakes: Predicting the impacts of contaminants delivered by spawning Pacific salmon. Great Lakes Fishery Trust (2013-2015; Chaloner , D., Lamberti, G., **Moerke, A.**, Janetski, D., and R. Rediske)

Use of fin rays for estimating age of Muskellunge. Hugh C. Becker Foundation (2015-2016; **Crane, D.P.**, Isermann, D.A., Simonson, T.D., Kampa, J.M, and **K.L. Kapuscinski**)

Engaging active STEM Education through aquaponics. Michigan STEM Partnership (2014-2015; **Evans, B.I.**, Glowinski, **S., Weber**, P., **Li, J.**, **Greil, R.**, and **R. Wilhelms**)

Recruiting engineers for aquaculture automation. MI STEM Partnership (2015; **Evans, B.I.**, and **C. Smith**)

Youth education in aquaculture (YEA). North Central Regional Aquaculture Center (2016; **Evans, B.I.**, and **C. Smith**)

Continuing work toward removal of BUIs in the St. Marys River AOC. Great Lakes Commission (2014-2015; **Glowinski, S.**, and **A. Moerke**)

Continuing work toward removal of BUIs in the St. Mary's River AOC 2015-2016. Michigan Department of Environmental Quality (2015-2016; **Kelly, M. M.**)

Re-emergence of epizootic epitheliotropic disease virus: potential effects and development of improved diagnostics & control measures. Great Lakes Fishery Trust (2014-2016; Faisal, M., and **J. Li**)

Development and management of St. Lawrence River fisheries. New York State Department of Environmental Conservation (2013-2016; Farrell, J.M., Whipps, C.M., and **K.L. Kapuscinski**)

Quantifying relationships between fish assemblages and nearshore habitat characteristics of the Niagara River. Niagara River Greenway Ecological Fund (2013-2016; **Kapuscinski, K.L.**, and **D.P. Crane**)

Thiamine analysis of Coho and Chinook Salmon eggs. Michigan Department of Natural Resources (2015**; J. Li**)

Bacterial Kidney Disease analysis of Atlantic Salmon gametes and larval fish. Michigan Department of Natural Resources (2015; **J. Li**)

VHS virus diagnostic assay of Walleye broodstock. Inter-Tribal Fisheries (2016; **J. Li**)

Effect of dietary beta-glucan derived from algae on growth performance, disease resistance and immune response in Atlantic Salmon. Algal Scientific Company (2014-2015; **Li, J.**, and **B. Evans**)

Furthering capacity to maintain high quality coastal wetlands in northern Michigan. US Environmental Protection Agency (2014-2015; Lishawa, S., Tuchman, N., Treering, D., **Zimmerman, G.,** and others)

Ecological responses to restoration of flow to the Little Rapids area. Great Lakes Commission and National Oceanic and Atmospheric Administration (2014-2017; **A. Moerke**).

Cooperative agreement for Sea Lamprey monitoring. US Fish and Wildlife Service (2015-2017; **Moerke, A.**, and **R. Greil**)

State of Michigan's Eurasian Watermilfoil biocontrol pilot study. Michigan Department of Environmental Quality (2014-2016; **Moerke, A.** and **G. Zimmerman)**

Monitoring fish movement and fish condition in tributaries of Whitefish Bay. Bureau of Indian Affairs-Great Lakes Restoration Initiative Funds (2015; Ripple, P., Zomer, F., **Moerke, A.**, **Kapuscinski, K.**, and **J. Li**)

GLIC Implementing Great Lakes coastal wetland monitoring. US Environmental Protection Agency, Great Lakes Restoration Initiative (2011-2015; Uzarski, D., Brady, V., Cooper, M., Albert, D., Ciborowski, J., Danz, N., Gathman, J., Grabas, G., Hokansen, A., Howe, B., Lamberti, G., **Moerke, A.**, Ruetz, C., Steinman, A., Tozer, D., and D. Wilcox)

Peer-reviewed Publications (LSSU PIs listed in **bold**)

Collins, S, B. Marshall, and **A. Moerke**. *In press*. Aerial insect responses to non-native Chinook salmon spawning in a Great Lakes tributary. Journal of Great Lakes Research doi:10.1016/j.jglr.2016.02.010

We investigated whether spawning by non-native Chinook salmon influenced aerial insect abundance in the riparian zone of Thompson Creek, a tributary of Lake Michigan, located in Michigan, USA. Specifically, we evaluated whether decades of salmon disturbance affected patterns of aquatic insect emergence, and how both live salmon and salmon carcasses influenced the abundance of terrestrial carrion flies. Retaining wall timbers from a low-head dam on Thompson Creek were removed, providing a unique opportunity to compare stream reaches that were exposed to the immediate ecological impacts of salmon (i.e., disturbance, subsidy effects) with reaches experiencing decades of spawning activity. Using sticky traps to collect aerial insects, we observed fewer adult aquatic insects in downstream reaches conditioned to decades of salmon disturbance in comparison to naïve upstream reaches. Reduced abundance in downstream reaches was primarily driven by taxa more susceptible to disturbance in the larval life stage (e.g., Diptera: Simuliidae, Ephemeroptera). A greater abundance of adult Chironomidae midges were detected in upstream reaches with higher numbers of spawning salmon and carcasses. Though abundance of adults differed between upstream and downstream reaches, we observed no evidence of early emergence. In addition, carrion fly abundance was greatest at reaches with more live and dead salmon. Evidence from our study suggests that non-native salmon have the potential to influence patterns of aerial insect abundance in riparian zones. Our findings suggest that non-native Chinook salmon can affect aerial insect assemblages; however, the propagating effects of these changes through riparian food webs warrant further investigation.

Gerig, B., D. Chaloner, D. Janetski, R. Rediske, J. O'Keefe, **A. Moerke**, and G. Lamberti. 2016. Congener patterns of persistent organic pollutants reveal Pacific salmon contaminant delivery to Great Lakes tributaries. Environmental Science & Technology 50(2): 554-563

In the Great Lakes, introduced Pacific salmon (*Oncorhynchus* spp.) transport persistent organic pollutants (POPs), such as polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs), during their spawning migrations. To determine the nature and extent of salmon POP biotransport, we compared PCB and PBDE congener patterns in spawning salmon directly to those in resident stream fish, both within streams and among lake basins. We hypothesized that stream biota exposed to salmon spawners would have congener patterns similar to salmon, the presumed contaminant source. Using permutational multivariate analysis of variance (PERMANOVA) and non-metric multidimensional scaling (NMDS), we found that POP congener pattern of resident fish was influenced by the presence of salmon, Great Lakes basin, resident species considered, and salmon spawner biomass. Congener patterns indicated that salmon are a significant source of POPs to brook trout in stream reaches receiving salmon spawners in Lakes Michigan and Huron basins but not in the Lake Superior basin. The contrasting congener patterns of mottled sculpin compared with salmon and brook trout suggests that brook trout and mottled sculpin either use salmon tissue to differing degrees, bioaccumulate or metabolize POPs differently, or acquire POPs from different sources. Overall, our POP congener analyses suggest that the extent of salmon contaminant biotransport and transfer into Great Lakes tributaries can be considerable, but both are location and species-specific.

Gunderson, M.D., **Kapuscinski, K.L.**, **Crane, D.P.**, and J.M. Farrell. *In press*. Habitats colonized by non-native flowering rush *Butomus umbellatus* (Linnaeus, 1753) in the Niagara River. Aquatic Invasions.

During the summer of 2012, we first observed non-native flowering rush *Butomus umbellatus* (Linnaeus, 1753) in the upper Niagara River, NY, USA, where this species had previously been undocumented. In a 2013 study, *Butomus* was present at 33 of 161 (20%) submersed nearshore (≤ 3 m) sites surveyed, was the species of greatest biomass at 27% of the sites where it was collected, and was observed growing at depths > 3 m. *Butomus* was disproportionately prevalent in the upper observed ranges of water depth and velocity. *Butomus* was also closely associated with coarse substrates, differing from canopy-forming species but not other linear-leaved species. Emergence of *Butomus* from the sediment generally occurred from late-May to early-June, with peak coverage and height occurring in mid- to late-July. Coverage was generally minimal by mid-September. Rhizome bulbil production occurred on specimens as small as 25 cm in length and was first observed in mid-August when water temperatures were about 22.5°C.

Although we did not investigate the ploidy status of *Butomus* in the Niagara River, the presence of these vegetative reproductive structures is consistent with reports of genetically diploid *Butomus* populations in North America. No linear correlations between the biomasses of *Butomus* and other species were detected, although the data suggest a possible limiting effect on the biomasses of other species in dense *Butomus* stands. Even if emergent *Butomus* was eradicated from shorelines and wetlands, submersed areas would likely act as a refuge from which *Butomus* could continue to distribute viable bulbils and rhizome fragments into the nearshore. Submersed *Butomus* is a potential ecosystem engineer because it can colonize barren areas with coarse substrates, reach high densities, and grow to a considerable height in the water column. Subsequently, deposition and retention of fine sediments may occur, potentially allowing other species to expand into previously unsuitable areas.

Li J., Ma, S.Y., and N.Y.S. Woo. 2016. Vaccination of Silver Sea Bream (*Sparus sarba*) against *Vibrio alginolyticus*: Protective evaluation of different vaccinating modalities. International Journal of Molecular Sciences 17(1): 40.

In order to develop more effective immunological strategies to prevent vibriosis of farmed marine fish in Hong Kong and southern China, various vaccine preparations including formalin-, phenol-, chloroform- and heat-killed whole cell bacterins and subcellular lipopolysaccharides (LPS), as well as different administrating routes were investigated. Fish immunized with the subcellular LPS exhibited the best protection (RPS = 100), while fish immunized with whole cell bacterins displayed varying degrees of protection (RPS ranged from 28 to 80), in descending order, formalin-killed > phenol-killed > heat-killed > chloroform-killed bacterins. Regarding to various administrating routes, fish immunized with two intraperitoneal (i.p.) injections exhibited the best protection, and the RPS values were 100 or 85 upon higher or lower doses of pathogenic *V. alginolyticus* challenges; Both oral vaccination and a combination of injection/immersion trial were also effective, which achieved relatively high protection (the RPS values ranged from 45 to 64.3); However, twice hyperosmotic immersions could not confer satisfactory protection especially when fish exposed to severe pathogenic bacteria challenge. Marked elevations of serum agglutinating antibody titer were detected in all immunized fish. Macrophage phagocytosis were enhanced significantly especially in the fish immunized by formalin- and phenol –killed bacterins through various administering routes. Both adaptive (specific antibody) and innate (phagocytic activity) immunity elicited by different immunization strategies were in parallel with the degree of protection offered by each of them. Although all vaccination trials had no significant effect on serum hematocrit and hemoglobin levels, the circulating lymphocyte counts were significant elevated in the fish immunized with LPS, formalin- and phenol-killed bacterins. Serum cortisol levels appeared to be reduced in all immunized fish except the trial of hyperosmotic immersion, which indicated the stressful impact on vaccinated fish.

Moerke, A., C. Ruetz, C. Pringle, and T. Simon. *In press*. Chapter 19: Macroconsumer-resource interactions *in* R. Hauer and G. Lamberti, editors. Methods in Stream Ecology, 3rd Edition, Academic Press, CA.

Macroconsumers, such as fish, decapod crustaceans, and amphibians, can be important determinants of stream structure and function. Here, we present three types of manipulative field experiments to evaluate top-down effects of macroconsumers in stream food webs and illustrate the role of macroconsumers in shaping prey communities and resource availability. The most basic approach presented is to use mesh exclosures and open-control cages to test how stream invertebrate density, benthic algal biomass and/or leaf breakdown rates respond to the absence of macroconsumers. Next, a more advanced approach to address similar ecological questions is to implement electric exclosures, which reduce the cage artifacts resulting from the physical effects of cage exclosures. Finally, we propose an optional enclosure/exclosure experiment to directly manipulate macroconsumer density in mesh cages. We also discuss modifications to these three approaches to evaluate macroconsumer roles in algal- or detrital-based foods webs and in initiating trophic cascades.

Sun, Y., Liu, L., **Li, J.**, and L. Sun. 2016. Three novel B-type mannose-specific lectins of *Cynoglossus semilaevis* possess varied antibacterial activities against Gram-negative and Gram-positive bacteria. Developmental & Comparative Immunology 55:194-202.

Lectins are a group of sugar-binding proteins that are important factors of the innate immune system. In this study, we examined, in a comparative manner, the expression and function of three Bulb-type (B-type) mannose-specific lectins (named CsBML1, CsBML2, and CsBML3) from tongue sole. All three lectins possess three repeats of the conserved mannose binding motif QXDXNXVXY. Expression of CsBML1, CsBML2, and CsBML3 was most abundant in liver and upregulated by bacterial infection. Recombinant (r) CsBML1, CsBML2, and CsBML3 bound to a wide arrange of bacteria in a dose-dependent manner and with different affinities. All three lectins displayed mannose-specific and calcium-dependent agglutinating capacities but differed in agglutinating profiles. rCsBML1 and rCsBML2, but not rCsBML3, killed target bacteria in vitro and inhibited bacterial dissemination in fish tissues in vivo. These results indicate for the first time that in teleost, different members of B-type mannose-specific lectins likely play different roles in antibacterial immunity.

Wang, Y.J., Wang, X.H., Huang, J., and **J. Li**. 2016. Adjuvant effect of *Quillaja saponaria* Saponin (QSS) on protective efficacy and IgM generation in Turbot (*Scophthalmus maximus*) upon immersion vaccination. International Journal of Molecular Sciences 17(3): 325.

The adjuvant effect of QSS on protection of turbot fry was investigated with immersion vaccination of formalin-killed *Vibrio anguillarum* O1 and various concentrations of saponin (5, 25, 45 and 65mg/L). Fish were challenged at day 7, 14 and 28 post-vaccination. Significantly high RPS [(59.1±13.6)%, (81.7±8.2)%, (77.8±9.6)%] were recorded in the fish received bacterin immersion with QSS at 45mg/L which are comparable to the positive control group vaccinated by intraperitoneal injection(IP). Moreover, a remarkable higher serum antibody titer was also demonstrated after 28 days in the vaccinated fish with QSS (45mg/L) than those vaccinated fish without QSS (*P*<0.05), but lower than the IP immunized fish (*P*<0.05). Significant up-regulation of IgM gene expression has also been identified in the tissues of skin, gill, spleen and kidney from the immunized fish in comparison to the control fish. Taken together, the present study indicated that QSS could remarkably evoke systemic and mucosal immune responses in immunized fish. Therefore, QSS might be a promising adjuvant candidate for fish vaccination via immersion administering route.

Presentations (LSSU PIs and students listed in **bold**)

Bradburn, L., Gao, J., and **J. Li**. Health status of migrating and resident fishes in three tributaries of Whitefish Bay, Lake Superior. Midwest Fish and Wildlife Conference (2016)

There are many diseases in freshwater fish of the Great Lakes region. Most of the research that has been completed focus on hatchery fish, and the wild disease etiology is unknown. This study was conducted to survey the healthy status of the fish using 3 tributaries into the Whitefish Bay of Lake Superior and to observe the diseases carried by migrating species. 15 fish from each species were collected from each stream; a bacterial swab, blood, and internal organs were taken from each fish. The hematological parameters (blood cell counts, hematocrit, and hemoglobin) were analyzed in the blood samples. The potential pathogenic bacteria and viruses which cause common diseases like BDK, Furunculosis, Cold Water Diseases, and VHS were diagnosed in the collected bacterial swab, blood and internal organ samples by using ELISA. Some preliminary data shows that there is no difference between hematological parameters of fish going upstream to spawn and fish coming downstream after spawning. Only some individual fish have abnormal hematocrit and blood cell levels. More details on the carried pathogens, as well as the health status are still under investigated.

Chaloner, D.T., Gerig, B.S., Janetski, D.J., Levi, P., **Moerke, A.H.**, Rediske, R.A., Ruegg, J., Tank, J.L., Tiegs, S.D., a.nd G.A. Lamberti. The effects of Pacific salmon spawners on stream ecosystems: why context matters. Society for Freshwater Science (2016)

Pacific salmon (*Oncorhynchus* spp.) provide a useful model for understanding the influence of environmental context on resource subsidies. First, salmon can transfer a large amount of organic material, accumulated as they mature into adults, which is then delivered to stream ecosystems when they spawn and die. Second, salmon have been stocked in a number of locations outside of their native range and thus provide an opportunity to explore how the environmental context influences the effects of resource subsidies. For over 10 years, we have evaluated several mechanisms by which salmon spawners influence stream ecosystems and the degree to which environmental context modulates those interrelated effects, including nutrient enrichment, substrate disturbance, and contaminant biotransport. Evidence from our research and others suggests that salmon can increase dissolved nutrient concentrations, disturb substrate, and biotransport contaminants. However, the magnitude and intensity of these effects depend upon the interaction between salmon run dynamics (e.g., magnitude, duration), and local (e.g., sediment size, contaminant levels) and watershed conditions (e.g., land use, nutrient status). These results suggest that Pacific salmon, and the resource subsidies they deliver, can influence streams in multiple ways but the direction and extent is strongly influenced by environmental context.

Crane, D.P., and **K.L. Kapuscinski**. Habitat Use by age-0 Muskellunge in the Upper Niagara River, New York. Hugh C. Becker Muskie Symposium (2016)

Studies of fine-scale habitat use by age-0 Muskellunge (*Esox masquinongy*) are uncommon and those that have been conducted have relied on targeted, non-random sampling designs, which may bias study results. We used a random sampling design to sample age-0 Muskellunge and shallow water (<1.3 m) habitat features in the upper Niagara River, New York during late July through early September 2013-2015. Comparisons of habitat features between sites where Muskellunge were present and absent, and Firth logistic regression were used to identify important characteristics of Muskellunge nursery locations. A total of 15 age-0 Muskellunge were collected at 11 of 297 sites. Wild Celery (*Vallisneria americana*) was the dominant aquatic vegetation, and sand and mud were the dominant substrate sizes at locations were age-0 Muskellunge were collected. The probability of age-0 Muskellunge presence was positively related to the proportion of the water column occupied by aquatic vegetation. Despite sampling nearly 300 sites, the small number of age-0 Muskellunge collected limited the types of analyses that could be performed. However, our results provide evidence that shallow water areas with abundant Wild Celery should be conserved or restored to provide rearing habitat for Muskellunge in the upper Niagara River. In future studies, sample sizes of age-0 Muskellunge may be increased, while maintaining a probability sampling design, by randomly sampling within predefined areas that contain habitat features identified at sites where Muskellunge were present in this study.

Daly, D., **Dunn**, **T.J.**, and **A.H. Moerke**. Effects of European frog-bit on water quality and fish assemblages in St. Marys River coastal wetlands. Midwest Fish and Wildlife Conference (2016)

Currently there are over 180 non-native species in the Great lakes basin; with nearly one-third being aquatic plants. Recently, a new aquatic invasive plant, European frog-bit (*Hydrocharismorsus-ranae)*, was identified in two bays, Munuscong Bay and Raber Bay, in the St. Marys River (Lake Huron). Frog-bit is a perennial invasive floating leaf macrophyte that was first identified in the State of Michigan in 2000 in Lake St. Clair and Detroit River marshes, but this was the first finding of frog-bit in more northern waters. Little research has been conducted on frog-bit invasions, and therefore its impacts on aquatic communities are unclear. Our objective was to determine the effects of European frog-bit on water quality and fish assemblages. In the summer of 2015, we selected 12 sites; 6 with frog-bit and 6 sites without frog-bit (reference) in *Typha* spp. dominated wetlands. At each site water quality (e.g., DO, temperature) was measured and fish were sampled using fyke nets following the Great Lakes Coastal Wetland monitoring protocol. Water quality parameters did not different significantly between frog-bit and reference sites. A total of 19 different species were caught in this study. Reference sites had significantly more species compared to frog-bit sites (7 vs 4 spp.). Mean fish CPUE also was higher in reference sites, with 125 (SE± 58) individuals compared to 42 (SE± 23) individuals in frog-bit sites, although variability was high and there was no significant difference between the sites. Brown Bullhead also was more abundant in frog-bit sites. Our findings suggest that frog-bit may be impacting coastal wetlands fish assemblages, but not water quality, and therefore further research is needed to understand the factors driving changes in fish assemblages.

Dunn, T.J., **Daly, D.**, and **A.H. Moerke**. Impacts of European frog-bit invasions on Great Lakes' wetland macroinvertebrate communities. Midwest Fish and Wildlife Conference (2016)

European frog-bit (*Hydrocharis morsus-ranae*) is a relatively new invader to the Great Lakes and in 2013 it was found established in wetlands of the St. Marys River, a Great Lakes connecting channel. Frog-bit is a rapidly growing floating plant that forms large dense mats and is capable of regrowth via fragmentation. These traits allow it to invade and establish quickly, potentially competing with native macrophytes and altering biodiversity in coastal wetlands. This threat poses a need for more information on the impacts associated with frog-bit invasions. The primary objectives of this study were to quantify differences between: 1) water quality and 2) the composition of macroinvertebrates in frog-bit invaded and non-invaded coastal wetlands. In July, 2015 samples were collected from 12 wetlands (6 reference and 6 invaded with frog-bit), in Munuscong Bay (St. Marys River, Lake Huron). Water quality (e.g., pH, DO mg) was measured in situ. Macroinvertebrates were collected using standardized sweeps and identified to lowest taxonomic level. Frog-bit invaded sites had significantly lower macroinvertebrate abundance (120.6 ± 12.6) compared to reference sites (154.5 ± 3.3), but no significant difference in taxa richness. Additional metric scores derived from a macroinvertebrate IBI showed trends toward higher scores in invaded sites.

Frey, R., D.T. Chaloner, W.M. Leevy, and **A.H. Moerke.** Developing a new methodology to detect microplastics in aquatic organisms. Midwest Fish and Wildlife Conference (poster, 2016)

Microplastic particles (<5 mm) are polluting the world's lakes and oceans, and are affecting aquatic organisms that mistake them for a viable food material. Current detection methods such as dissection and microscopic analysis are time consuming and labor intensive. Here, we investigated a new methodology to detect microplastics in aquatic organisms using fluorescence optical imaging (2D) scans. Further, we determined detection thresholds for different types and sizes of microparticles both in solution, fish stomachs, and in whole fish. Known quantities were placed in solution and inside whole juvenile Atlantic Salmon (*Salmo salar*) and scanned using multiple florescence filters on a Bruker Xtreme image station. Flouresence (integrated density) was quantified from scanned images. Our preliminary findings suggest that microplastics have novel fluorescence signatures within and among microplastic types which may be due to varying particle size and dye, but detection within animal tissue will require refined methods. The findings of this study may provide a more efficient approach to microplastic detection in freshwater and marine environments.

Greil, R., **Moerke, A.**, **Kapuscinski, K.**, and D. Borgeson. History of rearing and stocking Atlantic Salmon in the upper Great Lakes, with an emphasis on the St. Marys River. Midwest Fish and Wildlife Conference (2016)

State agencies in the upper Great Lakes attempted to create fisheries for Atlantic salmon by stocking hatchery-reared fish from 1972 to 1993. Efforts were abandoned early due to difficulties associated with rearing, high production costs, and poor returns to angler creels. However, the Aquatic Research Laboratory (ARL) at Lake Superior State University began rearing Atlantic salmon in 1985 and continues today, likely as a result of advantages related to its mission and facility design. The primary mission of the ARL is to train students, so reduced expectations for production numbers and returns to creel provided a longer timeline to achieve success. In addition, the ARL uses St. Marys River water in a flow-through system, which exposes fish to natural conditions during rearing. Since 1987, the ARL stocked over 871,000 age-1 Atlantic salmon that averaged 176 mm in length into the St. Marys River. Atlantic salmon stocked by the ARL have been caught in each of the Great Lakes, but most captures occur in the St. Marys River and Lake Huron. The average return to creel was 5.5% after the collapse of alewife in Lake Huron (2005-2010), which was at least 10 times higher than return rates for other stocked salmonids. Natural reproduction by Atlantic salmon was first documented in the St. Marys River in 2012, but has not been quantified and is unlikely sufficient to sustain a fishery. In consultation with the public, the Michigan Department of Natural Resources (MDNR) initiated an Atlantic salmon stocking program to see if these high return rates could be duplicated at sites outside of the St. Marys River. Beginning in 2012, the MDNR began acquiring eyed eggs from the ARL, rearing fish in state-run hatcheries, and stocking Torch Lake and four sites in the Lake Huron basin.

Gerig, B., Chaloner, D.T., Rediske, R., O’Keefe, J.P., Brueseke, M.A., Janetski, D.J., **Moerke, A.H.**, Pitts, D.A., and G.A. Lamberti. Patterns of contaminant accumulation in Brook Trout from streams receiving Great Lakes salmon runs. American Fisheries Society annual conference (2015)

Pacific Salmon (*Oncorhynchus* spp.) introduced to the Great Lakes bioaccumulate contaminants over their lifespan and deposit contaminated tissue in tributaries during spawning. This ecosystem linkage is a key factor regulating the concentration and pattern of persistent organic pollutants contaminants (POPs) in stream fish. However, uncertainty exists regarding salmon-mediated transport of heavy metals such as mercury (Hg) in the Great Lakes. We simultaneously compared salmon-mediated POP and Hg concentrations in resident Brook Trout (*Salvelinus fontinalis)* sampled from streams with and without salmon spawners across the upper Great Lakes. First, we assessed the relationship between POPs and Hg concentrations to determine if bioaccumulation patterns were similar. Second, we considered whether patterns of Brook Trout Hg concentrations in streams with salmon spawners varied similarly to POPs across Great Lakes basins. We found that Hg was positively related to POP concentration suggesting similar bioaccumulation processes associated with increasing fish length, age, and trophic position. Further, we found evidence for basin-specific variation in Brook Trout POP and Hg concentrations, suggesting fish in Lake Michigan streams, especially from reaches with salmon spawners, have elevated contaminant levels. Our research provides a framework for understanding and managing POP and Hg contaminant biotransport in the Great Lakes.

Hanchin, P., Sloss, B., Turnquist, K., Farrell, J., **Kapuscinski, K.**, Miller, L., Scribner, K., and C. Wilson. Brood source identification and the effects of supplementation on muskellunge in the Great Lakes. Hugh C. Becker Muskie Symposium (Poster, 2016)

Current Muskellunge (*Esox masquinongy*) management in Great Lakes States and Provinces call for stocking Muskellunge native to the Great Lakes to re-establish sustainable populations that have previously experienced population declines or extirpation. Accordingly, native Great Lakes Muskellunge brood sources must be identified or established to meet that need. Managers who seek to develop future Muskellunge brood stocks benefit from knowledge of stock structure to better match the origin of hatchery fish to the locations in which they will be stocked. Therefore our objectives were to (1) determine if the genetic structure of non-admixed Great Lakes Muskellunge populations is consistent with a genetic stock model that can be described in terms of genetic stock identification and degree of stock isolation for the identification of potential brood sources, and (2) determine if significant admixture is present in Great Lakes Muskellunge populations consistent with introgression between stocked and resident Great Lakes Muskellunge. Fourteen microsatellite loci were used to characterize genetic diversity and structure of >1,800 Muskellunge from >40 locations throughout the Great Lakes and associated inland drainages. Genetic diversity and molecular variance will be compared within and among various genetic structure models to identify possible influences of historical stocking and, ultimately, potential brood sources for Great Lakes Muskellunge supplementation efforts.

Hanchin, P., Sloss, B., Turnquist, K., Farrell, J., **Kapuscinski, K.**, Miller, L., Scribner, K., and C. Wilson. Brood source identification and the effect of supplementation on muskellunge in the Great Lakes. Michigan Chapter of the American Fisheries Society (Poster, 2015)

See abstract above

McIntyre, P.B., David, S., **Moerke, A.**, Childress, E., Neeson, T., Moody, A., Herbert, M., Khoury, M., Doran, P., and M. Diebel. Holding on, long gone, and back from the dead: Ecosystem implications of persistence, loss, and resurgence of fish migrations. Ecological Society of American annual meeting (2015)

Fish migrations are or once were major annual phenomena in most of the world's river and lake systems. Today, enormous numbers of barriers limit where fish can migrate, spawning habitats are often degraded even when accessible, and populations of many species are further depressed by fisheries. In the face of these pressures, some species have proven remarkably resilient, while others persist but have experienced large reductions in range size and local abundance. Still other migrations have disappeared entirely despite historical records of enormous numbers of fish, but there is recent evidence of resumption of migrations in at least one species. The ecosystem-level implications of these changes remain largely unknown. Here, we offer examples of each pattern drawn from the diverse potamodromous species of the Great Lakes. Collation of trait data across these species enables us to evaluate whether there are any recurrent patterns in life history, habitat requirements, or other factors that predict which species have proven most resilient to environmental change. The trait-based approach allows general inferences about potential ecosystem-level implications of losing or gaining fish migrations across such a diverse fauna.

Milan, J., **Kapuscinski, K.**, Ripple, P., and **A. Moerke**. Seasonal fish migration patterns in three Lake Superior tributaries. Midwest Fish and Wildlife Conference (Poster, 2016)

The numerous small tributaries that feed the Great Lakes likely play an important role for sustaining lake fish populations. In the Great Lakes, there are approximately 70 species known to spawn in rivers and streams, 19 of which are suggested to be obligate stream spawners. These tributaries provide critical habitat and nutrients for the offspring of the migratory fishes using them. As important as these tributaries appear to be, very little information exists on the extent or duration to which they are used. The objective of this study was to document the spawning migration patterns (numbers and timing) of Lake Superior fishes that use these tributaries throughout the year. To accomplish this, fyke nets were placed in three tributaries of Whitefish Bay, Lake Superior. Two nets were set biweekly back-to-back across each stream to capture in and out migrating fishes. Initial results showed 42 different species (12 migrants), with approximately 11,902 individuals captured among the three tributaries during the time of the study. The outcomes of this study will provide additional information on the importance of tributaries for Lake Superior fishes and provide baseline data to understand the potential impacts of climate change on the spawning phenology of Great Lakes fishes.

Miller, L.M., Farrell, J.M., **Kapuscinski, K.L.**, Scribner, K., Sloss, B.S., Turnquist, K., and C.C. Wilson. A review of Muskellunge population genetics: implications for management and research directions. Hugh C. Becker Muskie Symposium (2016)

At the original International Musky Symposium held in 1984, it was recognized that management agencies need policies for the sustainable management of native Muskellunge (*Esox masquinongy*) stocks and their genetic suitability. Identified research needs included documenting existing genetic diversity and evaluating effects of management on diversity. In this review, we summarize research over the past three decades that has addressed these needs and provided additional genetic information useful to managers. We then suggest future research directions to fill information gaps and benefit from advances in genetic technologies. Genetic data support the existence of three major regional stocks in the upper Mississippi River, Great Lakes, and Ohio River drainages, all of which derived from a Mississippian glacial refuge population. Each of these major lineages exhibits substructure, with numerous genetically distinct subgroups, influenced by geographic proximity, history and habitat connectivity. When traits such as growth, maximum size, survival and food consumption have been compared among strains stocked into common environments, researchers have usually found differences partly attributable to genetics. Genetic evaluations of ancestry in relation to stocking have revealed a wide range of outcomes, from substantial mixing of strains to no apparent contribution to resident populations. Genetic principles and data have led to state-wide stocking guidelines developed to conserve within- and among population genetic variation and avoid artificial selection in broodstock practices. Molecular data have also been used to estimate genetic effective population size of a wild population and as individual tags for mark-recapture estimates of abundance. Future research needs include a range-wide assessment of population genetic structure, including how stocking has affected structure of wild populations, resolution of the role of reproductive versus natal site homing in individuals returning to spawning sites, and application of genomic techniques that can move us toward an understanding of the genetic basis for differences in performance or adaptive traits.

Moerke, A. Emerging issues in the St. Marys River AOC. Michigan Tribal Environmental Council annual meeting (Invited, 2016)

Moerke, A. and M. Vinson. Potential climate change impacts on Lake Superior fishes. Superior Challenge Summer, CILER (Invited, 2016)

Moerke, A., Arend, K., Mockler, D., Ripple, P., Steinhart, B., and F. Zomer. Influence of low-order tributary inputs on the nearshore dynamics of Whitefish Bay, Lake Superior. Society for Freshwater Science (2016)

Tributaries are important conveyers of dissolved nutrients and allochthonous matter to downstream waters, and may result in "biological hotspots" in oligotrophic receiving systems. However, most research to date has focused on the importance of contributions from large rivers, and little is known regarding the importance of small tributary inputs to nearshore food webs in the Great Lakes. Here we describe the spatial and temporal dynamics of low-order tributary inputs to nearshore areas, and identify linkages between tributaries and nearshore food webs in Whitefish Bay, Lake Superior. We measured dissolved nutrients, DOC, and Chl *a*, and collected basal and consumer resources in three tributaries to Whitefish Bay and their downstream nearshore areas biweekly from April-August for two years. River nutrient concentrations were strong predictors of bay nearshore nutrient and Chl a concentrations, and stable isotope analysis suggests some incorporation of tributary inputs by bay seston. However, results varied between years and across tributaries. Thus, tributary inputs to Whitefish Bay appear to be spatially and temporally dynamic, yet may play seasonally important roles to biota in nearshore areas of Lake Superior.

Moerke, A., David, S.R., Childress, E.S., and P.B. McIntyre. Spatiotemporal variability in spring spawning dynamics of northern Lake Michigan migratory fishes. American Fisheries Society annual conference (2015)

Dozens of fish species undertake reproductive migrations from the Great Lakes into tributary rivers, yet the composition and timing of these migrations are poorly documented. To characterize patterns in phenology, demography, and assemblage of spring spawners in Lake Michigan, we captured fish in- and out-migrating over two years in six tributaries. We found that Longnose Suckers (*Catostomus catostomus*) and White Suckers (*Catostomus commersoni*) were the dominant spring migrants, followed by Northern Pike (*Esox lucius*) and Steelhead (*Oncorhynchus mykiss*). All of these species entered streams within a short temporal (~10 days) and thermal (6-8^{o}C) window, but the duration of migrations were more protracted than expected. Interannual arrival timing of spawning migrants varied by up to 4 weeks and was significantly correlated with temperature and discharge, although the strength of the relationship varied by species and stream. The demography of migrating suckers suggests size and sex-selective mortality may be occurring on larger males, which could have important implications for egg fertilization rates and recruitment. Our detailed records of the phenology of spring migratory fishes provide insight into the reproductive biology of Great Lakes fishes, and offers additional context for conservation efforts regarding ecosystem subsidies, non-native species, critical habitat protection, and climate change.

Moerke, A., David, S.R., Childress, E.S., and P.B. McIntyre. Spatiotemporal variability in spring spawning dynamics of northern Lake Michigan migratory fishes. University of Wisconsin's Center for Limnology Seminar Series (2015)

See abstract above

Turnquist, K., Farrell, J.M., **Kapuscinski, K.L.**, Miller, L.M., Scribner, K., Sloss, B.S., and C.C. Wilson. Muskellunge genetic integrity and structure in the Great Lakes: implications for propagation programs. Hugh C. Becker Muskie Symposium (2016)

Muskellunge (*Esox masquinongy*) have experienced considerable population declines and several extirpations in and around the Great Lakes. While few populations have persisted relatively unchanged, others have benefited from restoration efforts, and others still have yet to be restored. Additionally, historic and contemporary stocking of Great Lakes and non-Great Lakes strain Muskellunge poses a threat to the genetic integrity of remaining populations. Therefore, a broader understanding of the degree of current genetic differentiation among all major Great Lakes populations, including those existing in key tributaries is needed. Our goal was to describe the genetic diversity within and differentiation among all major Great Lakes area populations and to determine the extent of introgression that has resulted from past Muskellunge stocking efforts. Thirteen microsatellite loci were used to characterize genetic diversity and structure of more than 1,800 Muskellunge from 42 locations throughout the Great Lakes and associated inland drainages. Bayesian and maximum likelihood results suggest discrete genetic structure both east/west and inland-Great Lakes proper, including significant fine-scale structure at various locations throughout the Great Lakes. Genetic diversity, molecular variance, and other genetic measures were used to identify reasonable genetic management units (stocks) and potential brood sources for these various stocks.

Wenke, A., Clegg, E., and **A. Moerke**. Changes in stream biota and habitat following a perched culvert replacement in John's Creek, MI (Poster, 2016)

Michigan has over 36,000 miles of streams with thousands of road-stream crossings traversing them. However, many of these road-stream crossings consist of improperly installed culverts that act as barriers and are impassable to fish. The Two Hearted River watershed, MI, is an example of a watershed with a loss of connectivity. The Nature Conservancy recently led an effort to replace 13 barrier crossings to restore connectivity to 35 river miles in the Two Hearted River Watershed. One such replacement was a perched culvert at the CCI (Burma) Road and John's Creek. The goal was to restore connectivity by replacing the poorly functioning culvert with a bridge. To evaluate the effectiveness of the culvert replacement, stream habitat, and fish and macroinvertebrate assemblages were evaluated before (July 2014) and after culvert (November 2014) replacement. Two 100-m reaches were identified, one above, and one below the crossing and sampled for fish using triple-pass backpack electrofishing. Fishes in each reach were marked with a unique fin clip to identify movement between reaches. Replicate macroinvertebrate samples were collected in each reach using a surber sampler, and identified to family level. Course woody debris, substrate, and water quality (e.g., DO, temperature) were also measured. Prior to the culvert replacement, fish assemblages were only comprised of stream residents upstream, but also possessed YOY anadromous fishes downstream. Macroinvertebrate richness was low, and habitat was dominated by sand substrate. After culvert replacement, fish assemblages included resident and anadromous fish both upstream and downstream. Additionally, fish with a downstream fin clip were found upstream of the crossing, indicating movement across the road-stream crossing. Local macroinvertebrate richness also increased in both reaches after culvert replacement. The results of this study indicate that The Nature Conservancy's goal was met and fish now have access to the Two Hearted River watershed.

Zomer, F., **Moerke, A.**, **Kapuscinski, K.**, and P. Ripple. Rivermouth areas as biological hotspots in Whitefish Bay, Lake Superior. Midwest Fish and Wildlife Conference (Poster, 2016)

Lake Superior receives water from more than 800 tributaries, the majority of which are low-order streams. In an oligotrophic system such as Lake Superior, tributary inputs may create zones of increased productivity in rivermouth areas. The objective of this study was to compare density and distribution of larval, sub-adult and small-bodied adult fishes in rivermouth areas to distribution in nearshore areas that lack a tributary input (non-rivermouth). Two rivermouths and two non-rivermouth sites were sampled during the summer of 2014 for larval and sub-adult fishes. Larval fishes were sampled from May to June using a 500µm-mesh beach seine. Sub-adult and adult fishes were sampled from June to August with a 1cm-mesh beach seine. Replicate seine hauls (three for larval fish and two for sub-adult and small-bodied adult fish) were completed on both sides of two rivermouths as well as two paired, non-rivermouth sites. Lake Whitefish (*Coregonus clupeaformis*) and Suckers (*Catostomus* spp.) were the dominant larval species at all sites during May and June. On average, more than four times as many sub-adult and adult fishes were caught in beach seines at rivermouth sites than at non-rivermouth sites. Larval density was greater at non-rivermouth sites for Lake Whitefish while Sucker density was greater at rivermouth sites. Larval distribution was similar between rivermouth and non-rivermouth sites. Sub-adult and adult fishes were concentrated to a specific side of rivermouths and randomly distributed at non-rivermouth sites. The results of this study highlight the influence of tributaries on dynamics of nearshore fish communities in Lake Superior.

SENIOR THESIS ABSTRACTS

Each student whose major is within the School of Biological Sciences or School of Physical Sciences at LSSU must complete a senior thesis project. Below are abstracts from 13 student projects related to the ARL and Fish Disease Lab that were completed during the 2015-2016 academic year.

A health overview of fishes utilizing three tributaries of Whitefish Bay, Lake Superior

Lucas Bradburn, Jun Li

There are many diseases in freshwater fish of the Great Lakes region. Most of the research that has been completed focus on hatchery fish, and the wild disease etiology is unknown. This study was conducted to survey the health of the fish using 3 tributaries into Lake Superior and to observe the diseases carried by migrating species. 15 fish from each species were collected from each stream; a bacterial swab, blood, and internal organs were taken from each fish. The hematological parameters (blood cell counts and hematocrit) were analyzed from the blood samples. The potential pathogenic bacteria and viruses, which cause common diseases like Bacterial Kidney Disease, Furunculosis, Bacterial Cold Water Disease, Infectious Pancreatic Necrosis, Infectious Salmon Anemia, and Viral Hemorrhagic Septicemia, were diagnosed from the collected bacterial swab and internal organ samples of Great Lakes fishes using an ELISA. The blood cell count samples showed higher levels of blood cells from some baseline data, but the hematocrit percentages showed normal levels. VHS, IPN, and BKD were the most prevalent diseases and were seen in high levels. Longnose Suckers had the highest prevalence of exposure to disease followed by Coho Salmon. The minnow species tested were the least exposed to disease. This calls for further investigation and an increased awareness of the pathogens.

Effects of European Frog-bit on water quality and the fish assemblage in St. Marys River coastal wetlands

Devin Daly, Ashley Moerke

Currently there are over 180 non-native species in the Great lakes basin; with nearly one-third being aquatic plants. Recently, a new aquatic invasive plant, European frog-bit (*Hydrocharismorsus ranae)*, was identified in two bays in the St. Marys River (Lake Huron). Little research has been conducted on frog-bit invasions, and therefore its impacts on aquatic communities are unclear. Our objective was to determine the effects of European frog-bit on water quality and fish assemblages. In the summer of 2015, we selected 12 sites; 6 with frog-bit and 6 sites without frog-bit (reference) in *Typha* spp. dominated wetlands. Water quality was measured and fish were sampled using fyke nets following the Great Lakes Coastal Wetland monitoring protocol. Water quality did not different significantly between frog-bit and reference sites. Reference sites had significantly more fish species compared to frog-bit sites (7 vs 4 spp.). Mean fish CPUE also was higher in reference sites, with 125 (SE± 58) individuals compared to 42 (SE± 23) individuals in frog-bit sites, although variability was high and there was no significant difference between the sites. Our findings suggest frog-bit may be impacting coastal wetlands fish assemblages, but further research is needed to understand the factors driving changes in fish assemblages.

Impacts of European Frog-bit invasion on Great Lakes coastal wetland macroinvertebrate communities

Trevor Dunn, Ashley Moerke

European frog-bit (*Hydrocharis morsus-ranae*) is a relatively new invader to the Great Lakes. In 2013, it was found in wetlands of the St. Marys River, a Great Lakes connecting channel. Frog-bit is a rapidly growing floating plant that forms large dense mats and is capable of regrowth via fragmentation. The primary objectives of this study were to quantify differences between: 1) water quality, and 2) the composition of macroinvertebrates in frog-bit invaded and non-invaded coastal wetlands. In July, 2015 samples were collected from 12 wetlands (6 reference and 6 invaded with frog-bit), in Munuscong Bay (St. Marys River, Lake Huron). Macroinvertebrates were collected using standardized sweeps and identified to lowest taxonomic level. Frog-bit invaded sites had significantly lower macroinvertebrate abundance (120.6 ± 12.6) compared to reference sites (154.5 ± 3.3), but there was no significant difference in taxa richness. Additional metric scores derived from a macroinvertebrate IBI showed trends toward higher scores in invaded sites. This indicates that frog-bit may be altering the health and biological integrity of wetlands and calls for further control methods to be established.

Effect of timing of movement on survival rate of Atlantic Salmon embryos during hatchery rearing

Jonathan Edwards, Barbara Evans

Atlantic Salmon were once native to Lake Ontario but, were extirpated by 1900. Atlantic Salmon are now intensely reared in hatcheries for restoration stocking and in the aquaculture industry. The culturing of Salmon has grown very rapidly and rearing these fish requires an adept knowledge of the egg to adult stages. This research was aimed to clearly identify a time frame of when Atlantic salmon eggs are sensitive to mechanical shock. Some Salmonid eggs are sensitive to movement and may die if they are moved by hatchery personnel during this sensitive stage. To determine the duration of the sensitive stage, I followed Lake Superior State University's Aquatic Research Lab egg take protocol up until movement of the eggs to the egg tray. Then I moved batches of eggs from 0-48 hours on six hour intervals (nine treatments) to simulate mechanical shock. During each movement, dissolved oxygen, temperature and pH were assessed and eggs were inspected for mortality. Dead eggs were counted and removed until they reached eye stage. I found that eggs moved from the 0-12 hr treatments had a higher survival rate than the 48 hour treatments. The results of this study will movement practices during the egg take process for moving Atlantic Salmon eggs in hatchery setting.

Aquaculture automation challenge: experiential learning for promotion of Michigan aquaculture

Kacie M. Ferguson, Barbara Evans

Sustainable food production is essential to meet the rising global demand of high quality proteins, specifically seafood. Aquaculture can sustainably farm fish for human consumption; moreover, aquaculture has the potential to flourish as a Michigan industry. The Aquaculture Automation Challenge (AAC) is a competition designed to teach teams of high school students the skills necessary for creating and maintaining a small scale aquaculture system. By sparking interest early in youth, probable job placement can be created in this growing industry. I began public outreach by visiting four high schools in the Eastern Upper Peninsula to invite students to participate in the challenge. Following the recruitment period, a preliminary Open House was held at Lake Superior State University in order to familiarize the participants with aquaculture's purpose and describe the components of the competition. After viewing a system prototype demonstration, each team was given the opportunity to request system equipment to take back to their classrooms. Teams have been given approximately two months to develop and construct their aquaculture systems. Through the duration of system building, participants will document their successes and failures to create a final presentation of their efforts. Each team will present their project during the AAC and will be scored on system efficiency; teams with the highest scores will receive prizes, including scholarships. Upon completion of the competition, participants will fill out surveys regarding any gained interest in aquaculture.

A comparison of growth among different strains of Muskellunge (*Esox masquinongy*) in Neshonoc Lake, Wisconsin

Trevor Gronda, Kevin Kapuscinski

Muskellunge *(Esox masquinongy)* is an important top predator and a highly sought after game species. Therefore, Muskellunge populations are often an intensely managed. Stocking is a used management tool, but performance of stocked fish is not often addressed. I compared the growth of Muskellunge from three different source lakes that were stocked in to Neshonoc Lake in Wisconsin. Ages were estimated for individual Muskellunge that were marked prior to stocking using anal fin rays, and I back calculated growth from age 1 to age 4. Length at age showed that the Lac Courte Oreills were larger at age 4. Finally, length between ages showed Lac Courte Oreilles Muskellunge grew more between ages 0-1 and 3-4, where Lost and Teal Lakes grew the most between ages 1-2 and 2-3. The different strains did show a little variation, with the Chippewa Flowage Muskellunge proving to be the worst performing strain. Overall, the Lac Courte Oreills and Lost and Teal Lakes Muskellunge both appear to be viable candidates for future stocking.

Promoting awareness of European Frog-bit among boaters

James Johnson, Greg Zimmerman

European frog-bit (*Hydrocharis morsus-ranae*) is an invasive aquatic plant species that is spreading throughout the Great Lakes. Frog-bit forms dense mats of what look like small, hearshaped lily pads in slow moving water. Its high vegetative density, rapid reproduction and decomposition pose a threat to wetlands. European frog-bit recently reached two boat launches along the St. Marys River in Chippewa County, Michigan, the Munuscong River boat launch and the Raber Bay Landing boat launch. These locations represent a high risk of spreading due to transportation of propagules around the river and from one water body to the next. Thus public awareness early in the invasive species' establishment is important for containing its spread. For my experiential learning project, I worked with the Chippewa/Luce/Mackinac County Conservation District to increase boater's awareness and ability to identify European frog-bit, as well as to gauge people's boat washing habits and willingness to change behavior. To accomplish my objectives I designed signs to be placed at each of these boat launches, and brochures to be distributed to boaters. During the weekends of August through October of 2015 I spent time at both boat launches talking to boaters about the issues surrounding European frog-bit. During the course of my project I found that only 13 of the 115 boaters I encountered had previous knowledge of European frog-bit. I found that of the 13 boats that exited the water all 13 were drained of water, 7 boats had debris removed but only one was dried. Because of low levels of awareness, continued public outreach pertaining to European frog-bit and proper boat washing is necessary. The Raber Bay municipal boat launch should be the next area of focus for continued public outreach due to the emerging presence of this invasive species.

A population survey of native and non-native crayfish in three Delta County, Michigan rivers

Sean Leask, Kevin Kapuscinski

Crayfish are an important part of food webs in lakes and rivers. *Orconectes rusticus*, a crayfish native to the Ohio River Basin, is a non-native crayfish now found in Michigan waters. *O. rusticus* has been found to out compete and hybridize with crayfish native to Michigan and also has negative effects on macrophyte and macroinvertebrate populations in bodies of water they invade. The Michigan Department of Natural Resources currently allows the trapping of crayfish for personal consumption. The purpose of my study was to determine the catch per unit effort (CPUE), abundance, and biomass, in the Rapid, Whitefish, and Sturgeon Rivers, located in Delta County, in Michigan's Upper Peninsula. Each river was divided into two 50 m sections and eight traps were placed in each section. Traps were checked each day for 3-4 day, with captured crayfish being identified, marked, weighed and then released. *O.rusticus* was the dominant species in the Rapid and Whitefish Rivers, whereas the native *O. propinquus* was the only species found in the Sturgeon River. My study shows that native crayfish species may inhabit waters in numbers much lower than *O. rusticus*, and stricter regulations may need to be placed on rivers with small crayfish populations to prevent overharvest.

Replacement series analysis of the competition between *Phalaris arundincea* (reed canary grass) and *Calamagrostis canadensis* (Canada blue joint)

Jaclyn Schierbeek, Greg Zimmerman

Phalaris arundinacea (L.), or reed canary grass is an invasive species threatening many native wetland species including *Calamagrostis Canadensis* (Michx.), commonly known as canada blue joint. It has been found that reed canary grass has been able to dominate native territories throughout the United States. This study's objective is to observe the relationship between the growth patterns of reed canary grass and canada blue joint in a controlled environment. Reed canary grass and canada blue joint rhizomes were dug up from an existing marsh when dormant and planted in a replacement series to determine what the effects of the different concentrations of the invasive plant would have on the native plant. The climate, water, nutrient, and sunlight were all kept constant so that the only dependent variable would be the spreading rate of competition. It was found that reed canary grass grew exceptionally well whereas canada blue joint's spreading rate remained small. When analyzed with the replacement series model it was found that reed canary grass was the more aggressive competitor. However, candada blue joint didn't experience a decrease past the initial decline of vegetative growth due to the addition of reed canary grass. This suggests that canada blue joint might not be completely outcompeted by reed canary grass, yet the presence of the invasive plant will limit its growth. It can be proposed from these results that reed canary grass is a problem causing invasive species that negatively affects many native species.

Does Vulnerability to predation differ between Round Goby and Mottled Sculpin?

Michael Schneider, Kevin Kapuscinski

Since the round goby *Neogobius melanostromus* invaded the Great Lakes in 1990, mottled sculpin *Cottus bairdii* numbers have declined. The more aggressive round goby evict mottled sculpin from shelter, potentially making the sculpin more vulnerable to predation. The objectives of my study were to observe the competition for cover between round goby and mottled sculpin, and determine if competition for cover between round goby and mottled sculpin affected their vulnerability to predation by walleye *Sander vitreus*. Experimental tanks were set up with one of three cover treatments: no cover, limited cover, and adequate cover. Two round goby and two mottled sculpin were introduced to each tank and observed for 24 hr, after which one walleye was introduced and observed for 48 hr. All tanks were video recorded continuously; observations were made on evictions, biting/chasing, strikes by walleye, and time in cover by analyzing video footage. Only 5 strikes by walleye were observed, which was not sufficient to statistically test. Time in cover was used to infer vulnerability. Round goby spent more time in cover without the presence of the walleye, however there was no difference in time in cover in the presence of the walleye. Round goby were more aggressive than mottled sculpin. Vulnerability could not be confidently concluded using the available results. A repeat study with more effective predators is needed.

Assessment of Mussel Populations in Lake St. Clair, MI

Shannan Trudell, Barbara Evans

The purpose of the study was to determine the density of mussels on the floor of Lake St. Clair, MI and compare the data to a previous study conducted by Thomas Nalepa in 18992. SCUBA gear was utilized to determine the species and quantities within a .5 meter squared quadrat. Total numbers of mussels ranged from 0-114 per .5 meters squared. All mussels were concluded to be Dreissena Rostriformis bugensis or the quagga mussels. Quantities were then compared to that of Nalepa's 1992 study to determine if there was a significant difference between the past and the present densities of mussels. A binomial confidence interval and a permutation test analog of a paired t-test were conducted and determined that between 1992 and 2015 there was no significant difference in the quantities of mussels present; however, in 1992 the dominate species identified were zebra mussels and in 2015 all specimens identified were quagga mussels showing a distinct shift from one species to the next.

Eurasian Watermilfoil (*Myriophyllum spicatum*) cover in the Les Cheneaux bays and management action assessment

Justin Vinson, Greg Zimmerman

Geographic information system (GIS) tools were utilized to produce a geospatial analysis of the Les Cheneaux bays. Point intercept data from EnviroScience Inc., a consulting firm engaged by the watershed association, was used to determine whether milfoil cover had been reduced between 2013-2014, and produce a predictive model of all 23 bays. It was found that milfoil cover was reduced in 2014. Similarly the power of predictive models showed their usefulness by eliminating 25.7%, and 47.2% surface area in respective years. Overall, the scope of these results is to provide the Les Cheneaux Watershed Council with useful tools and analysis to focus management activities on areas with the greatest need.

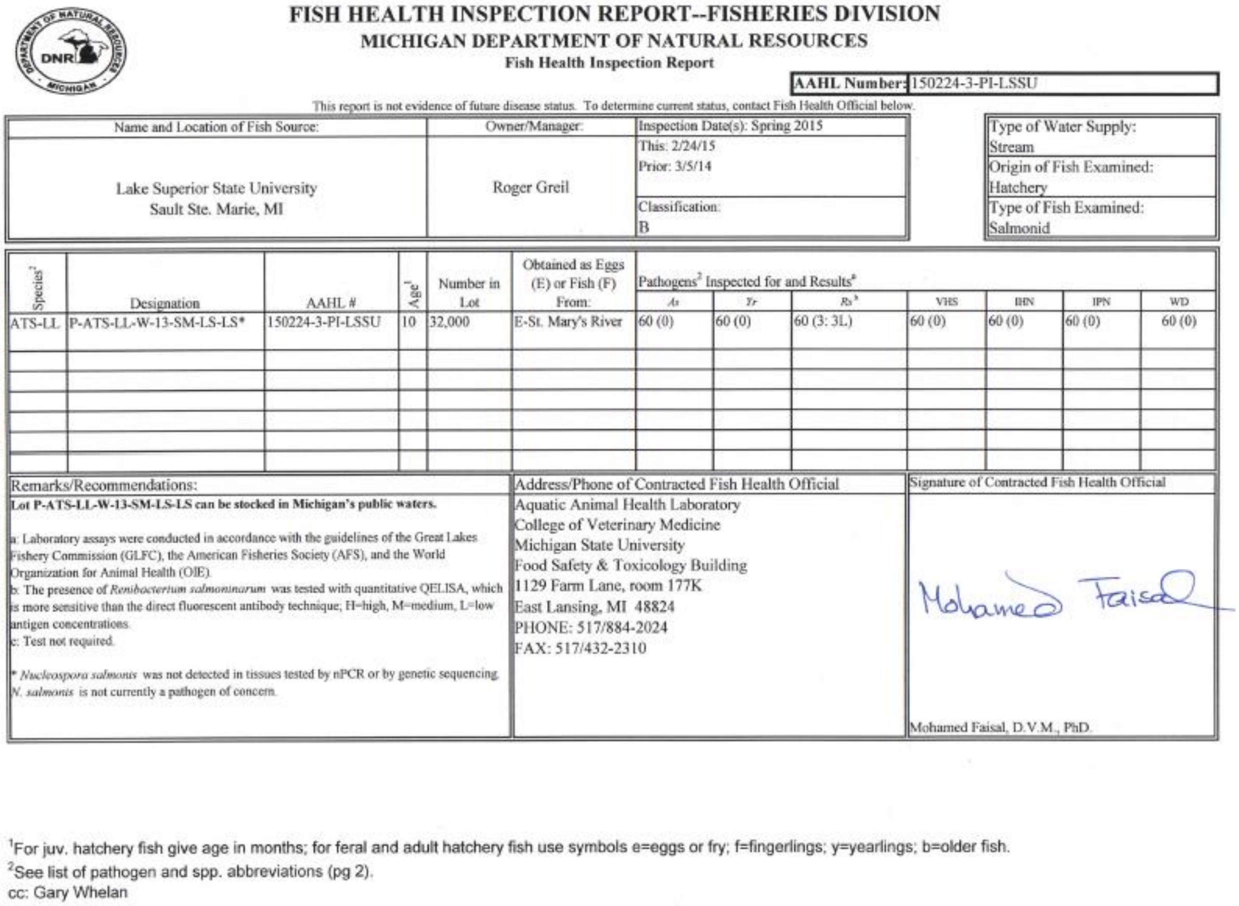
Changes in stream biota and habitat following a perched culvert replacement in John's Creek, MI

Austin Wenke, Ashley Moerke

Abstract: The Nature Conservancy recently led an effort to replace 13 barrier crossings to restore connectivity to 35 river miles in the Two Hearted River Watershed. One such replacement was a perched culvert on John's Creek, where the goal was to restore connectivity by replacing the poorly functioning culvert with a bridge. To evaluate the effectiveness of the culvert replacement, stream habitat, and fish and macroinvertebrate assemblages were evaluated before (July 2014) and after culvert (November 2014) replacement. Two 150-m reaches were identified, one above, and one below the crossing and sampled for fish stream habitat, macroinvertebrates, and fish. Prior to the culvert replacement, fish assemblages were only comprised of stream residents upstream, but also possessed YOY migratory fish downstream. Macroinvertebrate richness was low, and habitat was dominated by sand substrate. After culvert replacement, fish assemblages included resident and migratory fish both upstream and downstream. Additionally, fish with a downstream fin clip were found upstream of the crossing, indicating movement across the road-stream crossing. Macroinvertebrate assemblages showed little response, possibly due to temporary disturbances associated with construction activities. Overall, the results of this study indicate that The Nature Conservancy's goal was met and fish now have access to the Two Hearted River watershed.

APPENDICES

Appendix 1. Results of fish health inspection of age-1 Atlantic Salmon from lot P-ATS-LL-W-13-SM-LS-LS conducted by Michigan State University.



FISH HEALTH INSPECTION REPORT--FISHERIES DIVISION
MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Fish Health Inspection Report

AAHL Number: 150224-3-PI-LSSU

This report is not evidence of future disease status. To determine current status, contact Fish Health Official below.

Name and Location of Fish Source: Lake Superior State University Sault Ste. Marie, MI	Owner/Manager: Roger Greil	Inspection Date(s): Spring 2015 This: 2/24/15 Prior: 3/5/14	Type of Water Supply: Stream
			Origin of Fish Examined: Hatchery
		Classification: B	Type of Fish Examined: Salmonid

Species[2]	Designation	AAHL #	Age[1]	Number in Lot	Obtained as Eggs (E) or Fish (F) From:	Pathogens[2] Inspected for and Results[a]						
						As	*Yr*	*Rs*[b]	VHS	IHN	IPN	WD
ATS-LL	P-ATS-LL-W-13-SM-LS-LS*	150224-3-PI-LSSU	10	32,000	E-St. Mary's River	60 (0)	60 (0)	60 (3: 3L)	60 (0)	60 (0)	60 (0)	60 (0)

Remarks/Recommendations:

Lot P-ATS-LL-W-13-SM-LS-LS can be stocked in Michigan's public waters.

a: Laboratory assays were conducted in accordance with the guidelines of the Great Lakes Fishery Commission (GLFC), the American Fisheries Society (AFS), and the World Organization for Animal Health (OIE).

b: The presence of *Renibacterium salmoninarum* was tested with quantitative QELISA, which is more sensitive than the direct fluorescent antibody technique; H=high, M=medium, L=low antigen concentrations.

c: Test not required.

* *Nucleospora salmonis* was not detected in tissues tested by nPCR or by genetic sequencing. *N. salmonis* is not currently a pathogen of concern.

Address/Phone of Contracted Fish Health Official

Aquatic Animal Health Laboratory
College of Veterinary Medicine
Michigan State University
Food Safety & Toxicology Building
1129 Farm Lane, room 177K
East Lansing, MI 48824
PHONE: 517/884-2024
FAX: 517/432-2310

Signature of Contracted Fish Health Official

Mohamed Faisal

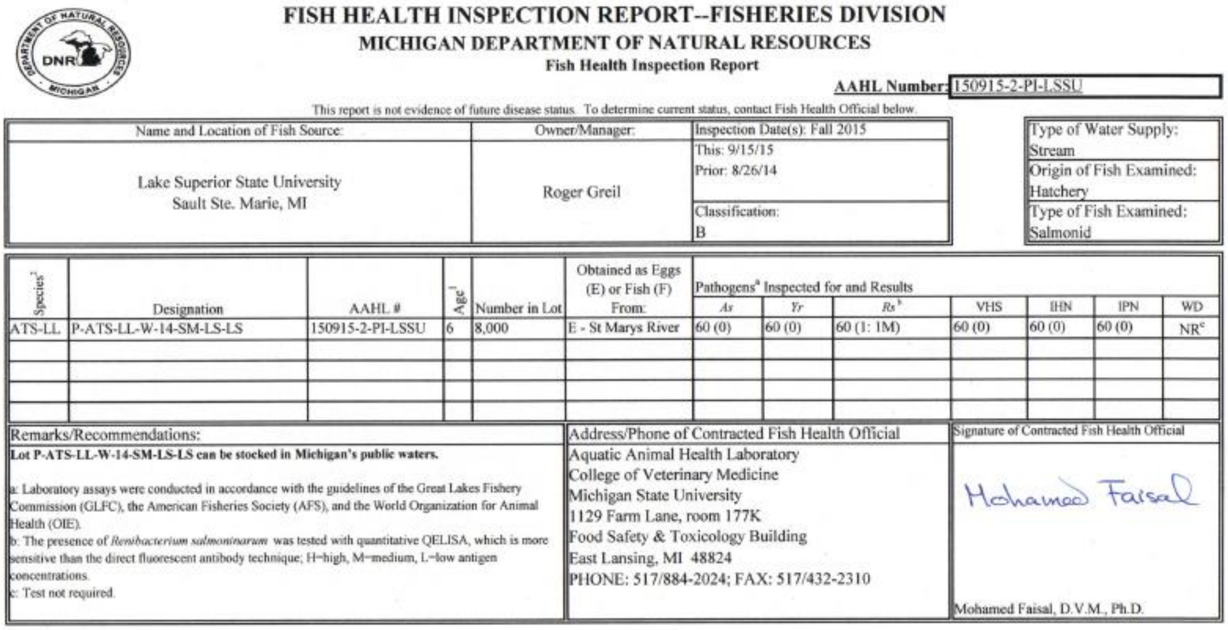
Mohamed Faisal, D.V.M., PhD.

[1] For juv. hatchery fish give age in months; for feral and adult hatchery fish use symbols e=eggs or fry; f=fingerlings; y=yearlings; b=older fish.

[2] See list of pathogen and spp. abbreviations (pg 2).

cc: Gary Whelan

Appendix 2. Results of fish health inspection of age-0 Atlantic Salmon from lot P-ATS-LL-W-14-SM-LS-LS conducted by Michigan State University.



FISH HEALTH INSPECTION REPORT--FISHERIES DIVISION

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

Fish Health Inspection Report

AAHL Number: 150915-2-PI-LSSU

This report is not evidence of future disease status. To determine current status, contact Fish Health Official below.

Name and Location of Fish Source:	Owner/Manager:	Inspection Date(s): Fall 2015	Type of Water Supply:
Lake Superior State University Sault Ste. Marie, MI	Roger Greil	This: 9/15/15 Prior: 8/26/14	Stream
			Origin of Fish Examined: Hatchery
		Classification: B	Type of Fish Examined: Salmonid

Species[2]	Designation	AAHL #	Age[1]	Number in Lot	Obtained as Eggs (E) or Fish (F) From:	Pathogens[a] Inspected for and Results						
						As	*Yr*	*Rs*[b]	VHS	IHN	IPN	WD
ATS-LL	P-ATS-LL-W-14-SM-LS-LS	150915-2-PI-LSSU	6	8,000	E - St Marys River	60 (0)	60 (0)	60 (1: 1M)	60 (0)	60 (0)	60 (0)	NR[c]

Remarks/Recommendations:

Lot P-ATS-LL-W-14-SM-LS-LS can be stocked in Michigan's public waters.

a: Laboratory assays were conducted in accordance with the guidelines of the Great Lakes Fishery Commission (GLFC), the American Fisheries Society (AFS), and the World Organization for Animal Health (OIE).

b: The presence of *Renibacterium salmoninarum* was tested with quantitative QELISA, which is more sensitive than the direct fluorescent antibody technique; H=high, M=medium, L=low antigen concentrations.

c: Test not required.

Address/Phone of Contracted Fish Health Official

Aquatic Animal Health Laboratory
College of Veterinary Medicine
Michigan State University
1129 Farm Lane, room 177K
Food Safety & Toxicology Building
East Lansing, MI 48824
PHONE: 517/884-2024; FAX: 517/432-2310

Signature of Contracted Fish Health Official

Mohamed Faisal

Mohamed Faisal, D.V.M., Ph.D.

[1] For juv. hatchery fish give age in months; for feral and adult hatchery fish use symbols e=eggs or fry; f=fingerlings; y=yearlings; b=older fish.

[2] See list of pathogen and spp. abbreviations (pg 2).

cc: Gary Whelan

Appendix 3. Data on individual Atlantic Salmon used for gamete collection in 2015. Note: 000-099 and 000A-030A are females, and 100-199 and 100A-130A are males.

Date taken	Number	TL (mm)	WT (kg)	Volume (L) of eggs taken	# of eggs in 12" Von Bayer tray	# of eggs
11/5/2015	000	658	3.33	0.875	50	4,527
11/5/2015	100	772	3.42			
11/5/2015	001	662	3.27	0.700	47	3,019
11/5/2015	101	570	1.63			
11/5/2015	002	590	2.25	0.600	57	3,040
11/5/2015	102	748	3.5			
11/5/2015	003	678	3.49	0.475	52	2,760
11/5/2015	103	738	3.58			
11/5/2015	004	687	2.32	0.450	51	2,470
11/5/2015	104	723	2.53			
11/5/2015	005	672	2.59	0.525	53	3,250
11/5/2015	105	790	3.05			
11/5/2015	006	589	2.32	0.500	57	3,800
11/5/2015	106	597	1.81			
11/5/2015	007	720	3.69	0.600	48	2,740
11/5/2015	107	594	1.95	.		
11/5/2015	008	675	3.28	0.825	47	3,550
11/5/2015	108	522	1.41			
11/5/2015	009	709	3.23	0.175	49	851
11/5/2015	109	549	1.5			
11/5/2015	010	638	2.56	0.750	50	3,800
11/5/2015	110	747	3.994			
11/5/2015	011	730	4.17	1.025	51	5,640
11/5/2015	111	510	1.44			
11/5/2015	012	665	2.61	0.425	53	2,633
11/5/2015	112	620	2.37			
11/5/2015	013	635	2.3	0.350	48	1,600
11/5/2015	113	685	2.87			
11/5/2015	014	614	2.43	0.450	47	2,070
11/5/2015	114	540	1.58			
11/5/2015	015	790	4.69	1.425	47	6,140
11/5/2015	115	680	2.99			
11/5/2015	016	750	3.88	1.000	45	3,757
11/5/2015	116	695	2.61			
11/5/2015	017	791	4.17	1.101	45	4,130
11/5/2015	117	673	2.78			

11/5/2015	018	560	2.01	0.400	57	3,040
11/5/2015	118	710	3.19			
11/5/2015	019	530	1.72	0.175	54	1,140
11/5/2015	119	800	4.91			
11/5/2015	020	670	3.63	0.900	46	3,620
11/5/2015	120	551	1.34			
11/5/2015	021	674	3.2	0.575	50	2,975
11/5/2015	121	690	2.87			
11/5/2015	022	641	2.97	0.900	47	3,880
11/5/2015	122	640	2.09			
	Average eggs per fish		**3,236**		**Total # of eggs**	**74,432**
11/9/2015	023	676	3.97	0.950	52	5,500
11/9/2015	123	553	1.36			
11/9/2015	024	710	3.18	0.850	48	3,890
11/9/2015	124	560	1.89			
11/9/2015	025	520	1.54	0.250	62	2,400
11/9/2015	125	582	1.89			
11/9/2015	026	640	3.52	1.200	48	5,490
11/9/2015	126	654	2.5			
11/9/2015	027	560	1.78	0.400	60	3,570
11/9/2015	127	742	3.52			
11/9/2015	028	690	3.74	1.000	48	4,570
11/9/2015	128	670	1.44			
11/9/2015	029	725	3.81	1.000	49	4,860
11/9/2015	129	600	1.95			
11/9/2015	030	730	3.94	1.000	44	3,510
11/9/2015	130	590	1.83			
11/9/2015	031	655	2.97	0.925	47	3,980
11/9/2015	131	730	3.7			
11/9/2015	032	710	3.36	1.100	49	5,350
11/9/2015	132	530	1.37			
11/9/2015	033	670	2.03	0.625	50	3,230
11/9/2015	133	610	2			
11/9/2015	034	575	2.6	0.550	59	4,700
11/9/2015	134	675	3.04			
11/9/2015	035	530	1.95	0.500	54	3,260
11/9/2015	135	575	2.01			
11/9/2015	036	625	2.98	0.950	47	4,090
11/9/2015	136	590	1.48			
11/9/2015	037	630	2.72	0.650	38	3,160
11/9/2015	137	605	2.29			

11/9/2015	038	565	1.29	0.625	51	3,440
11/9/2015	138	720	2.98			
11/9/2015	039	570	2.03	0.550	55	3,790[a]
11/9/2015	139	595	2.11			
11/9/2015	040	705	3.87	1.005	43	3,450
11/9/2015	140	515	1.29			
11/9/2015	041	525	1.61	0.550	57	4,180
11/9/2015	141	565	1.66			
11/9/2015	042	540	1.52	0.425	58	3,420
11/9/2015	142	550	1.64			
11/9/2015	043	692	2.73	0.750	50	3,880
11/9/2015	143	602	2.14			
11/9/2015	044	672	2.1	0.150	59	1,280
11/9/2015	144	571	1.96			
		Average eggs per fish	**3,864**		**Total # of eggs**	**85,000**
11/12/2015	045	733	3.18	0.850	44	2,980
11/12/2015	145	586	1.9			
11/12/2015	046	704	3.28	0.400	46	1,600
11/12/2015	146	682	3.29			
11/12/2015	047	722	3.27	0.650	47	2,800
11/12/2015	147	627	1.8			
11/12/2015	048	710	3.24	0.700	52	4,060
11/12/2015	148	602	2.31			
11/12/2015	049	622	2.85	0.800	47	3,450
11/12/2015	149	61.3	1.96			
11/12/2015	050	660	2.57	0.650	47	2,800
11/12/2015	150	590	1.99			
11/12/2015	051	560	1.71	0.400	57	3,040
11/12/2015	151	611	2.2			
11/12/2015	052	765	3.29	0.750	52	4,350
11/12/2015	152	594	2.01			
11/12/2015	053	531	1.86	0.500	53	3,090
11/12/2015	153	758	4.16			
11/12/2015	054	515	1.45	0.350	59	2,990
11/12/2015	154	515	1.29			
11/12/2015	055	74.6	4.52	0.900	45	3,380
11/12/2015	155	574	1.85			
11/12/2015	056	664	2.78	0.850	46	3,410
11/12/2015	156	564	1.78			
11/12/2015	057	645	3.1	0.750	48	3,890
11/12/2015	157	62.5	2.08			

11/12/2015	058	581	2.57	0.500	53	3,090
11/12/2015	158	637	1.82			
11/12/2015	059	645	2.52	0.850	48	3,890
11/12/2015	159	611	2.21			
11/12/2015	060	700	3.43	0.950	50	4,915
11/12/2015	160	680	2.39			
11/12/2015	061	620	2.72	0.850	48	3,890
11/12/2015	161	550	1.71			
11/12/2015	062	715	3.28	0.950	47	4,090
11/12/2015	162	610	2			
11/12/2015	063	550	1.67	0.425	57	3,230
11/12/2015	163	528	1.2			
11/12/2015	064	551	1.72	0.400	57	3,040
11/12/2015	164	535	1.27			
11/12/2015	065	571	2.31	0.800	52	4,640
11/12/2015	165	565	1.78			
11/12/2015	066	572	2.04	0.400	62	3,910
11/12/2015	166	570	1.79			
11/12/2015	067	710	3.89	1.250	48	5,720
11/12/2015	167	600	2.12			
11/12/2015	068	675	3.66	0.900	51	4,950
11/12/2015	168	675	1.65			
11/12/2015	069	675	3.32	1.000	52	5,880
11/12/2015	169	57	1.57			
11/12/2015	070	675	3.07	1.000	49	4,860
11/12/2015	170	705	3.61			
11/12/2015	071	640	2.69	0.800	52	3,010
11/12/2015	171	525	1.32			
11/12/2015	072	565	1.99	0.450	59	3,840
11/12/2015	172	585	1.9			
11/12/2015	073	715	3.67	0.950	48	4,340
11/12/2015	173	720	3.33			
11/12/2015	074	700	3.53	0.700	47	3,010
11/12/2015	174	530	1.43			
11/12/2015	075	625	3.24	0.750	49	3,640
11/12/2015	175	530	1.32			
11/12/2015	076	580	2.31	0.400	60	3,570
11/12/2015	176	571	1.8			
	Average eggs per fish		**3,730**		**Total # of eggs**	**119,355**
11/16/2015	077	612	2.65	0.625	50	3,030
11/16/2015	177	572	1.65			

11/16/2015	078	782	4.46	1.500	46	6,030
11/16/2015	178	573	1.8			
11/16/2015	079	725	2.85	0.900	49	4,370
11/16/2015	179	586	1.78			
11/16/2015	080	539	1.8	0.450	54	2,940
11/16/2015	180	557	1.37			
11/16/2015	081	652	2.98	0.950	49	4,620
11/16/2015	181	552	1.45			
11/16/2015	082	682	3.78	1.000	47	4,310
11/16/2015	182	642	2.39			
11/16/2015	083	682	2.89	1.000	54	6,530
11/16/2015	183	563	1.68			
11/16/2015	084	625	2.6	0.925	49	4,500
11/16/2015	184	670	2.34			
11/16/2015	085	555	2.01	0.550	57	4,180
11/16/2015	185	545	1.6			
11/16/2015	086	672	3.66	1.475	48	6,750
11/16/2015	186	680	2.94			
11/16/2015	087	540	1.75	0.425	54	2,770
11/16/2015	187	610	2.28			
11/16/2015	088	640	2.44	0.575	52	3,330
11/16/2015	188	690	2.47			
11/16/2015	089	510	1.49	0.325	55	2,240
11/16/2015	189	565	1.78			
11/16/2015	090	660	3.21	0.925	47	3,980
11/16/2015	190	713	2.8			
11/16/2015	091	555	1.88	0.625	51	3,440
11/16/2015	191	592	1.99			
11/16/2015	092	485	1.15	58.000	46	2,210
11/16/2015	192	573	1.77			
11/16/2015	093	693	3.22	48.000	51	5,720
11/16/2015	193	632	2.51			
11/16/2015	094	663	2.63	0.725	47	3,120
11/16/2015	194	586	1.92			
11/16/2015	095	687	3.71	0.900	46	3,620
11/16/2015	195	694	3.08			
11/16/2015	096	570	1.93	0.450	51	2,470
11/16/2015	196	682	2.81			
11/16/2015	097	683	3.31	0.925	49	4,500
11/16/2015	197	606	1.96			
11/16/2015	098	700	3.84	1.100	49	5,350

11/16/2015	198	691	2.78			
11/16/2015	099	570	2.27	0.550	60	4,900
11/16/2015	199	571	1.74			
11/16/2015	000-A	645	2.87	1.000	46	4,020
11/16/2015	100-A	552	1.71			
11/16/2015	001-A	561	2.03	0.575	56	4,190
11/16/2015	101-A	693	2.81			
11/16/2015	002-A	677	2.47	0.550	50	2,840
11/16/2015	102-A	555	1.89			
	Average eggs per fish		**4,075**		**Total # of eggs**	**105,960**
11/19/2015	003-A	775	4.18	1.25	44	4,390
11/19/2015	103-A	710	2.96			
11/19/2015	004-A	685	2.6	0.45	51	2,470
11/19/2015	104-A	569	1.64			
11/19/2015	005-A	510	1.47	0.475	60	4,240
11/19/2015	105-A	695	2.94			
11/19/2015	006-A	690	3.69	0.95	50	4,910
11/19/2015	106-A	723	3.37			
11/19/2015	007-A	680	2.83	0.6	52	3,480
11/19/2015	107-A	641	2.21			
11/19/2015	008-A	655	2.53	0.525	48	2,400
11/19/2015	108-A	575	1.75			
11/19/2015	009-A	700	3.03	0.9	54	5,880
11/19/2015	109-A	633	2.4			
11/19/2015	010-A	635	2.61	0.75	45	2,810
11/19/2015	110-A	675	2.33			
11/19/2015	011-A	750	4.57	0.7	53	4,330
11/19/2015	111-A	667	2.1			
11/19/2015	012-A	584	2.39	0.75	52	4,350
11/19/2015	112-A	564	1.38			
11/19/2015	013-A	620	2.85	0.85	48	3,890
11/19/2015	113-A	679	3.03			
11/19/2015	014-A	701	3.26	0.95	49	4,620
11/19/2015	114-A	565	1.74			
11/19/2015	015-A	641	3.06	0.825	48	3,770
11/19/2015	115-A	575	1.56			
11/19/2015	016-A	670	3.04	0.475	62	3,830
11/19/2015	116-A	555	1.47			
11/19/2015	017-A	523	1.56	0.75	47	3,230
11/19/2015	117-A	593	2.04			
11/19/2015	018-A	669	2.54	0.475	60	3,460

11/19/2015	118-A	550	1.7			
11/19/2015	019-A	530	1.62	0.45	59	3,840
11/19/2015	119-A	563	1.83			
11/19/2015	020-A	530	1.72	0.75	49	3,640
11/19/2015	120-A	453	0.79			
11/19/2015	021-A	650	2.31	0.375	59	3,200
11/19/2015	121-A	580	1.65			
11/19/2015	022-A	530	1.7	0.325	64	3,490
11/19/2015	122-A	582	1.93			
11/19/2015	023-A	510	1.28	0.5	54	3,260
11/19/2015	123-A	695	6.69			
11/19/2015	024-A	540	1.53	0.5	45	2,580
11/19/2015	124-A	581	1.78			
11/19/2015	025-A	678	3.08	0.8	45	4,640
11/19/2015	125-A	520	1.18			
11/19/2015	026-A	677	2.56	0.275	60	3,260[b]
11/19/2015	126-A	493	1.56			
11/19/2015	027-A	463	0.94	0.55	38	4,180
11/19/2015	127-A	605	2.08			
11/19/2015	028-A	554	1.82	0.225	43	1,300
11/19/2015	128-A	648	2.45			
11/19/2015	029-A	503	1.19	1.375	44	5,530
11/19/2015	129-A	612	1.99			
11/19/2015	030-A	506	1.3	0.375	55	2,580
11/19/2015	130-A	57.3	1.76			
		Average eggs per fish	**3,699**		**Total # of eggs**	**103,560**
		Grand total				
		# of eggs collected	**488,307**			
		Average eggs per fish	**3,728**			
		# of eggs used	**482,772**			

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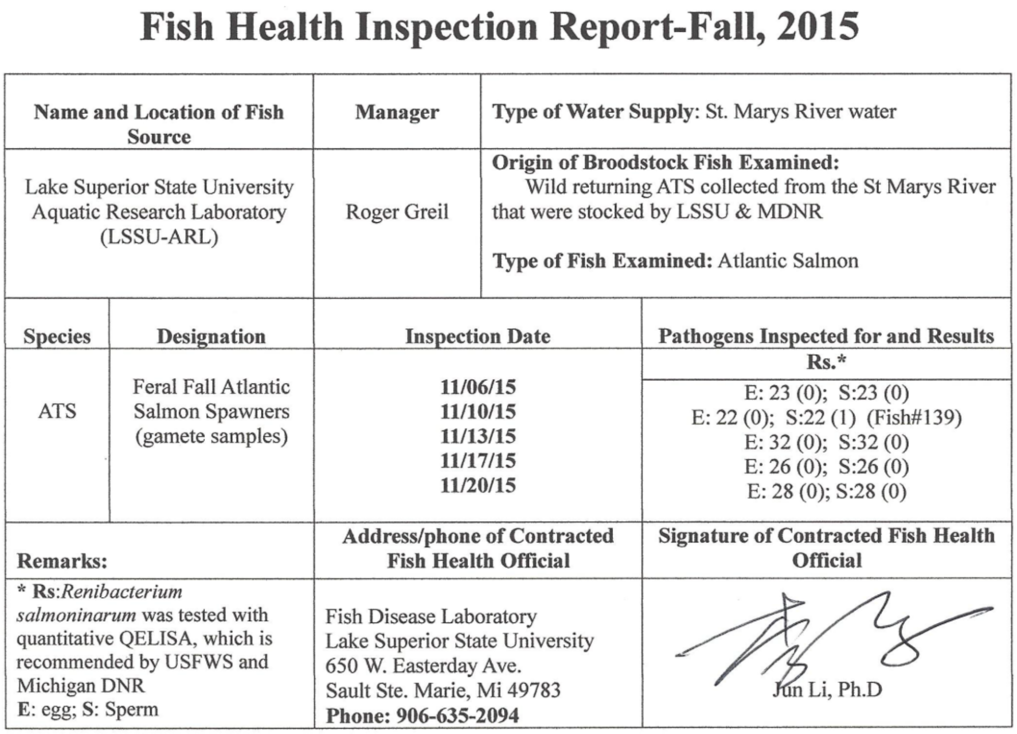
[a] Sperm tested positive for BKD, eggs discarded

[b] 1,745 dead eggs discarded

Appendix 4. Results of 2015 Atlantic Salmon broodstock testing for presence of *Renibacterium salmoninarum* (Bacterial Kidney Disease) conducted by the ARL's Fish Disease Lab.



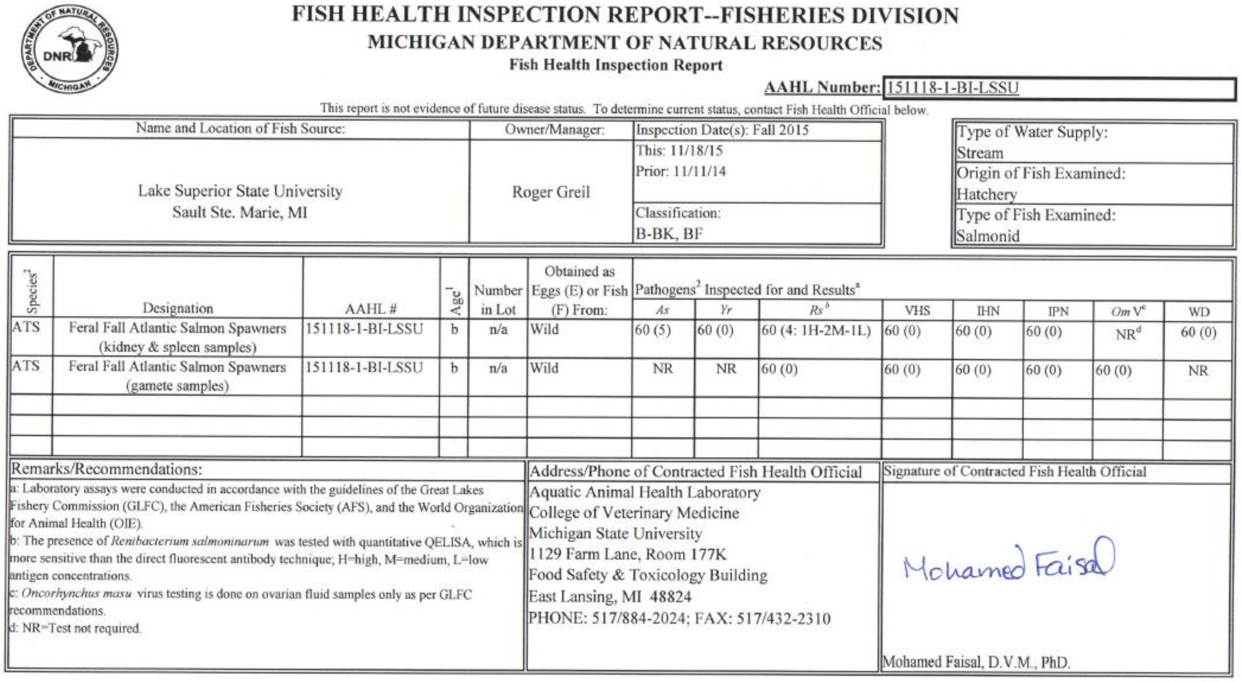
Fish Health Inspection Report-Fall, 2015

Name and Location of Fish Source	**Manager**	**Type of Water Supply**: St. Marys River water
Lake Superior State University Aquatic Research Laboratory (LSSU-ARL)	Roger Greil	**Origin of Broodstock Fish Examined:** Wild returning ATS collected from the St Marys River that were stocked by LSSU & MDNR **Type of Fish Examined:** Atlantic Salmon

Species	**Designation**	**Inspection Date**	**Pathogens Inspected for and Results**
			Rs.*
ATS	Feral Fall Atlantic Salmon Spawners (gamete samples)	**11/06/15**	E: 23 (0); S:23 (0)
		11/10/15	E: 22 (0); S:22 (1) (Fish#139)
		11/13/15	E: 32 (0); S:32 (0)
		11/17/15	E: 26 (0); S:26 (0)
		11/20/15	E: 28 (0); S:28 (0)

Remarks:	**Address/phone of Contracted Fish Health Official**	**Signature of Contracted Fish Health Official**
* **Rs**:*Renibacterium salmoninarum* was tested with quantitative QELISA, which is recommended by USFWS and Michigan DNR **E**: egg; **S**: Sperm	Fish Disease Laboratory Lake Superior State University 650 W. Easterday Ave. Sault Ste. Marie, Mi 49783 **Phone: 906-635-2094**	Jun Li, Ph.D

Appendix 5. Results of fish health inspection of 2015 Atlantic Salmon broodstock conducted by Michigan State University.



FISH HEALTH INSPECTION REPORT--FISHERIES DIVISION
MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Fish Health Inspection Report

AAHL Number: 151118-1-BI-LSSU

This report is not evidence of future disease status. To determine current status, contact Fish Health Official below.

Name and Location of Fish Source:
Lake Superior State University
Sault Ste. Marie, MI

Owner/Manager:
Roger Greil

Inspection Date(s): Fall 2015
This: 11/18/15
Prior: 11/11/14

Classification:
B-BK, BF

Type of Water Supply:
Stream
Origin of Fish Examined:
Hatchery
Type of Fish Examined:
Salmonid

Species[2]	Designation	AAHL #	Age[1]	Number in Lot	Obtained as Eggs (E) or Fish (F) From:	Pathogens[2] Inspected for and Results[a]							
						As	*Yr*	*Rs*[b]	VHS	IHN	IPN	*Om* V[c]	WD
ATS	Feral Fall Atlantic Salmon Spawners (kidney & spleen samples)	151118-1-BI-LSSU	b	n/a	Wild	60 (5)	60 (0)	60 (4: 1H-2M-1L)	60 (0)	60 (0)	60 (0)	NR[d]	60 (0)
ATS	Feral Fall Atlantic Salmon Spawners (gamete samples)	151118-1-BI-LSSU	b	n/a	Wild	NR	NR	60 (0)	60 (0)	60 (0)	60 (0)	60 (0)	NR

Remarks/Recommendations:

a: Laboratory assays were conducted in accordance with the guidelines of the Great Lakes Fishery Commission (GLFC), the American Fisheries Society (AFS), and the World Organization for Animal Health (OIE).

b: The presence of *Renibacterium salmoninarum* was tested with quantitative QELISA, which is more sensitive than the direct fluorescent antibody technique; H=high, M=medium, L=low antigen concentrations.

c: *Oncorhynchus masu* virus testing is done on ovarian fluid samples only as per GLFC recommendations.

d: NR=Test not required.

Address/Phone of Contracted Fish Health Official
Aquatic Animal Health Laboratory
College of Veterinary Medicine
Michigan State University
1129 Farm Lane, Room 177K
Food Safety & Toxicology Building
East Lansing, MI 48824
PHONE: 517/884-2024; FAX: 517/432-2310

Signature of Contracted Fish Health Official
Mohamed Faisal
Mohamed Faisal, D.V.M., PhD.

Appendix 6. Dosages for treatments of Atlantic Salmon eggs.

Saline Bath
0.75% needed
0.75/100 = 0.0075
0.0075*20L = 0.15 mL or g
0.15*1000 = 150 g needed for 20 L of H_2O

Erythromycin Treatment
2 ppm (mg/L) needed
2 mg/L*20 = 400,000 mg
400,000/0.23 = 1,739,130 (23% active)
1,739,130/10,000 = 173.9
173.9/1000 (to get to g) = 0.174g per 20 L of H_2O

Iodine Treatment
1% active
1% free iodine to get 100 ppm (mg/L) dilute 100 times
20 L = 20,000 mL
20 L*1,000 mL = 20,000 mL
20,000 mL/100 = 2,000 mL
2,000 mL*50 = 100,000 mL
100,000 / 1,000 (to mL) = 100 mL of Iodine needed for 20 L of H_2O