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Review of Attributes of Landlocked Atlantic Salmon in Relation to their Management in Lake Huron

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Introduction

This document was prepared for the purpose of guiding planning efforts designed to test the stocking of landlocked Atlantic Salmon in Lake Huron. It is not a thorough literature review, but instead focuses on attributes of landlocked Atlantic Salmon that are relevant to their potential performance in Lake Huron and on Michigan's previously evaluated Atlantic Salmon introductions. The review of Michigan's experiences is limited to those instances for which there was continuous stocking of at least three years and for which there was at least a modicum of evaluation available. There were a number of past stocking of Atlantic Salmon efforts that were, unfortunately, not evaluated and therefore not included in this review.

What are Landlocked Atlantic Salmon?

Atlantic Salmon are native to the northern Atlantic Ocean from the Iberian Peninsula to northern Russia and Scandinavia, and the British Isles to Iceland, the Canadian Maritime Provinces, and New England (Thorstad et al. 2011). They evolved with, and probably are more closely akin to, sea-run Brown Trout than to the Pacific salmonids such as steelhead. Most Atlantic Salmon populations are anadromous, migrating as smolts from freshwater tributary spawning and nursery habitats to salt water at ages of one or two years old. Some populations, known as landlocked salmon, remain in fresh water their entire life cycle, the smolts migrating to cold, freshwater lakes rather than the ocean (Thorstad et al. 2011). Like Pacific Salmon, Atlantic Salmon undergo smoltification, a physiological process that adapts them to the transition to a saltwater environment. Importantly for the Great Lakes, coloration changes as they smolt to a color scheme that blends better with a lacustrine environment, camouflaging them from predators and their prey. Smolting also stimulates downstream migration to lakes and a change in behavior from a territorial, benthic stream dweller to that of a pelagic, possibly shoaling lake or ocean fish (Thorstad et al. 2011).

Michigan Stocking History Since 1972

From 1972 to 1982 over 250,000 landlocked Atlantic Salmon were stocked in Michigan in several large inland lakes and in rivers that are tributary to lakes Michigan and Huron. Several landlocked strains, Quebec, Gullspang (from Norway), Sebago and Penobscot (from Maine), and a Vermont strain

[1] Retired

were used in these introductions. Survival was generally below 1%, but there was better survival in two inland lakes, Gull Lake and Higgins Lake (Galbraith and Schneider 1983; Dexter 2004). Evaluation was hampered by lack of systematic creel surveys and was dependent principally upon reports from anglers and occasional confirmations of identity by biologists. Mature fish returning to Lake Michigan tributaries commonly were in poor health and egg quality was poor; most fry resulting from these eggs likely died shortly after hatching. Many locations were stocked with yearlings that were too small to smolt in the year of stocking and many stocked fish remained in the stocking tributaries during the ensuing summer. Galbraith and Schneider (1983) concluded that many of the fish were stocked at too small a size to smolt, which compromised survival, and that stocking inland lakes gave better return-to-creel rates than stocking the smolts into the Great Lakes. Atlantic Salmon are vulnerable to thiamine deficiency, especially those individuals that feed heavily on Alewives (Fisher et al. 1996; Werner et al. 2006). In retrospect, and in view of subsequent findings with Pacific Salmon stocked in the Great Lakes (Brown et al. 2005), thiamine deficiency may have contributed to the lower performance of Great Lakes stockings of Atlantic Salmon by causing low egg survival from returning fish and poor health and mortality of the adults.

Three stocking sites figure prominently in this Michigan stocking history: Gull Lake, Torch Lake, and the St. Marys River. Each was stocked in successive years for a period long enough to permit evaluation.

Gull Lake

Gull Lake, a 2,030-acre lake in southwest Michigan, was stocked with an average of 23,300 yearlings per year during the period 1986–1990 for a stocking rate of 10.6 fish per acre. Despite a lack of Rainbow Smelt, a preferred prey for landlocked Atlantic Salmon (Boucher and Warner 2006), the stocking efforts were successful. In Gull Lake, Atlantic Salmon diet was composed of a combination of mayfly nymphs, small Bluegills and perch, and minnows based on a small number of fish examined. In 1987, the year after stocking began, 2,222 Atlantic Salmon were harvested. This harvest rate was nearly 10% of the 25,356 fish stocked in 1986. Atlantic Salmon proved to be very catchable through the ice during winter of 1987, but the season for harvest was closed. Unfortunately, there were no estimates of harvest after 1987.

Stocking targeted a small tributary, Prairieville Creek, and broodstock fish were collected from the creek using a portable weir and trap nets placed near the creek mouth. Fish stocked near the small tributary produced similar or better returns of spawning-phase fish to the creek than fish stocked directly into the river. In three years of trapping, 130, 185, and 314 returning salmon were collected during spawn-taking operations in 1988, 1989, and 1990, respectively. Interestingly, more females than males were observed in each year. First spawning, or age at maturity, for most fish was age 2 and 3 at lengths of 450–575 mm (17.7–22.7 inches). Repeat spawning was not uncommon and some fish spawned in alternate years, skipping years between spawning events. The 1986–1990 stockings established a population estimated to be 6–8 adult fish per acre by 1992, resulting in declining growth rates. This accumulation of adult fish was in spite of observations that the fish stocked were in poor health, having suffered fungal infections and bacterial gill disease immediately prior to release (Dexter 2004). The perception that the prey base had been adversely affected led to the abandonment of this apparently successful stocking program after 1990, although some fall fingerlings were stocked in Gull Lake in 1991 and 1992 (Dexter 2004). The Gull Lake experience led to the recommendation that stocking rates for inland waters be 1–2 fish per acre for sport fisheries and 2–4 per acre for broodstock lakes.

Torch Lake

Torch Lake has been stocked intermittently with fall fingerlings and spring yearlings since 1986, but the years 1998–2006 were consistently stocked with a substantial numbers of yearlings (Table 1). Torch Lake is a deep, 18,770-acre oligotrophic lake with a Rainbow Smelt and Cisco prey base. An average of 31,000 yearlings was stocked annually 1998–2006. The yearlings were rather large, averaging 199 mm (7.8 inches). The stocking rate during that period averaged 1.65 yearlings per surface acre, which is on the high end of rates recommended by the Maine Department of Inland Fisheries and Wildlife for stocking landlocked Atlantic Salmon (Boucher and Warner 2006). However, there were no estimates of angler use or harvest during or subsequent to stocking the fish. The only information available on the fishing opportunity afforded by Atlantic Salmon is from angler reports to managers. These reports suggest that stocking has established a popular fishery in Torch Lake.

Some anglers have recorded length-weight data and collected scale samples, but the number of these samples is insufficient to determine age, growth rates, or other biological parameters of the Torch Lake population (H. Seites-Hettinger, MDNR Traverse City Office, personal communication). Interestingly, following cessation of yearling stocking in 2006, cooperating anglers did not report a noticeable reduction in fishing quality, perhaps suggesting that fall fingerlings stocked in 2008 and 2009 may have contributed significantly to the fishery. The Atlantic Salmon fishery at Torch Lake is regarded best during spring, when the fish are near shore and can be caught in 4–6 ft of water. Angling success declines during summer, but recovers as surface temperatures cool in fall. Anglers are increasingly recognizing that a good summer fishery exists for those equipped to fish the lake's deeper, offshore waters (H. Seites-Hettinger, personal communication).

Little is known about whether the Torch Lake Atlantic Salmon move to tributaries and attempt spawning. Adult Atlantic Salmon are commonly observed in Torch River, the lake's outlet. They have also been reported in the Clam River, Torch Lake's principal tributary, which drains from the "Chain of Lakes." Some of these could be spawning-phase fish. However, neither the outlet nor the Clam River inlet have habitat suitable for salmonid spawning. Other streams flowing into Torch Lake are small, the largest of which is Spencer Creek, near the Alden Village stocking site (H. Seites-Hettinger, personal communication).

Table 1.–Atlantic Salmon stocking history of Torch Lake.

Stocking year	Number stocked	
	Yearling	Fall fingerlings
1986		14,760
1987		
1988		
1989		
1990		12,490
1991		39,735
1992		40,000
1993		
1994	5,799	
1995		
1996		
1997		13,164
1998	20,876	31,926
1999	30,430	32,717
2000	30,567	
2001	31,304	
2002	28,487	26,470
2003	46,148	
2004	24,158	
2005	39,210	
2006	27,896	6,180
2007		19,012
2008		22,620
2009		
2010		
2011		22,747
2012	20,000 [a]	

[a] Preliminary number

St. Marys River

Lake Superior State University (LSSU), under a Memorandum of Agreement with the Department of Natural Resources, has stocked Atlantic Salmon in the St. Marys River since 1986. The fish are raised at the LSSU Aquatic Research Laboratory (ARL). The LSSU ARL Laboratory is a cooperative venture with the Cloverland Electric Company and allows LSSU to raise the fish adjacent to the St. Marys River and use water from the river for their culture operations. From 1995 to 2008 LSSU has stocked an average of 36,771 spring yearlings annually that average 179 mm (approximately 7.0 inches) in total length at stocking. Fish are stocked when the temperature of the upper St. Marys River approaches 8°C, which is usually near June 1. The return to creel from this program has been stable and relatively high, apparently unaffected by the Alewife collapse in Lake Huron and even benefitting from the decline in Chinook Salmon. In recent years, the return to creel has been near 6% (Figure 1; Johnson and Gonder 2013).

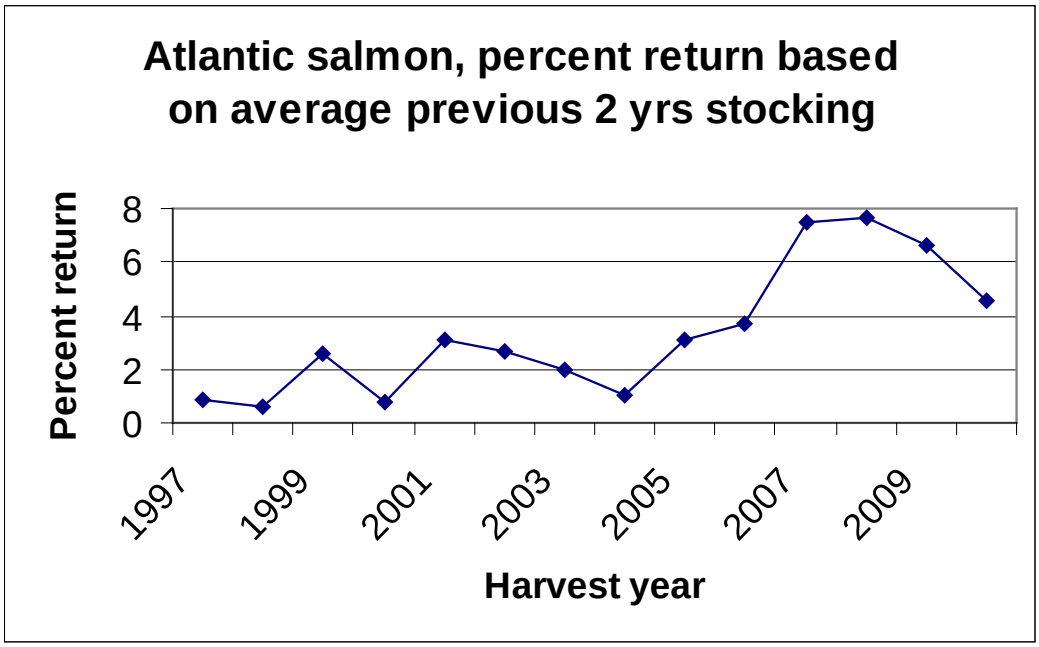

Figure 1.–Return to creel estimated for Atlantic Salmon stocked by LSSU at Sault Ste. Marie and caught in the St. Marys River and Michigan waters of Lake Huron.

Since 2003, the LSSU Atlantic Salmon program has collected enough eggs from returning, spawning-phase adults, to supply egg needs for culture operations. Prior to 2004, however, several sources were used to establish the St. Marys River spawning population (Table 2). This mix of gametes founded what is now the "St. Marys River" broodstock.

Table 2.–Number of eggs received by Lake Superior State University, by source, for culture in the Aquatic Research Laboratory, 1985–2003.

Strain	Number	Percent
Wolf Lake SFH Brood (West Grand Lake)	38,479	2.0
Gull Lake (West Grand Lake)	314,641	16.3
Minnesota (West Grand Lake)	31,000	1.6
Penobscot (Maine)	493,569	25.5
Sebago (Maine)	72,601	3.8
Torch (West Grand Lake)	9,228	0.5
West Grand Lake (Maine)	975,893	50.4

Gull Lake was established as a broodstock lake during the 1980s and thus was a major source of eggs for the establishment of the St. Marys River population. Most of the eggs used for stocking Gull Lake were, in turn, from West Grand Lake. Thus, approximately 74.5% of the eggs used to found the St. Marys River population were either West Grand Lake (assuming Gull Lake are West Grand Lake strain) or Sebago strain and 25.5% were from the Penobscot strain. The Penobscot strain proved more difficult to culture and, due to losses during culture, comprised only about 5% of the fish stocked in the

St. Marys River. Many of the Penobscot strain fish were given strain-specific tags and could be recognized at time of spawning. Few eggs were ever taken from Penobscot-strain brood fish returning to the upper St. Marys River, and what few eggs were taken suffered almost complete mortality (R. Greil, Lake Superior State University, personal communication). The result is that the founding strain for the St. Marys River broodstock is almost entirely from Maine's West Grand Lake.

In Maine, landlocked Atlantic Salmon were native to four basins, including West Grand Lake in the St. Croix Basin of north-central Maine and Sebago Lake in the Presumscot River basin in southern Maine. These populations share a common, postglacial ancestry with sea-run Atlantic Salmon (Boucher and Warner 2006). Grand Lake Stream, the outlet of West Grand Lake, provides excellent spawning habitat. Thus, much reproduction of West Grand Lake strain Atlantic Salmon occurs in the lake's outlet. The LSSU experience has shown that West Grand Lake strain Atlantic Salmon return to an upstream stocking site (upper St. Marys River) to spawn, despite their ancestry as an outlet spawner. There is the possibility that this strain is capable of taking advantage of either outlet or inlet spawning opportunities. Lake Huron's outlet, the St. Clair River, appears to offer a suitable habitat for an outlet-spawning-run fishery.

Life History Attributes of Landlocked Atlantic Salmon

Atlantic Salmon stocked by LSSU have consistently provided a better catch per number of fish stocked (return to creel) than any other salmonid stocked in Lake Huron (Johnson and Gonder 2013). Most importantly, returns to creel actually rose and have remained higher (Johnson and Gonder 2013; Alpena Fisheries Research Station, unpublished data) since the food web change, including Alewife collapse, that occurred in 2003-04 (Riley et al. 2008). The rise may also indicate the altered food web is more favorable to Atlantic Salmon survival than when Alewives were the dominant prey. Return to creel averaged 5.5% after the 2004 Alewife collapse (Figure 1), which is nearly 10 times the return to creel for steelhead during the same period. Changes in fish culture methods at LSSU ARL (lower rearing densities) that improved fish health at time of stocking may also have contributed to the apparent rise in survival since 2004.

These return-to-creel rates are higher than for other salmonids, such as steelhead, Chinook Salmon, and Brown Trout stocked in Lake Huron by the Michigan Department of Natural Resources (MDNR). However, the high survival of Atlantic Salmon stocked by LSSU in the St. Marys River does not logically lead to a firm conclusion that Atlantic Salmon are uniquely well suited to Lake Huron. There are several alternative explanations for the high return-to-creel rates experienced by the LSSU stockings, including:

1. LSSU's facility is different from any of MDNR's fish culture stations. It is located on the St. Marys River and uses St. Marys River water for its water supply. The fish are not transported before stocking but instead are released directly to the St. Marys River from their raceways. These conditions should significantly reduce the stress levels experienced by LSSU's Atlantic Salmon at release, which could translate into much higher survival rates.
2. The St. Marys River may be an exceptionally well-suited Atlantic Salmon stocking site. There is an ample supply of larval Rainbow Smelt for prey and water temperatures are ideal at time of stocking. Stocking is in fact timed such that the fish are released when the St. Marys River reaches 8°C in late May or early June. This is the ideal temperature and time of year for smoltification to occur in yearling Atlantic Salmon (Hosmer 1979; Zydlewski 2005).
3. Nearly 80% of the documented catches of Atlantic Salmon from the fish stocked by LSSU are from the St. Marys River, rather than Lake Huron. This may be a reflection of the imprinting to the river that LSSU fish receive by being cultured from egg to smolt in river water. The river is obviously a different environment than Lake Huron, and Atlantic Salmon may be more vulnerable to angling in the confines of the river than in the open lake.

Alternatively, there are reasons to believe that Atlantic Salmon are indeed better suited to Lake Huron, as measured in terms of return to creel, than other salmonids typically stocked by the MDNR. These include:

1. Smoltification triggers a strong tendency in Atlantic Salmon to swim downstream and rapidly migrate through river mouths and estuaries to open water. Ground speed migration rates in the range of .2 to 28 km per day have been measured, with individual movements as much as 60 km per day. Smolts often migrate downstream near the stream's surface; this may be an adaptation to take advantage of areas of highest downstream current speed or to avoid predators (Thorstad et al. 2011). Thus, unlike Brown Trout, which do not smolt or move offshore, or Chinook Salmon, which smolt but only migrate to beach zones during spring (Johnson et al. 2007), Atlantic Salmon smolts migrate to offshore waters of lakes and oceans where predation rates on them may be lower. This offshore migration therefore may translate into higher post-stocking survival for Atlantic Salmon stocked as smolts or pre-smolts than for species that do not migrate offshore after stocking.
2. Like Brown Trout, Atlantic Salmon are tolerant of relatively high temperatures (Thorstad et al. 2011; Coghlan and Ringler 2005) and may therefore be more available than other salmonids to anglers fishing closer to shore in mid-summer. This may be especially true for mature Atlantic Salmon, which begin their spawning migrations in July. Atlantic Salmon feed and grow at warmer temperatures than, for example, steelhead. Lethal and optimal growth temperatures are approximately 31°C (87.8°F) and 19°C (66.2°F) for Atlantic Salmon and 27°C (80.6°F) and 17°C (62.6°F) for steelhead. In Lake Ontario tributaries with mean summer temperatures higher than 20.5°C (70°F), stocked Atlantic Salmon survived and grew, whereas stocked Rainbow Trout failed and wild Rainbow Trout were absent (Coghlan and Ringler 2005). Thus, a combination of their summer migration to stocking/spawning sites and tolerance of warmer temperatures means Atlantic Salmon may be capable of providing stream and nearshore fisheries at times of year other stocked salmonids cannot. Unlike Brown Trout, Atlantic Salmon appear to be very catchable during spring and summer. This is a general perception, based on no known research comparing the catchability of the two species, but Brown Trout are acknowledged to be less vulnerable to angling in lakes than are many other species.
3. Atlantic Salmon begin their upstream migrations during summer. There is no consensus as to why this early spawning migration occurs; it causes Atlantic Salmon to forego growth opportunities in the lake available to other salmonids that migrate to streams in late summer or fall (Thorstad et al. 2011). Regardless of the reason, this migration, which for the LSSU population begins in late June and early July (Behmer et al. 1993), brings Atlantic Salmon into streams and nearshore waters of Lake Huron at times of peak angling pressure. This convergence of spawning migrations and angling pressure, combined with the relatively high vulnerability of Atlantic Salmon to angling, renders Atlantic Salmon more vulnerable to harvest than species that migrate in fall and winter. Therefore, return to creel could be higher for Atlantic Salmon even if post-stocking survival did not differ from that of other species.
4. Atlantic Salmon appear to be opportunistic in their feeding behavior. For example, after the collapse of Alewives in Lake Huron, Round Gobies became one of the most available prey species in Lake Huron (J. He, MDNR, Alpena Fisheries Research Station, unpublished data; Riley et al. 2008). In 2009, after the Alewife collapse, Round Gobies made up only 6% by weight of the diets of Chinook Salmon while Atlantic Salmon diets were composed of 25% gobies. Atlantic Salmon also consumed a variety of other fish and invertebrates including Rainbow Smelt (J. Schaeffer, U.S. Geological Survey, Great Lakes Science Center, unpublished data). Rainbow Smelt are the preferred prey of landlocked

Atlantic Salmon in Maine (Boucher and Warner 2007) and are a leading offshore prey fish in Lake Huron (Riley et al. 2008).

5. Studies appear to be lacking that compare return to creel of Atlantic Salmon with other stocked salmonids in the same waters and stocking sites. There are, however, reasons to think that "stocking power" of Atlantic Salmon, that is, the survival realized by a given number of fish stocked, is greater than for some other species. The Gull Lake stockings of 1986–1990 (10.6 yearlings per acre) produced a large enough population (6–8 adult fish per acre by 1992) to produce density-related limitations such as declining growth and diminished prey base. In Maine, where landlocked Atlantic Salmon are stocked in 127 lakes, stocking rates have been reduced as managers realize that "overstocking, even to a minor extent, can result in depressed smelt abundance, followed by slow salmon growth and reduced fishing quality". Stocking rates in Maine presently do not exceed 1.5 yearlings per surface acre and average between 0.4 and 0.7 per acre. From 2000 to 2004 Maine annually stocked an average of 113,000 spring yearlings in its inland lakes at an average rate of 0.43 per acre. These fish averaged about 7 inches in length and 3 oz at time of stocking. Returns to creel for yearling Atlantic Salmon stocked in 13 Maine lakes averaged 23% from 1988 to 1996 (Boucher and Warner 2006). By comparison, returns to creel of steelhead in Lake Huron averaged 0.5% from 2005–2010 (Johnson and Gonder 2013).

The present experimental stocking, which began in 2011, of Atlantic Salmon raised in MDNR hatcheries and stocked at the same time and location as LSSU-raised fish will allow comparison of return to creel and allow us to tease out the degree to which two factors — culture and release practices versus ecological attributes of Atlantic Salmon — have contributed to the high return-to-creel rates of LSSU fish. Additional research is needed to determine the potential to establish fisheries for Atlantic Salmon elsewhere in Lake Huron.

Types of Fishing Opportunities Afforded by Landlocked Atlantic Salmon

Some attributes of Atlantic Salmon translate into unique fishing opportunities. Some of these have been alluded to above, including the use of both inlet (St. Marys River) and outlet (West Grand Lake, Grand Lake Stream) spawning sites by the West Grand Lake strain, and their migration to spawning sites during early summer. Oceanic Atlantic Salmon are best known for the stream fishing opportunities they offer during their spawning migrations in summer and fall (Gingrich et al. 1974) but Maine's landlocked Atlantic Salmon are "taken in the sport fishery by almost every means of legal angling." The open-water fishery is probably most popular during early spring until warmer water temperatures drive Atlantic Salmon to deeper, cooler waters in summer, but trolling fisheries persist during that time of year, and ice fishing is gaining in popularity (Boucher and Warner 2006). Their early summer migration to spawning/stocking sites corresponds with months of peak recreational fishing at most Lake Huron ports, which will further increase their availability to angling. In Maine, the timing of landlocked salmon spawning runs often depends on flows and water temperatures. Stream fisheries can be delayed by warm water temperatures (Boucher and Warner 2006). The St. Marys River, on the other hand, is cool enough in most summers for the spawning run to commence in June and July (Behmer et al. 1993). Most of Lake Huron's other large tributaries are impounded, causing them to be relatively warm in summer; presumably spawning runs to these rivers would be delayed until their temperatures declined to the upper temperature limits for Atlantic Salmon, approximately 20–22°C (68–73°F). Possibly, maturing Atlantic Salmon would stage off these river mouths during summer, offering nearshore boat fishing opportunities.

River fishing opportunities for landlocked Atlantic Salmon begin with the staging of maturing fish off river mouths in early summer (Boucher and Warner 2006) followed by the upstream migration

which may continue through fall, but Atlantic Salmon do not spawn until November. Many spent fish remain in rivers during winter, offering angling opportunities for these “kelts” until spring (Thorstad et al. 2011).

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Literature Cited

Behmer, D. J., Greil, R. W., Scott, S. J., and Hanna T. 1993. Harvest and movement of Atlantic Salmon stocked in the St Marys River, Michigan. Journal of Great Lakes Research 19:533-540.

Boucher, D. P., and K Warner. 2006. Maine landlocked salmon: Life history, ecology, and management. Maine Department of Inland Fisheries and Wildlife, Division of Fisheries and Hatcheries, Augusta.

Brown, S. B., D. C. Honeyfield, J. G. Hnath, M. Wolgamood, S. V. Marcquenski, J. D. Fitzsimons, and D. E. Tillett. 2005. Thiamine status in adult salmonines in the Great Lakes. Journal of Aquatic Animal Health 17:59-64.

Coghlan, S. M., Jr., and N. H. Ringler. 2005. Temperature-dependent effects of Rainbow Trout on growth of Atlantic Salmon parr. Journal of Great Lakes Research 31:386-396.

Dexter, J. L., Jr. 2004. Gull Lake as a broodstock source for landlocked Atlantic Salmon, 1991–96. Michigan Department of Natural Resources, Fisheries Technical Report 2004-1, Ann Arbor.

Fisher, J. P., J. D. Fitzsimons, G. F. Combs, Jr., and J. M. Spitsbergen. 1996. Naturally occurring thiamine deficiency causing reproductive failure in Finger Lakes Atlantic Salmon and Great Lakes lake trout. Transactions of the American Fisheries Society 125:167-178.

Johnson, J. E., S. P. DeWitt, and J. A. Clevenger, Jr. 2007. Investigations into causes of variable survival of Chinook Salmon stocked into Lake Huron. Michigan Department of Natural Resources, Fisheries Research Report 2086, Ann Arbor.

Johnson, J. E., and D. Gonder. 2013. Status of introduced salmonines. Pages 50–59 *in* The state of Lake Huron in 2010. S. C. Riley, editor. Great Lakes Fishery Commission Special Publication 13-01, Ann Arbor, Michigan.

Galbraith, M. G., and J. C. Schneider. 1983. Atlantic Salmon in the Great Lakes (Michigan waters). Michigan Department of Natural Resources, Federal Aid in Sport Fish Restoration, Study Final Report, F-35-R-9, Study 410, Ann Arbor.

Gingrich, A., C. J. Kerswill, and A. J. McClane. 1974. Atlantic Salmon *Salmo salar*. Pages 70–77 *in* A. J. McClane, editor. McClane's New Standard Fishing Encyclopedia and International Fishing Guide. Holt, Rinehart, and Winston, New York.

Hosmer, M. J. 1979. Effects of hatchery procedures on later return of Atlantic Salmon to rivers in Maine. Progressive Fish Culturist 41:115-119.

Riley, S. C., E. F. Roseman, S. J. Nichols, T. P. O'Brien, C. S. Kiley, and J. S. Schaeffer. 2008. Deepwater demersal fish community collapse in Lake Huron. Transactions of the American Fisheries Society 137:1,879-1,890.

Thorstad, E. B., F. Whoriskey, A. H. Rikardsen, and K. Aarestrup. 2011. Aquatic nomads: the life and migrations of the Atlantic Salmon. Pages 1–32 *in* Atlantic Salmon Ecology. Wiley-Blackwell, Chichester, West Sussex, United Kingdom.

Werner, R. M., B. Rook, and R. Greil. 2006. Egg-thiamine status and occurrence of early mortality syndrome (EMS) in Atlantic Salmon from the St. Marys River, Michigan. Journal of Great Lakes Research 32:293-305.

Zydlewski, G. B. 2005. Evidence for cumulative temperature as an initiating and terminating factor in downstream migratory behavior of Atlantic Salmon smolts. Canadian Journal of Fisheries and Aquatic Sciences 62:69-78.

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