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Investigation of Stocking Methods for Expanding the Steelhead Fishery in Lake Huron

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Abstract

The Laurentian Great Lakes have undergone massive food web changes brought about by the colonization of aquatic invasive species. Invasive dreissenid mussels led to the collapse of Lake Huron's Alewife *Alosa pseudoharengus* population in the mid-2000s, and the demise of this salmonine prey species led to the subsequent collapse of the Chinook Salmon *Oncorhynchus tshawytscha* fishery and loss of recreational angling opportunities. In response, fisheries managers have worked to restore angling opportunities by stocking other salmonine species such as steelhead *Oncorhynchus mykiss* that are not dependent on Alewives for prey. However, differences in steelhead survival between two frequently used stocking methods, acclimation pens or direct plants, have not been examined. Improvements in survival of stocked steelhead by using the most successful stocking method would create additional angling opportunities and contribute to a more diverse recreational fishery. Accordingly, we stocked yearling steelhead into acclimation pens or as direct plants in Great Lakes harbors and tributary streams from 2011–2013 to determine if survival differed among stocking strategies. There were no significant differences in survival between steelhead smolts that were acclimated or directly planted. Stocking in Great Lakes harbors resulted in aggregations of fish in the vicinity of the stocking sites in the spring and contributed to local open water fisheries in May and June. Stocking in tributary streams with ample public access and liberal fishing seasons resulted in a significant year-round recreational fishery. Both large (210 mm) and small (180 mm) and harbor and tributary stocked steelhead groups contributed to the open water fishery, but only the tributary stocked groups contributed to spawning-phase fisheries in the fall and winter. There is potential for expansion of the steelhead fishery in Lake Huron if yearlings are stocked in tributary streams with ample public access which provide the best mix of open water and tributary fishing opportunities.

INTRODUCTION

In a pattern predicted by Hecky et al. (2004), invasive dreissenid mussels caused a loss of nutrients from the pelagic zone of Lake Huron, which is believed to be a leading factor in the collapse of Alewives *Alosa pseudoharengus* and other demersal prey from 2003–04 (Riley et al. 2008). The Alewife collapse, in turn, was followed by sharp declines in certain pelagic salmonines, particularly Chinook Salmon *Oncorhynchus tshawytscha* (Bence et al. 2008). In the face of severely reduced numbers of Alewives, predators were forced to shift away from Alewife as a primary diet source or suffer the consequences of starvation (Johnson et al. 2007). As a result, Chinook Salmon, which had been a major contributor to recreational fisheries of Lake Huron, became rare and incidental in the catch. Angler effort declined considerably, dropping 71% at 10 key deep-water ports on the Michigan side of Lake Huron (-199,000 4-hour angler days per year) compared to effort observed at the same ports from 1991–2004 (Michigan Department of Natural Resources, unpublished data). Given that a Great Lakes angler day was valued at $56.52 USD in trip and equipment expenditures (US Department of the Interior, Fish and Wildlife Service and US Department of Commerce, US Census Bureau 2002), the estimated annual economic loss of the Chinook Salmon fishery at these 10 ports was $11,250,000 USD.

Steelhead *Oncorhynchus mykiss* are a highly desired species that can contribute to diverse recreational fishing opportunities. The resiliency of steelhead is evident in their generalist dietary preferences and ability to capitalize on invertebrates and alternative prey fish in Lake Huron in the absence of Alewife (Bence et al. 2008; Roseman et al. 2014). However, stocked steelhead are vulnerable to predation from other fish such as Walleye *Sander vitreus* (Johnson et al. 2007) and avian predators like the Double Crested Cormorant *Phalacrocorax auritus* following typical direct plants where fish are released from a transport truck directly into the receiving waterbody. A protected acclimation period for stocked fish may provide a reprieve from predation, giving stocked fish time and space to recover from the stresses of transport and stocking. Physiological stress responses from handling have been documented (Barton 2000) and can negatively affect post-stocking behavior, predator-avoidance responses, and survival after stocking (Specker and Schreck 1980; Olla et al. 1995; Mesa 1994). In one study, salmonines subjected to stress were more likely to be consumed by predators during a one-hour period of exposure to predators (Mesa 1994) than unstressed fish. In other studies, stressed salmonines were slower to react to light stimuli for up to three hours after exposure to the stress relative to unstressed fish and the effects of multiple exposures to stress were cumulative (Sigismondi and Weber 1988). Use of acclimation pens at stocking sites would allow time for symptoms of stress to decline to background levels, potentially enhancing post-release survival and ultimately returns to the creel. Acclimation significantly increased both the open-lake harvest and returns to the stocking site (homing) for spring fingerling Chinook Salmon stocked in the Au Sable River, a tributary to Lake Huron (Johnson et al. 2007). Year-old Atlantic Salmon *Salmo salar* acclimated in net pens for seven days survived twice as well as direct plants in a river in Norway, hinting at the potential for success with yearling steelhead (Finstad et al. 2003).

Acclimation post-stocking has been shown to have positive impacts on Chinook Salmon survival in Michigan waters of the Great Lakes (Johnson et al. 2007, MDNR unpublished data). In studies in Michigan waters of Lakes Michigan and Huron, spring fingerlings were held in pens in large tributaries near the mouths of the rivers. Spring fingerling Chinook put on significant growth over the course of two to four weeks while in the pens. The amount of growth realized in the pens varied with the highest growth measured in pens located in warmer tributaries. The effect of these pen operations on survival of fingerlings to adulthood were compared to direct plants in the same tributaries. The survival advantage offered by penning varied among the various ports but was 1:1 at the lowest and up to 3:1 at the highest (Johnson et al. 2007) in the Au Sable River. Findings in Lake Michigan with Chinook followed a similar trend with survival benefits for pen acclimated fish but due to study design the results were not statistically significant (MDNR unpublished data). These findings resulted in establishment of acclimation pens for Chinook at many stocking locations in Lake Huron by 1999.

Post-stocking acclimation of steelhead yearlings has not been thoroughly evaluated in the Great Lakes. Since 1998, the New York Department of Environmental Conservation (NYDEC) and local fishing club partners have reared yearling steelhead in acclimation pens. Pens were located in tributaries to the Western basin of Lake Ontario. The practice is generally perceived to improve survival of steelhead (Sanderson et al. 2016), however, there were no direct plant groups for comparison and the effects of pen rearing had not been systematically evaluated. Michigan Department of Natural Resources (MDNR) conducted a limited study in one tributary in one year with acclimation-penned, winter-run steelhead. Approximately 10,000 yearling steelhead were coded-wire tagged and stocked in acclimation pens and a nearly equal number direct planted in the Grand River (tributary to Lake Michigan) in 1990 (J. Clevenger, MDNR, unpublished data). Angler returns of acclimation-penned and direct-planted groups were approximately equal. Studies on the Pacific coast evaluating effects of acclimation penning on survival to adulthood with both winter- and summer-run steelhead are mixed, with one study showing a positive effect (Clarke et al. 2010) and one showing no effect (Kenaston et al. 2001). At most sites, fish released from acclimation pens migrated downstream at faster rates than direct-planted fish but there was no significant difference between groups that were penned and direct-planted with respect to survival to adulthood. The survival advantage for pen-reared steelhead could be attributed to the increased size of smolts released from acclimation pens compared to direct plants (Clarke et al. 2010).

Large yearling steelhead are traditionally stocked by the State of Michigan to produce returns in recreational fisheries, but the benefits of stocking smaller yearling smolts (≤180 mm) have not been well studied. Smaller yearling smolts are available from the State hatchery system and may be a cost-effective alternative to more expensive large smolts (≥210 mm). This project is designed to test the use of acclimation pens for improving the survival of two sizes of stocked steelhead yearlings at both Great Lakes harbor and Great Lakes tributary stocking locations.

Steelhead are more plastic in their food preferences than other salmonines (Roseman et al. 2014). Steelhead rely more heavily on terrestrial invertebrates and Round Gobies *Neogobius melanostomus* than other salmonines, allowing them to capitalize on a stable and abundant food source that other salmonines don't utilize. This trait may allow steelhead to flourish in a system where other salmonines are nutritionally limited.

Anglers and fisheries managers generally have a positive view toward diverse fisheries which should be more resilient and provide more consistent angling opportunities in the face of current and future ecosystem disruptions. By investigating the possibility of expanding steelhead catch rates in the Lake Huron recreational fishery, we hope to provide fisheries managers with options to increase recreational fishing effort and resulting economic activity. Our objectives for this study were to:

1. Compare and describe returns of recreational fisheries of steelhead stocked directly and steelhead stocked after spending time in an acclimation pen.
2. Determine whether steelhead stocked at non-tributary locations contribute to offshore fisheries and spawning-phase fisheries at harbor stocking sites.

METHODS

STUDY SITES

Sites selected for this study included one tributary stocking location (Van Etten Creek, Oscoda, Iosco County), and two harbor stocking locations (Harrisville, Alcona County, and Harbor Beach, Huron County) that were distributed across Michigan's waters of the Lake Huron basin (Table 1, Figure 1). These stocking locations already had existing infrastructure for acclimation and committed local angling groups to assist with monitoring and maintenance. The acclimation site at Harrisville was an existing imprinting pond (Mill Creek, old hatchery-type raceways) which drained directly into the harbor. The direct plant occurred in the Harrisville harbor at the boat ramp. The acclimation site at Van Etten Creek (Oscoda) is a holding pond at a harvest facility that was formerly used for returning Chinook Salmon. The direct plant location at Van Etten Creek (Oscoda) was directly adjacent to and below the pen. The Harbor Beach site included acclimation pens placed at locations where pens were traditionally placed for Chinook Salmon. The direct plant at Harbor Beach was immediately adjacent to the net pen. Since Chinook Salmon were no longer stocked, pens were readily repurposed for yearling steelhead. Acclimation pens at Harbor Beach consisted of floating PVC plastic frames with netting suspended within the frame. Dimensions of the pens were approximately 3.2 m long by 1.8 m wide by 1.5 m deep and four of these pens were utilized at Harbor Beach. Netting mesh size was approximately 1.2 cm and the top of the net could be opened to introduce the fish and a zipper was employed on one side of the net to facilitate release of the fish.

TABLE 1. Number of steelhead stocked by location, size group, treatment (stocking method), and date. All steelhead stocked from 2011–2013 were coded-wire tagged. Small ≤180 mm TL, Large ≥210 mm TL.

Year	Location	Site	Size group	Treatment	Stock-out date	Number stocked
2011	Harrisville	Mill Creek	Small	Acclimation	05/23/2011	14,090
		Harbor	Small	Direct	05/23/2011	14,369
	Oscoda	Van Etten creek	Large	Acclimation	05/25/2011	19,566
		Van Etten creek	Large	Direct	05/25/2011	21,603
	Harbor Beach	Harbor	Small	Acclimation	05/31/2011	14,774
		Harbor	Small	Direct	05/31/2011	15,697
2012	Harrisville	Mill Creek	Large	Acclimation	05/14/2012	14,628
		Harbor	Large	Direct	05/14/2012	13,652
	Oscoda	Van Etten creek	Small	Acclimation	05/16/2012	19,869
		Van Etten creek	Small	Direct	05/16/2012	19,736
	Harbor Beach	Harbor	Small	Acclimation	05/22/2012	14,755
		Harbor	Small	Direct	05/22/2012	15,751
2013	Harrisville	Mill Creek	Small	Acclimation	05/13/2013	14,991
		Harbor	Small	Direct	05/13/2013	12,849
	Oscoda	Van Etten creek	Small	Acclimation	05/15/2013	19,677
		Van Etten creek	Small	Direct	05/15/2013	19,710
	Harbor Beach	Harbor	Large	Acclimation	05/20/2013	14,916
		Harbor	Large	Direct	05/20/2013	13,429

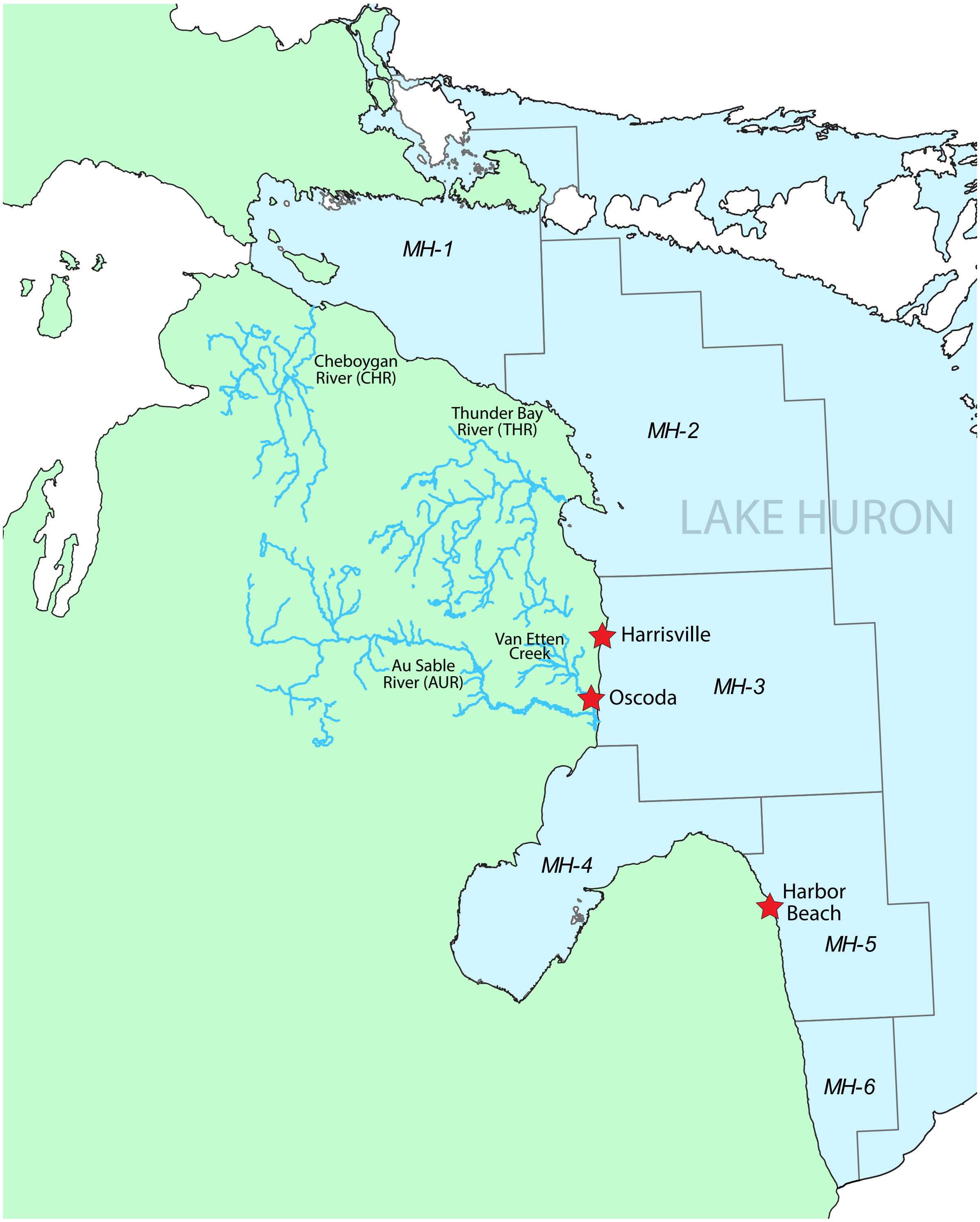

FIGURE 1. Map indicating stocking locations (stars), recovery statistical management unit, and river systems.

MARKING, TAGGING, AND STOCKING OF STUDY FISH

During 2010, a year prior to initiation of marking and tagging efforts, we tested the feasibility of stocking two lots of fish during a pilot project at each of the three locations. One of the lots was placed at an acclimation site and the second was directly stocked into Lake Huron. Cooperating angling clubs (Lincoln Lions Club, Harrisville; Lake Huron Sportfishing, Inc, Au Sable; and the Thumb Area Chapter of the Michigan Steelheaders, Harbor Beach) maintained the acclimation facilities and tested their capacity to hold the desired number of steelhead. As demonstrated by minimal losses of fish, their facilities proved to be adequate for the numbers of fish to be reared. Fish quality assessments conducted according to Goede and Barton (1990) at stock-out revealed the fish to be of good quality and there was no evidence their health had been compromised by the acclimation process.

To minimize the effect of hatchery source on the study results, all fish used were raised at the MDNR Thompson State Fish Hatchery in Manistique, Michigan. The Thompson Hatchery is a groundwater fed, serial reuse hatchery with constant water temperatures (10° C). Fingerling steelhead were adipose fin-clipped in the fall of each year and coded-wire tagged in the spring. Tag groups destined for acclimation pens were transferred to the locations within days of tagging while tag groups to be directly planted were held at the hatchery for two weeks before stocking. During the two weeks when fish were held in acclimation pens, they were fed by volunteers according to procedures provided by MDNR hatchery staff. Steelhead held at the hatchery were fed the same diet at similar rates. After two weeks, the acclimated fish and those held at hatcheries were assessed for condition and quality following procedures outlined in Goede and Barton (1990). Condition and quality assessments considered internal and external parameters and were used as the basis to confirm the acclimated fish were similar in size and health to those that remained at the hatchery prior to release. After approximately two weeks of acclimation, the steelhead were released and the corresponding direct plant group from the hatchery was transferred and stocked at the same site at the same time (Table 1).

SIZE DIFFERENCES

During the 2010 pilot project we observed that steelhead available for Harrisville and Harbor Beach acclimation and direct plants groups were significantly smaller at stocking than those delivered to the Au Sable River. Average length of steelhead when delivered to the acclimation pens was 218 mm at the Au Sable River and 171 mm at Harbor Beach and Harrisville. The percentage of steelhead that were smolting was 88% for the larger groups at the Au Sable River and 63% for the smaller groups at Harbor Beach and Harrisville. While it was desirable to control size at stocking across all sites to reduce significant variability, this proved impossible since hatchery constraints dictated that some steelhead produced each year must be of the smaller size. The MDNR hatchery system was at capacity for producing large smolts for this study and since it required adding two new harbor sites for stocking, we used smaller yearling smolts for some of the sites on a rotating basis such that each site received large steelhead (≥210 mm) one year and small steelhead (≤180 mm) the other two years of the stocking phase of the study (Table 1). Size of fish was held constant for both acclimated fish and direct plants within the sites. During the three-year stocking phase of the study each site received large fish for both the acclimation and direct plant groups one of the years and small fish for both treatments the other two years. Additional large steelhead were fin-clipped, coded-wire tagged, and direct-planted in the Au Sable River at a different location for a separate study in 2012–2013. These fish were stocked at a location upstream and a month earlier than the acclimation and direct planted fish. Return rates of Au Sable River (Rea Road) fish are reported, but these fish were not included in the analysis comparing acclimation practices versus direct stocking. A direct comparison of the effect of size on return rates was not possible because small and large fish were never stocked at the same port in the same year.

RECOVERIES OF TAGGED FISH

Adipose fin-clipped steelhead with coded-wire tags were recovered throughout the Great Lakes by MDNR Statewide Angler Survey Program creel clerks during the April–October open water fishing season, by U.S. Fish and Wildlife Service (USFWS) Great Lakes Mass Marking Program field technicians who searched for fish with missing adipose fins captured in the recreational fishery and during fishing tournaments, and by anglers who voluntarily provided snouts from adipose fin-clipped fish. In the winters of 2012–2013 and 2013–2014, the MDNR conducted a winter creel census on inland reaches of the Au Sable River in Oscoda County from Lake Huron to Foote Dam to assess fishing effort and catch from October–April each year. Steelhead snouts containing coded-wire tags were processed by MDNR Fisheries Division staff at the Charlevoix Fisheries Research Station and by USFWS staff at the Great Lakes Mass Marking Lab in Green Bay, Wisconsin. Returns of adipose fin-clipped steelhead were monitored from April 2011 through the end of the open water fishery season in 2016. Basin specific returns were, perhaps unsurprisingly, higher for the Lake Huron Basin where Great Lakes waters and tributaries represented 95% of all the returns. Only 4% of recoveries occurred in Lake Michigan, 1% in Lake Erie and 0% were returned in the Lake Superior basin.

DATA SUMMARY AND STATISTICAL ANALYSIS

Coded-wire tag returns from all sources were compiled by staff at the Charlevoix Fisheries Research Station from 2011 until the end of the fishing season in 2016. Return rates of acclimated and direct planted groups were adjusted for the number of fish released and represented as returns per 10,000 fish stocked (± 1 SE). Comparison of return rates between acclimated and direct planted cohorts were made using three-way ANOVA statistical methods where independent factors were year-class, stocking site, and treatment (acclimated and direct plant). Statistical analyses were performed in R version 3.5.1 using the "lme4" package (R Core Team 2017).

RESULTS

A total of 403 out of 295,653 marked steelhead stocked from 2011–2013 were recovered by MDNR creel clerks, USFWS field technicians, and volunteer anglers. The majority of fish recovered in this investigation were two, three, and four years old (23%, 33%, and 29%, respectively). Only 2% of steelhead were harvested in the same year they were stocked and less than 12% of fish returned as five- and six-year-olds. Totals include the acclimated and direct planted groups at Harrisville, Van Etten Creek (Oscoda), and Harbor Beach. The number of fish remaining at-large at the end of the study was assumed to be very small given low returns of five- and six- year-old fish. The total number of angling returns was highest for fish stocked at the Van Etten Creek (Oscoda; 198 fish) sites, followed by Harbor Beach (154 fish), and Harrisville (51 fish). Most angler-caught fish were returned from the 2011 stocking year (191 fish), followed by the 2012 (144 fish), and 2013 stocking years (68 fish).

We found no evidence for differential returns between direct-plant and acclimated fish (ANOVA: $F=1.14$; $df=1, 6$; $P=0.33$). Across all sites, adjusted return rates averaged 32 fish/10,000 fish stocked (SE=6) for direct-plant steelhead and 27 fish/10,000 fish stocked (SE=7) for acclimated fish. Point estimates of average adjusted return rates of direct-planted groups released at Van Etten Creek (Oscoda) and Harrisville were greater than for acclimated fish, while at Harbor Beach the opposite was true; yet none were statistically significant (Table 2). There were significant interactive effects with stocking location (ANOVA: F=1.38; df=2, 6; P=0.32) and stocking year (ANOVA: F=0.62; df=2, 6; P=0.46). The stocking site and year influenced return rates (ANOVA: F=5.48; df=2, 6; P=0.04) when acclimation vs. direct plant comparisons were absent. Harrisville had substantially lower returns than Van Etten Creek (Oscoda) and Harbor Beach and the 2013 year-class returned at substantially lower rates than 2011 and 2012.

TABLE 2. Annual returns per 10,000 fish stocked of acclimation pen and direct planted steelhead among stocking years 2011-2013. Total represents the average return per 10,000 fish stocked ± 1 SE. All comparisons among direct plant and acclimation site fish were non-significant.

	Oscoda		Harrisville		Harbor Beach	
Stocking year	Direct	Acclimation	Direct	Acclimation	Direct	Acclimation
2011	64	59	25	11	25	60
2012	52	28	31	14	41	32
2013	12	9	1	1	40	32
Total	42 ± 16	32 ± 14	19 ± 9	8 ± 4	32 ± 5	44 ± 8

Harrisville and Harbor Beach sites were new stocking sites initiated for this study, so it was not possible to compare steelhead catch and effort from the recreational fishery prior to initiation of the study. Angler returns at the tributary and harbors that were the focus of this investigation were skewed toward fish that had been stocked locally. For the ports of Harrisville, Oscoda, and Harbor Beach, 88%, 77%, and 75% of the measured returns were from lots stocked at or near the port, respectively (Figure 2). Most of the study fish caught at the ports where they were stocked were harvested during May and June. In those two months, Harbor Beach (153 fish) had substantially greater returns than Harrisville (24 fish) and Oscoda (nine fish). Annual creel census estimates of effort and harvest of steelhead were highest from the Au Sable River in the years creel was conducted there, followed by the ports of Oscoda, Harbor Beach, and Harrisville (Figures 3A and 3B). Similarly, total catch per unit effort (CPUE), which includes both harvested and released steelhead, was substantially higher in the Au Sable River in the two winters when creel census was performed than it was for any other study port; Harbor Beach ranked second in CPUE for steelhead followed by Oscoda and Harrisville (Figure 3C). Across the entire main basin of Lake Huron, the greatest numbers of study fish returned were from the Au Sable River fishery and southern statistical management units MH-5 and MH-6 (Figure 4).

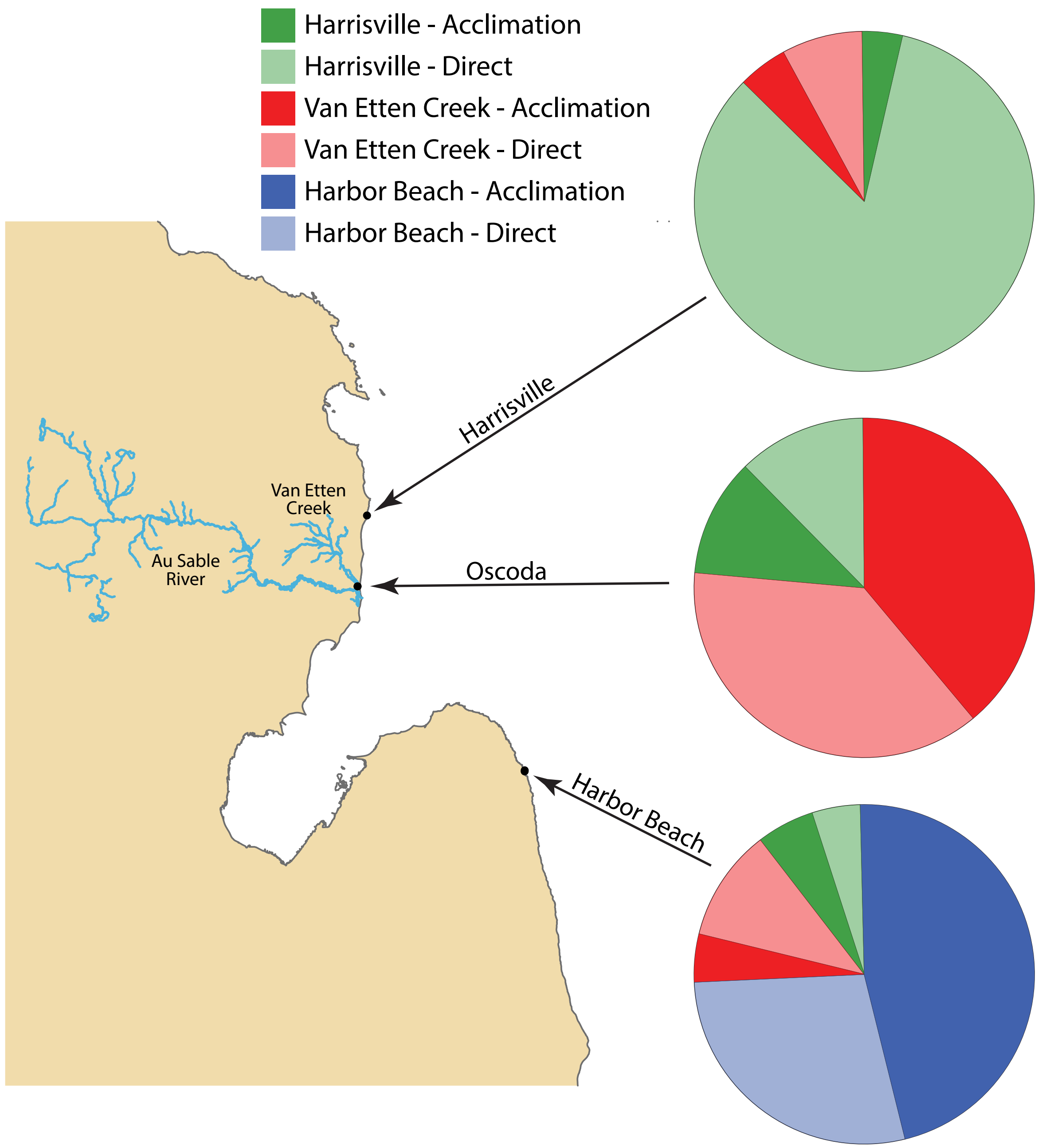

FIGURE 2. Proportions of marked study fish returned from acclimation pens and direct-plant stocking to three creel ports (Harrisville, Oscoda, and Harbor Beach). Returns are summarized by stocking location. Numbers returned were standardized per 10,000 fish stocked prior to allocating as proportions.

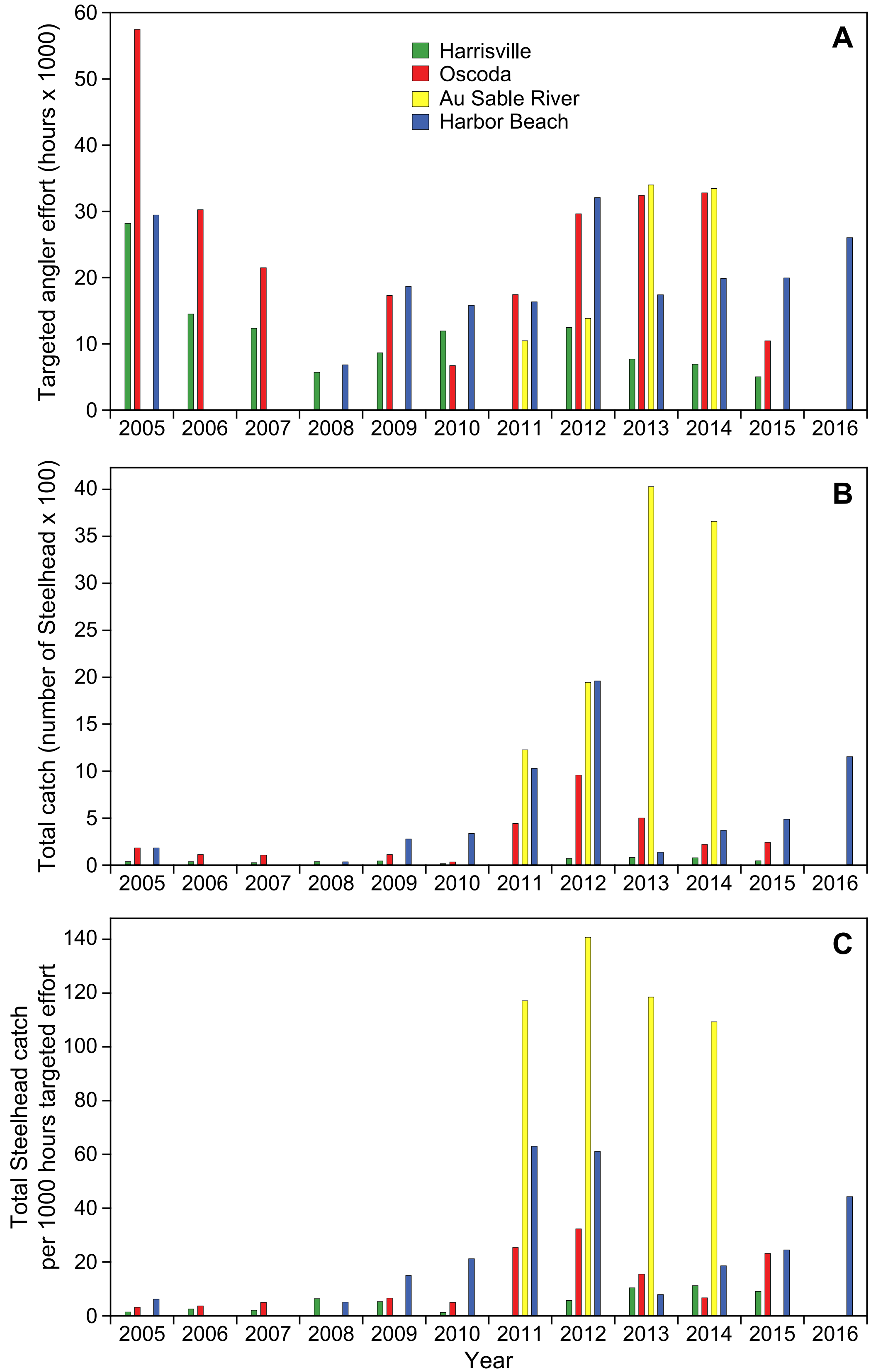

FIGURE 3. Targeted steelhead fishing effort in hours (A.), total catch (harvest and release) of steelhead (B.), and total catch of steelhead per 1,000 hours of targeted angler effort (C.) for each study port from 2005–2016.

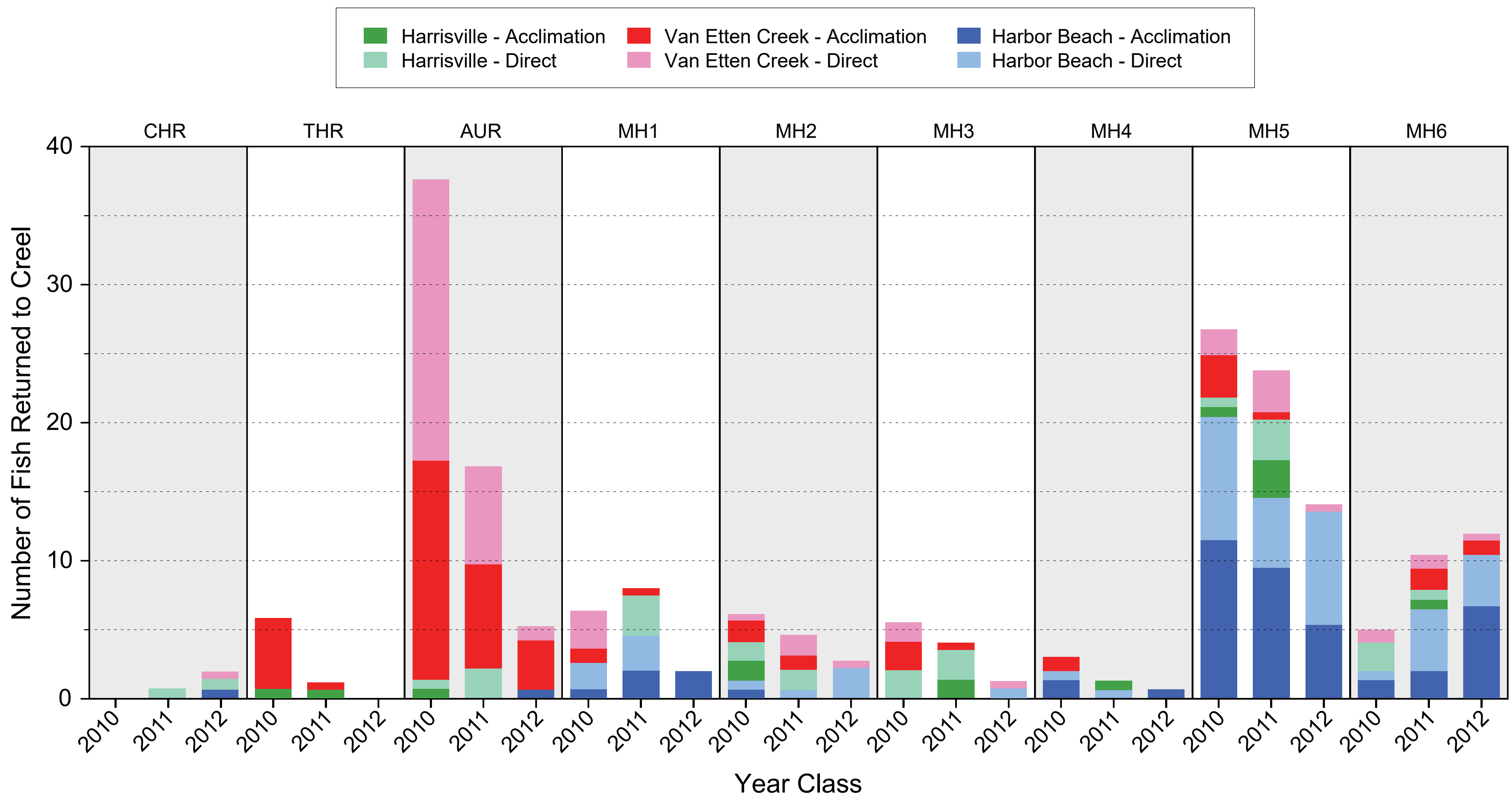

FIGURE 4. Numbers of marked study fish recovered based on stocking location and year-class. Returns are reported from recreational fisheries in specific statistical management units (MH1, MH2, MH3, MH4, MH5, and MH6; Figure 1), the Au Sable River (AUR), Cheboygan River (CHR), and Thunder Bay River (THR). Numbers are standardized per 10,000 fish stocked. VEC= Oscoda, VEC-AS= Oscoda Acclimation site, HAR= Harrisville, HAR-AS= Harrisville Acclimation site, HB= Harbr Beach, HB-AS= Harbor Beach Acclimation site.

DISCUSSION

In this study, acclimation did not provide a benefit to survival of steelhead in the same way it did for Chinook Salmon. Acclimation penning likely benefited Chinook by allowing time for smaller fingerlings to acclimate to their surroundings and grow in size prior to release in the wild (Johnson et al. 2007). There are several reasons why steelhead yearlings might not benefit from acclimation pens when compared to Chinook Salmon. The differences in the size of the fish at stocking and the unique out-migration behaviors of the two species distinguish them; steelhead are typically stocked as yearlings (target stocking length of 198 mm) which are substantially larger than Chinook spring fingerlings (target stocking length of 82 mm). The larger size of steelhead should translate into stronger swimming and predator avoidance skills. There is less alternative prey available to meet predator demand because of the collapse of Alewife populations in Lake Huron (Riley et al. 2008). Additionally, newly recovering populations of Walleye and Lake Trout have led to predation rates in the main basin of Lake Huron exceeding those of the pre-Alewife-collapse period (He et al. 2015). As such, concerns regarding predation pressure on stocked salmonines remain. For example, Walleye are an important predator of stocked salmonines in Lake Huron (Johnson et al. 2007) and are abundant in most nearshore waters of Lake Huron in the spring; while any adult Walleye is capable of preying on fingerling Chinook, typically a Walleye would need to be larger than 710 mm to be capable of preying on a 198 mm steelhead smolt (Porath and Peters 1997). A very small proportion of the Lake Huron Walleye population is this size or greater (Fielder and Thomas 2014). Further, and in contrast to young Chinook Salmon, which remain in nearshore zones for longer periods of time, steelhead leave nearshore areas shortly after exiting streams and head for open water in the Great Lakes where predation pressures from the Walleye population are presumably lower. Additionally, handling stress in stocked yearling steelhead appears to be lower than in spring fingerling Chinook Salmon, as evidenced by the very low mortality observed during handling and transport in this study and Keneston et al. (2001).

The recreational fishery for steelhead in open waters of the lake is characterized by high temporal (both seasonal and annual) and spatial variability. Annual variations in effort and therefore harvest, are probably highly influenced by weather, associated species distributions, and angler preferences. The fishery for steelhead in the Au Sable River is quite large compared to the open water fisheries. Winter creel census performed on the lower river in fall and winter of 2012–13 and 2013–14 documented a significant fishery for steelhead. In these two fall/winter periods the estimated harvest and effort for steelhead on the Au Sable River was ranked higher than any other Lake Huron port with catch and targeted effort for steelhead in those two years averaging 45,892 hours and 5,430 steelhead caught (MDNR unpublished data). These data support the management paradigm that the highest value for a steelhead fishery is of those in tributary streams while the open water fishery is generally of secondary value (MDNR 2004).

While not designed to address optimal sizes for stocking, results of this study confirm the appropriateness of existing guidelines in Michigan. The current Fish Stocking Guidelines (MDNR 2004) for Michigan steelhead dictate steelhead smolts should be between 5–7 fish/pound (190–210 mm in length). The large and small fish in this study survived at similar rates hinting that fish larger than 200 mm may not survive any better. The extra cost to produce larger fish in hatcheries or risk associated with acclimation pens in this case is not merited. As the Lake Trout population grows and the biomass of older Lake Trout large enough to consume 200–300 mm prey increases, there may be a need to revisit size criteria in the future (Johnson et al. 2015, 2017).

Reasons for low return rates of the small cohorts stocked in Harrisville and Van Etten Creek in 2013 are not clear. Seelbach (1985) found substantially better returns of spring yearling relative to fall fingerling steelhead therefore, it is possible there would be a stronger effect for smaller steelhead than used in this investigation. In New York, where stocked steelhead were 30–60% smaller than those used in our investigation, the Department of Environmental Conservation continues to utilize acclimation pens because of a perceived positive effect on survival as fish grew significantly while in the pens. For example, yearlings released from eight New York pens after 23 days had, on average, doubled in weight (Sanderson et al. 2016). However, New York did not use controls to compare for the effect of penning (Sanderson et al. 2008).

Creel census results in conjunction with returns of tagged fish show that fish stocked in harbors and tributaries survive and contribute to fisheries lake-wide. However, the extent that they contribute locally may be more related to angler access and angler knowledge of their presence than their absolute numbers. Clearly the best return on investment for stocked steelhead occurs at stocked tributaries or ports where angler access is high and fishing regulations and seasons are liberal.

The greatest return of steelhead was observed in the Au Sable River, a system which has sustained a robust fishery for steelhead for many years and is thought to be maintained in large part by stocked fish. Suitable spawning habitat is found only in the Pine River, a tributary to Van Etten Creek which is known to be a minor source of reproduction. Winter creel in the Au Sable River during the two six-month periods from October–March in 2012–2013 and 2013–2014 documented a steelhead fishery producing catch rates two, four, and 20 times the open water catch rates at Harbor Beach, Oscoda, and Harrisville, respectively. Anglers have generous access to the fishery in the Au Sable River due to various boat and shore access points on public lands, the long season the fish are in the river, and liberal regulations that allows fishing year-round. The large stocking effort and ample public access have made the river a premier steelhead fishing destination.

While creel clerks may have missed some effort and harvest in the vicinity of Harrisville and Harbor Beach harbors from October through April, it is unlikely that harvest was considerable. Creel census clerks working Great Lake ports typically start working in early April and surveys end in October. Most marked steelhead returned from this study were harvested in late May and June. Steelhead catch per angler hour at the port of Harbor Beach was double that of Oscoda and nearly 10 times higher than Harrisville. Public access to pier or shore fishing opportunities may be an impediment at Harrisville. However, boat access is available during the open-water season and fish could presumably be caught from small boats if anglers targeted them.

Relative to other anadromous salmonines, Steelhead exhibit greater plasticity and resilience when adapting to environmental change. This is shown in dietary observations where Steelhead readily switch to invasive Alewives, Rainbow Smelt *Osmerus mordax*, or Round Goby when they're available (Diana 1990) and return to native fish species, invertebrates, and terrestrial insects (Roseman et al. 2014) when they are not. Steelhead rely heavily on Round Gobies in the summer months in Lake Huron and might utilize this prey resource at other times of the year as well. Little is known about steelhead diets in the open lake during the winter months. Based on growth rates, there is little evidence of nutritional limitation or stress for steelhead in Lake Huron (Johnson and Gonder 2014).

The number of steelhead available to fisheries may be enhanced by increasing stocking rates. Results of an expanded stocking program should be monitored and an adaptive approach used to adjust numbers based on indices of survival and return rates. The MDNR Fisheries Division has secured funding to allow expansion and upgrades to Thompson State Fish Hatchery and the Little Manistee River Weir egg take facility. Hatchery upgrades will ensure that steelhead of sufficient quality and numbers would be available to meet management requests. Upgrades at the Little Manistee weir help to ensure the state's sole steelhead gamete collection facility can operate to support a quality steelhead propagation program.

CONCLUSIONS

1. Acclimation does not provide a survival advantage for steelhead of the size used in this study.
2. Both small and large steelhead of the size used in this study had equal survival.
3. Stocking steelhead in tributaries with ample public access and liberal fishing seasons can provide significant fishery benefits.
4. Stocking rates of yearling steelhead in Lake Huron may be increased to take advantage of alternate prey availability provided it is conducted in an adaptive management context.

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