New York State
Department of Environmental Conservation
Division of Fish and Wildlife

EVALUATION OF STEELHEAD STOCKING SIZE AND LOCATION ON EMIGRATION AND ADULT RETURNS IN CHAUTAUQUA CREEK, NY

Bureau of Fisheries
November 2019

DATA COLLECTIONS THAT MADE THIS WORK POSSIBLE WERE SUPPORTED BY THE FEDERAL AID IN SPORT FISH RESTORATION PROGRAM

Report Citation:

Markham, J.L., and J.M. Robinson. 2019. Evaluation of steelhead stocking size and location on emigration and adult returns in Chautauqua Creek, NY. New York State Department of Environmental Conservation, Albany, New York, USA.

Evaluation of Steelhead Stocking Size and Location on Emigration and Adult Returns in Chautauqua Creek, NY

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Acknowledgments

We would like to thank the many dedicated NYSDEC employees who were integral in collecting the data used in this study. This study would not have been possible without all the work and cooperation from the entire staff at the Salmon River Hatchery. Mike Connerton and Chris Balk were integral in running the tagging trailer. Don Einhouse, Steve LaPan, and Steve Hurst provided invaluable guidance and editorial review for this investigation. Funding for this study was largely supported by Federal Aid in Sportfish Restoration.

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Executive Summary

New York's Lake Erie tributaries have long supported important steelhead (*Oncorhynchus mykiss*) sport fisheries, attracting anglers from across the country and generating substantial economic benefits to the Western New York area. Targeted tributary steelhead effort generally exceeds 130,000 angler-hours/year and is second only to the in-lake walleye fishery. The goal of New York's Lake Erie steelhead management program is to maintain a high-quality fishery that provides diverse angling experiences and broad angler satisfaction. An effective stocking program resulting in steelhead returning to the streams in which they were stocked is an essential part of maintaining this high-quality fishery. This requires sufficient numbers of stocked fish to survive, imprint, and return to these streams as adults. Recent research has illustrated New York's dependence on "stray" steelhead from other jurisdictions, making New York fisheries vulnerable to management decisions outside of our control. The goal of this study is to identify strategies that will maximize the return of steelhead stocked in NY waters, resulting in improved fishery performance and resiliency. Our objective was to develop a better understanding of how size-at-stocking and stocking location interact to influence emigration and adult returns. In this study we take an experimental approach, stocking two different uniquely tagged size groups (large: ~140 mm (5.5 inches), small: ~100 mm (4.0 inches)) of yearling steelhead at two stream locations (upper site: 4 miles upstream; lower site: near the stream mouth), then monitoring in-stream juvenile emigration and adult returns for each group.

This study revealed that most of the stocked yearling steelhead >150 mm (5.9 inches) had emigrated from the stream by the end of May, but that many of the smaller yearling steelhead remained in the stream with some migrating upstream. Steelhead that remained in the stream appeared to lose body condition over time and likely experienced high mortality. Marked steelhead from this study only comprised ~15% of the overall sample of returning adults with the highest returns from the experimental group of large fish stocked upstream—over four times the rate of smaller fish stocked upstream. Because New York's Lake Erie stocked steelhead typically average less than 150 mm (usually 127 mm or 5.0 inches), we conclude that many of the yearling steelhead stocked by New York are too small to imprint, instead remaining stream residents where they experience poor survival and ultimately make minimal contributions to the adult steelhead fishery.

To improve the adult return rate of New York's stocked steelhead and improve fishery performance, we recommend the following management actions while acknowledging the current challenges associated with raising steelhead in the New York hatchery system:

Management Recommendations:

1. Explore measures to increase the size of our stocked steelhead to a minimum of 150 mm through hatchery experimentation (e.g. rearing density reduction, grading, diet) and infrastructure improvements.
2. Continue the practice of stocking steelhead well upstream of the lake confluence to facilitate imprinting.
3. Provided steelhead >150 mm are available, stock these fish beginning in late March or early April to allow fish more time to acclimate, imprint, and emigrate prior to May temperature increases.

Background

Rainbow trout and/or steelhead (*Oncorhynchus mykiss* - steelhead hereafter) have long supported important sport fisheries in Lake Erie, especially in the tributaries of Ohio, Pennsylvania, and New York. Over 180,000 angler-hours were spent in New York tributaries during the 2011-12 steelhead season (Markham 2012). The tributary fishery has a large economic impact to the Western New York area; anglers pursuing tributary steelhead in 2007-08 spent an estimated $3.2 million within the three local counties (Reinelt et al. 2013). While most anglers are New York residents (~88%), the fishery attracts many out of state anglers from across the country (Markham 2019). Fishing quality over the past 15 years has generally been very good and angler satisfaction remains high (Markham 2019).

Steelhead have been stocked in the Lake Erie system since the late 1800s, mainly to support recreational fisheries (Crawford 2001). Populations became established in the tributaries during the early decades of the 1900s (MacCrimmon 1977), then declined in the 1940s and 1950s due to lack of stocking, sea lamprey (*Petromyzon marinus*) predation, and water quality degradation (Berst and Wainio 1967; Kustich and Kustich 1999). Populations rebounded in the 1970s, mainly due to a renewed stocking effort beginning in 1975 (Crawford 2001). By 1989, 1.1 million yearling steelhead were being stocked lakewide annually (Coldwater Task Group 2019). The 1990s brought significant ecosystem changes to Lake Erie primarily due to the invasion of the zebra mussel (*Dreissena polymorpha*). Steelhead fisheries continued to thrive during this time while Pacific salmon fisheries declined. Eventually Pacific salmon stocking was collectively phased out and stocking programs by Lake Erie fisheries management agencies were redirected to steelhead. By the early 1990s, annual steelhead stocking had increased to over 1.7 million yearlings and now range from 1.75 to 2.0 million yearlings annually (Coldwater Task Group 2019).

In the New York waters of Lake Erie, steelhead stocking was intermittent until the mid-1980s with most salmonid stocking directed at domestic rainbow trout and brown trout (*Salmo trutta*) along with Chinook *(Oncorhynchus tshawytscha)* and coho *(Oncorhynchus kisutch)* salmon. However, in 1985 steelhead stocking increased to 100,000 yearlings upon completion of the New York State Department of Environmental Conservation's (Department) Salmon River Fish Hatchery and continued to increase to 214,000 fish by 1993 as Chinook and coho salmon stockings were phased out. The current steelhead stocking target is 255,000 Washington strain yearlings which are distributed among eight tributaries (Markham et al. 2016).

In addition to stocking, the steelhead population is augmented by natural reproduction in some high-quality tributaries (Markham 2007, Roth 2002). Studies of Cattaraugus Creek by Mikol (1976) and Goehle (1998) using scale analysis concluded that approximately 22% and 25%, respectively, of the spring spawning steelhead were naturally produced in that system. More recent investigations using otolith microchemistry indicate that 12-17% of the steelhead runs in both Cattaraugus Creek and Chautauqua Creek were naturally produced (Budnik et al. 2018). Although these studies found modest contributions of wild fish in some of Lake Erie's highest quality tributaries, it is important to note that wild steelhead do not comprise a significant portion of the overall lake wide population. Therefore, a robust stocking effort remains essential for maintaining our tributary steelhead fishery.

Rationale

The goal of New York's Lake Erie steelhead management program is to maintain a high-quality fishery that provides diverse angling experiences and broad angler satisfaction (Markham et al. 2016). An effective stocking program is an essential part of maintaining this high-quality fishery with the goal of producing steelhead fisheries in the streams where fish are stocked. This requires sufficient numbers of stocked fish to survive, imprint, and return as adults in subsequent years. The long-standing stocking strategy for New York's Lake Erie tributaries has been to stock steelhead as far upstream in the watershed as practical. This stocking strategy is based on the theory that survival and imprinting (i.e. homing) of stocked yearling steelhead that average around 125 mm (5.0 inches) is improved in upstream areas (Floyd Cornelius: retired Lake Erie Biologist, personal communication).

Smolting is a physiological process whereby migratory trout and salmon imprint on the tributaries they inhabit, emigrate downstream to the ocean (or in this instance Lake Erie), then return to spawn in their "natal" tributary (McCormick et al. 1998). Smolting is related to fish size, and many studies (Bjornn et al. 1979; Budnik and Miner 2017, Chrisp and Bjornn 1978, Peven et al. 1994, Quinn 2005, Seelbach 1987, Wagner et al. 1963; Wallis 1968) indicate that steelhead should be at least 150 mm (5.9 inches) at stocking to maximize post-stocking survival. Ideally, steelhead should be stocked as smolts that are physiologically ready to imprint, then quickly emigrate from the river (Wagner 1968).

For decades, it was assumed that the most adult steelhead in New York's Lake Erie tributaries were of New York hatchery origin. In 2009, 2010, and 2015 Budnik et al. (2018), using otolith chemistry, found that the proportional contribution of stray adult steelhead in New York's tributaries (Cattaraugus and Chautauqua Creeks) was higher (72-88%) than in other Lake Erie jurisdictions (18-57%). The stray adult steelhead in the New York tributaries were overwhelmingly of Pennsylvania and Ohio hatchery origin. These results indicate that the success of the New York steelhead fishery is mainly due to stocking by other jurisdictions, rather than New York's stocking efforts.

To understand why the New York stocked steelhead were having a disproportionately low contribution to New York streams, we conducted pilot studies in 2013 and 2014 to examine in-stream post-stocking emigration by juvenile steelhead and to assess whether newly stocked steelhead were detectable in predator diets. This study indicated that: 1) a portion of the stocked steelhead failed to emigrate from the stream to the lake, and 2) we could not detect nearshore predation by walleye or smallmouth bass on stocked steelhead smolts (Markham 2014; Markham 2015). In response to these studies and those of other investigators, we hypothesized that the limited observed contribution by New York stocked steelhead was attributable to poor post-stocking survival at smaller sizes (126 mm (5.0 inches) relative to other Lake Erie jurisdictions (~190 mm (7.5 inches); Coldwater Task Group 2019).

The goal of this study is to identify strategies that will maximize the return of steelhead stocked in New York's Lake Erie tributaries, resulting in improved performance and resiliency of this important fishery. We take an experimental approach, stocking two different size groups of uniquely tagged yearling steelhead at two different stream locations, then monitor the in-stream migration and adult returns for each group. Finally, we discuss management implications and recommendations based on the study results.

The specific objectives of this study were to:

1. Determine the instream emigration patterns of steelhead stocked at different locations and sizes.
2. Identify the combination of steelhead stocking size and stocking location that will result in the highest adult returns.
3. Develop science-based guidance for steelhead management in New York's Lake Erie tributaries.

Methods

Study Site

Chautauqua Creek is the westernmost of New York's stocked Lake Erie tributaries, located approximately 14 miles west of Dunkirk and 9 miles east of the PA/NY state line. The creek is approximately 17 miles long, starting near the town of Sherman, NY and flowing north through the village of Westfield before emptying into Lake Erie at Barcelona. It is a medium gradient stream with gravel and bedrock, draining approximately 36 miles of agricultural land and forested hills. There are also several tributaries entering the creek that add additional stream mileage. A dam with fish passage is located about five miles upstream of the mouth. In the study area, the creek averages approximately 40 feet in width, but experiences seasonal variability due to torrential spring flows during snow melt to almost non-existent flows during the dry summer months. Chautauqua Creek was chosen for this study because of its convenience for sampling in terms of location and size, and because it is considered one of New York's higher quality tributary fisheries on Lake Erie (Markham 2019). This stream is annually stocked with 40,000 yearling steelhead about four miles upstream from the mouth. It also supports detectable levels of naturally produced steelhead (Markham 2011; Budnik et al. 2018).

Study Fish

Washington strain steelhead used for this study were raised at the Salmon River Fish Hatchery (SRFH) located in Altmar, NY. For the 2015 stocking, fish were sorted into two size groups using an AutoFish marking system during February 2015. Steelhead <115 mm (4.5 in) were considered "small" and fish >120 mm (4.7 in) were considered "large". For the 2016 stocking, fish were similarly sorted during November 2015 with steelhead <100 mm (3.9 in) considered "small" and fish >105 mm (4.1 in) considered "large". The difference in the bounds for the small and large groups between years was necessary to achieve the desired sample sizes given what the hatchery had available for marking. A 5.0 mm gap between these size ranges was left to minimize overlap between the two size groups. Two groups of each size range of fish were tagged with unique marks for a total of four distinct lots of fish. Small groups were either adipose clipped (AD) or coded-wire tagged (CWT) while larger groups were either AD+CWT or left ventral (LV) clipped. Target numbers for each lot were 15,000 fish. After tagging, marked lots were combined into two raceways according to stocking location; the LV (large) and CWT (small) marked lots were combined into one raceway for stocking at a new location within 0.5 miles of the stream mouth, and the AD+CWT (large) and AD (small) marked lots were combined for stocking in the traditional stocking location approximately four miles upstream of the mouth. Clip and tag retention evaluation, along with length and weight sampling were performed at the SRFH a week prior to stocking. Correction factors to account for tag loss in each group were applied to determine the number of each group stocked.

Out-Migration Sampling

Three primary electrofishing sites (Upper site just downstream of the traditional stocking location, Lower site near the creek mouth, and a Middle site) were used to monitor emigration of stocked steelhead (Figure 1). The Lower site was moved slightly upstream in 2016 in response to a significant change in stream channel flow patterns from the original site sampled during 2015. All primary sites were sampled once a week from stocking through the end of May using a Smith-Root Model 15-D gasoline powered backpack electrofishing unit. Additional sampling of primary sites occurred thereafter through the end of July depending on availability of personnel and weather conditions.

During each sampling event, two passes were conducted to obtain a depletion-based population estimate. If the number of fish caught on the second pass was not less than the number of fish sampled on the first pass, a third pass was completed to achieve a depletion. Blocker seines were not used

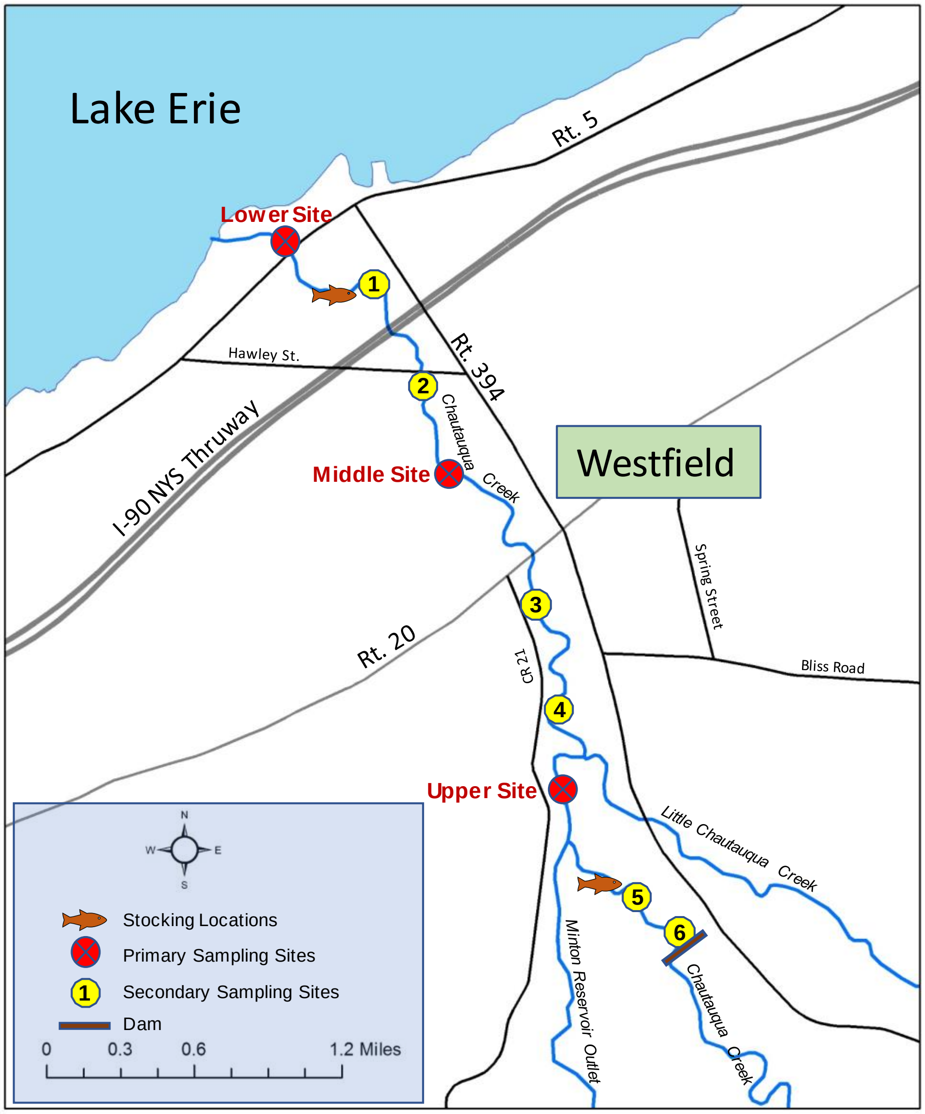

FIGURE 1. Stocking and sampling sites in Chautauqua Creek (Chautauqua County, NY). Fish symbols indicate the lower and upper stocking locations. Red circles refer to three primary juvenile steelhead sampling sites (Lower, Middle, and Upper Sites); yellow numbered circles (1-6) represent secondary sites. Sampling sites were used for stocked steelhead emigration assessment in 2015 and 2016.

due to stream size and flow characteristics. Instead, pool heads or riffles were used as upper barriers at all sites to minimize upstream migration of fish out of the sampling area. Steelhead trout were the only species collected. All juvenile steelhead were placed into buckets and transferred to in-stream flow-through holding containers for examination. Trout from each run were counted, measured (mm TL), weighed (g), and checked for clips and/or CWT's. All fish were released alive upon completion of data collection. Other data collected at each site included water and air temperature, stream clarity, flow conditions, time of sampling, and conductivity. Population estimates for two-pass sampling were calculated following the methods in Seber and Le Cren (1967).

Fulton's *K* coefficient of condition was calculated as:

$$K = \frac{W}{L^3} X$$

where W = weight (g), L = length (mm), and X is a scaling constant (10^5 used here to convert small decimals to a mixed number that is more easily comprehended, Nielsen and Johnson 1983). One-way analysis of variance (ANOVA) and post-hoc comparisons via Duncan multiple range test were used to examine if differences in body condition over time. All stocking groups, regardless of stocking location and size, were combined for this analysis.

To determine the complete extent of stocked steelhead movement throughout the stream, six secondary sites were sampled in addition to the three primary sites near the end of May and June in 2015, and in May, June, and July in 2016. Two of these sites were equally spaced between the Lower and Middle sampling sites, two between the Middle and Upper sites, one between the Upper site and the dam, and the uppermost site just below the dam (Figure 1: Sites 1-6). A single electrofishing pass was completed at the secondary locations. Population estimates at these locations were determined using the average catchability coefficient (0.585) determined from the primary sampling sites (Seber and LeCren 1967).

Adult Returns

Adult steelhead were sampled via electrofishing during the 2015/16, 2016/17, and 2017/18 fishing seasons (fall through spring). Adult steelhead were sampled opportunistically depending on their availability, location in the stream, and sampling conditions. Sampling dates were spread out over each fishing season to account for possible variations in timing of specific runs of fish. Most of the adult sampling (and collections) occurred in the upper portion of the sampling area just upstream of the Upper site at an intermittent barrier; smaller collections were also made in the lower and middle portions of the stream. Adults were held in 170 liter tubs and anesthetized using Aqui-S® prior to examination. Each adult steelhead was measured (mm TL), weighed (g), and examined for clips and/or CWT's. The presence of visible hook marks and sea lamprey wounds was also noted. To avoid resampling bias, the upper tip of the caudal fin was clipped prior to release to ensure that recaptured fish were not counted during subsequent sampling events.

Cohorts of adult steelhead from stocking that occurred both before and after this study were present in the creek. To avoid including these fish in adult return analyses we developed length-based criteria to assign each fish to an age category/stocking event (Table 1). These ranges were determined using length frequency at age based on an interagency steelhead diet study conducted in 2004 in Lake Erie (Kayle 2007). Sampled steelhead outside of these size ranges were considered to be stocked outside of this study period and were excluded from analysis. Sampling detection metrics for adult steelhead were scaled to the number of detections per 10,000 fish stocked to compare adult returns of each marked group. This was calculated by dividing the number of sampled fish per marked group by the corrected number of fish stocked per marked group, multiplied by 10,000.

TABLE 1. Length-based criteria used to determine the upper and lower size ranges (mm) of adult steelhead by sampling year in Chautauqua Creek, NY.

Sampling Year	Study Ages	Size Range (mm)
2015/16	2	250 - 475
2016/17	2, 3	250 - 675
2017/18	3, 4	475 - 725

Results

Stocking Size and Mark Retention

On April 13th, 2015, four days prior to stocking, a sample ranging from 454 to 500 fish from each marked lot were measured, weighed, and evaluated for clip and/or tag retention (Table 2). Growth of size groups was similar between both raceways with large size groups averaging 139 mm (5.5 in) and small size groups averaging 103 and 105 mm (4.1 in). Overlap in the length distribution between the small groups and the large groups was minimal (Figure 2). Mean weights were also similar between raceways with the large size group averaging 27.0 and 27.7 g and the small groups averaging 11.6 and 12.3 g. Non-clipping error was very low (0.8–1.1%) for the LV and AD groups; tag loss was higher in the CWT group (11.4%) (Table 2). Mark retention was not determined in the AD+CWT group because these fish resided in the same raceway as the AD fish, making AD+CWT fish that lost a CWT appear to be part of the AD group.

On April 7th, 2016, two weeks prior to stocking, 400 fish from each unique lot were measured, weighed, and evaluated for clip and/or tag retention (Table 2). Growth of each group was similar in both raceways with large size groups averaging 141 and 144 mm (5.5 and 5.6 in) and small size groups averaging 99 and 102 mm (3.9 and 4.0 in). Greater overlap in the length distributions between the small and large groups was evident in 2016 and was mainly attributable to relatively higher growth by a portion of fish in the small size group that grew into the larger size groups length range at the time of stocking (Figure 2). Mean weights were also similar between raceways with the large size group averaging 25.1 and 27.0 g and the small groups averaging 10.0 and 11.4 g. Similar to 2015, non-clipping error was low (1.0–2.2%) for the LV and AD groups; tag loss was higher in the CWT group (11.2%) (Table 2). As in 2015, mark retention was not determined for the AD+CWT group.

Stocking

Stocking in 2015 occurred on April 17th with the LV and CWT groups stocked near the stream mouth and the AD+CWT and AD groups stocked in the traditional location upstream (Figure 1). The actual stocking numbers were corrected for tag loss (Table 3). To account for the unknown mark retention error in the AD+CWT group, we applied a correction factor equal to the tag loss rate (11.4%) for the CWT group and transferred these fish (13,386*0.114 = 1,526) into the corrected number stocked in the AD group. Steelhead that were not AD clipped from the AD+CWT group (i.e. only had CWT) were negligible, and therefore no further corrections were applied.

Stocking in 2016 occurred on April 22nd with the same groups stocked in the same locations as 2015 (Table 3). Adjustments for tag loss, including the adjustment for CWT tag loss rate (11.2%) in the AD+CWT group, were made just as in 2015 (Table 3).

Water Temperature

Water temperatures at the time of sampling ranged between 43 and 82^{o}F in 2015 (Figure 3). Water temperatures reached 70^{o}F near the end of June at some sites and were well above that during July. In

TABLE 2. Mean length (mm), mean weight (g), sample size and mark retention of four marked lots of steelhead stocked into Chautauqua Creek, NY, April 2015 and 2016.

			2015				2016			
Mark	Stocking Location	Size Group	Sample Size	Mean Length	Mean Weight	Mark Retention	Sample Size	Mean Length	Mean Weight	Mark Retention
CWT	Lower	Small	490	105	12.3	88.6%	400	102	11.4	88.8%
LV	Lower	Large	500	139	27.7	99.2%	400	141	25.1	97.8%
AD	Upper	Small	455	103	11.6	98.9%	400	99	10.0	99.0%
AD+CWT	Upper	Large	454	139	27.0	-----	400	144	27.0	-----

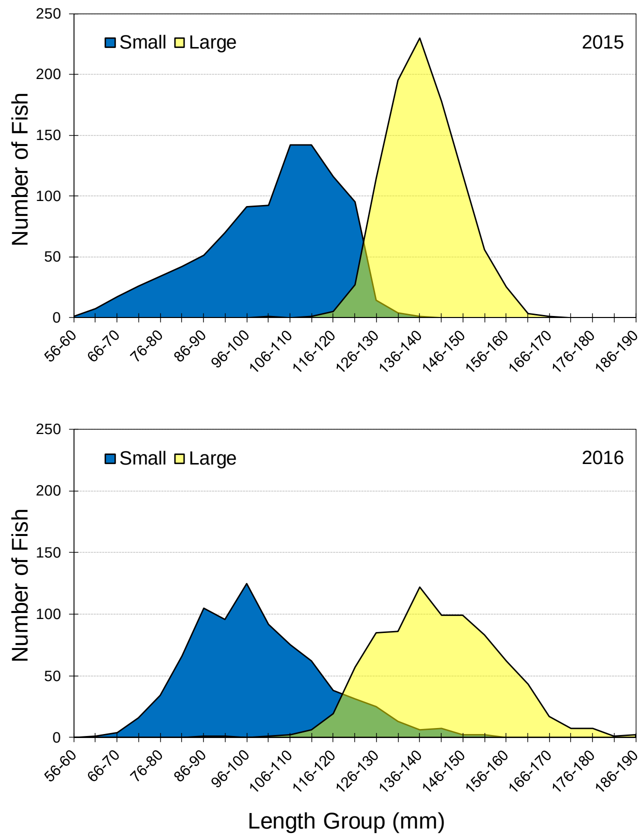

FIGURE 2. Length frequency distribution of small and large groups of steelhead stocked in Chautauqua Creek, NY, April 2015 (upper panel) and 2016 (lower panel).

2016, water temperatures ranged between 46 and 77°F at the time of sampling, exceeding 70°F at some sampling sites by the beginning of June and remaining near or above this until sampling concluded at the end of July. In both years daily water temperatures varied between sites depending on the time of day the site was sampled with warmer temperatures generally occurring at sites sampled later in the day.

Abundance by Date

There were nine post-stocking sampling events at primary sampling sites in 2015 between April 20th and July 27th, and eight events in 2016 between April 25th and July 27th. The Middle site was not sampled on the initial sampling day in either year to allow fish to distribute into this area. The highest catches in both years occurred at the beginning of the survey but dropped quickly two weeks post-stocking (Figure 3). Most of the steelhead had vacated the primary sampling sites by the beginning of June. Higher overall catches occurred at the Upper site compared to the Middle and Lower sites. Initial catches at the Lower site were low in 2015 but high in 2016, possibly due to the change in sampling location that occurred. A similar pattern of continuous declining abundance of the upper large group was apparent at both the Upper and Middle sites. In contrast, the upper small group persisted at both sampling sites and exhibited a slower and more inconsistent rate of decline in abundance compared to the upper large group. Both the lower large and lower small groups appeared to decline rapidly in abundance following stocking. The upper stocking groups were only found in very low abundances at the Lower site. Some of the lower small group was also found at both the Middle and Upper sites in both years, but the lower large group was only found at upstream sites in 2016.

TABLE 3. Mark retention corrected number of steelhead stocked in Chautauqua Creek, NY on April 2015 and 2016.

			2015			2016		
Mark	Stocking Location	Size Group	Number Stocked	Mark Retention	Corrected Number Stocked	Number Stocked	Mark Retention	Corrected Number Stocked
CWT	Lower	Small	15,223	88.6%	13,488	15,760	88.8%	13,995
LV	Lower	Large	15,310	99.2%	15,188	15,000	97.8%	14,670
AD	Upper	Small	15,226	98.9%	16,585	15,930	99.0%	17,502
AD+CWT	Upper	Large	13,386	-----	11,860	15,458	-----	13,727

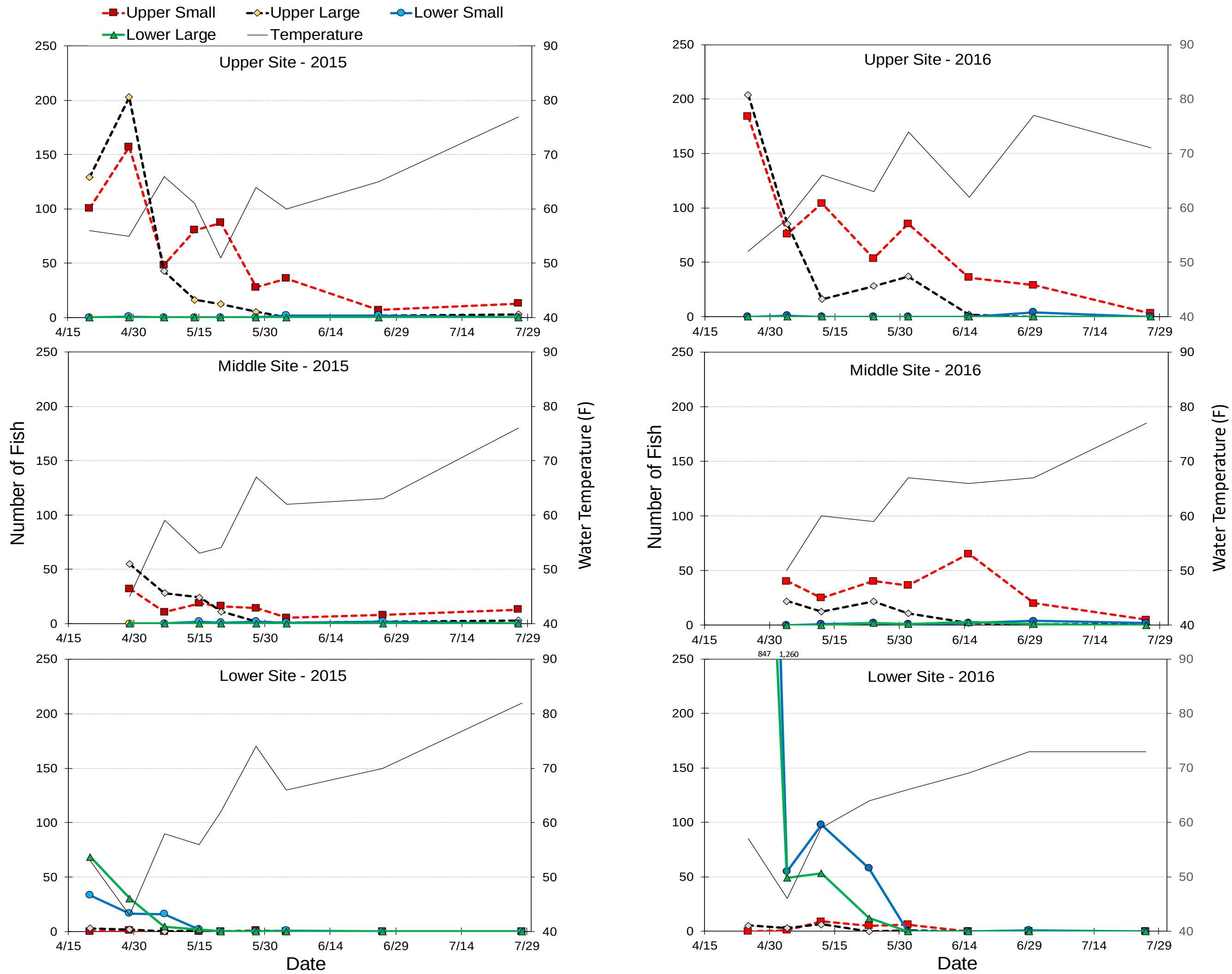

FIGURE 3. Population estimates of the four groups of stocked steelhead by sample date for the Upper, Middle, and Lower primary sampling sites on Chautauqua Creek, NY in 2015 (left panel) and 2016 (right panel) are on the primary y-axis. Upper stocked groups have dashed lines while lower stocked groups have solid lines. Water temperature associated with each sampling event is on the secondary y-axis (black line without markers).

Abundance by Stream Mile

Sampling was conducted at both primary and secondary sites located from the stream mouth to the dam at the end of both May and June in 2015 and at the beginning of June, end of June, and end of July in 2016. Similar patterns were evident in both years with the highest abundance of the small groups just upstream of their respective stocking locations (Figure 4). This pattern was consistent between the sampling dates, however the number of fish residing at these locations declined between the beginning and end of the sampling period. The upstream stocked groups of steelhead were found over a broader range of the stream compared to the groups stocked near the stream mouth. Upstream migration of steelhead stocked at the lower stocking site into sites upstream was also apparent, mainly by individuals from the lower small stocking group.

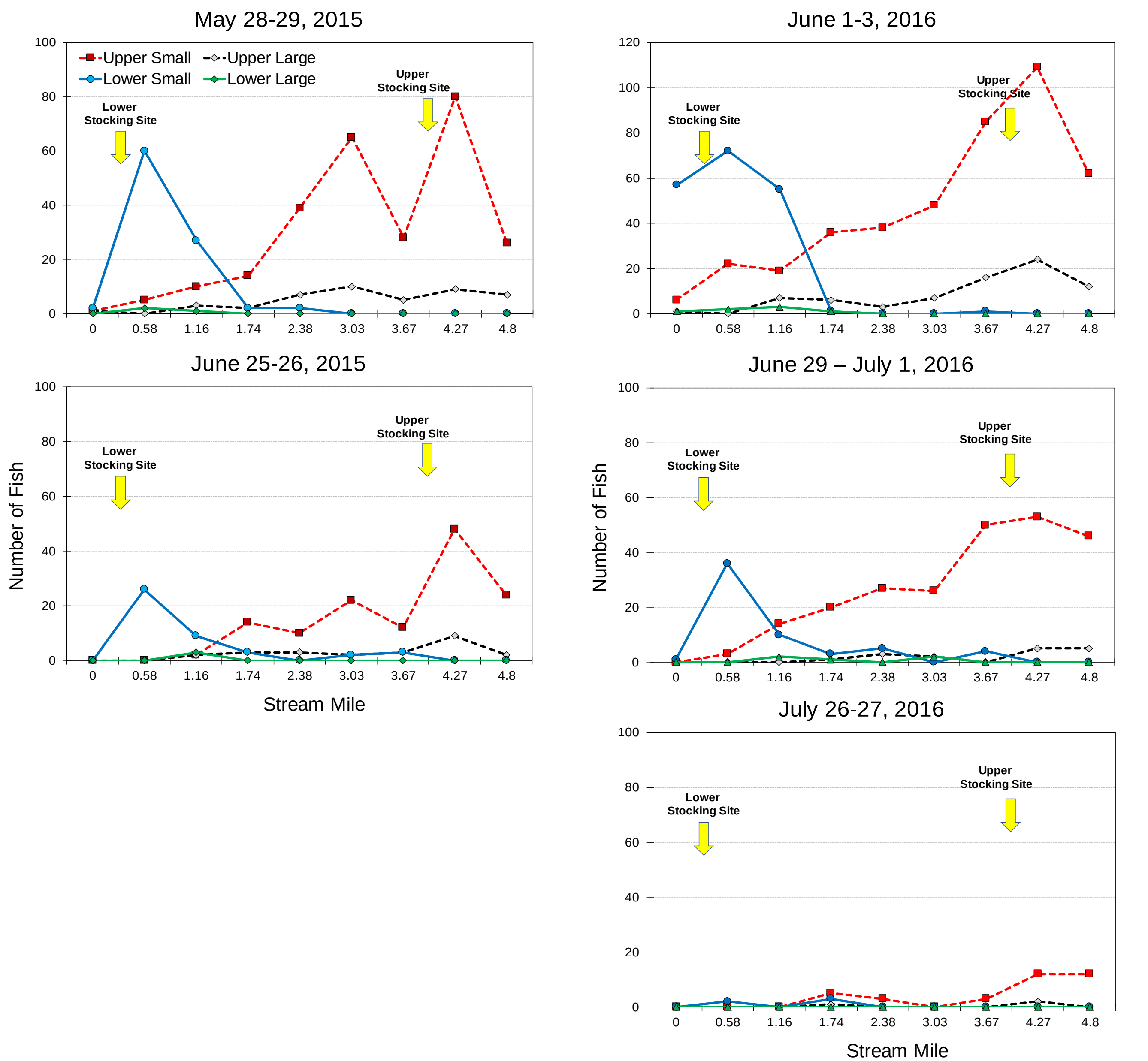

FIGURE 4. Population estimates of the four groups of stocked steelhead at both primary and secondary sampling sites from the mouth upstream to the dam on Chautauqua Creek, NY, 28-29 May and 25-26 June, 2015 (left panel), and 1-3 June, 29 June 29 - 1 July, and 26-27 July, 2016 (right panel). Yellow arrows indicate lower and upper stocking sites relative to the sampling sites.

Length by Date

Individual lengths of marked steelhead present in the stream at the Upper, Middle, and Lower primary sample sites (combined) indicate that most of the fish >150 mm vacated the sampling sites by the end of May (Figure 5). This pattern was consistent between the two sample years. Stocked steelhead greater than 150 mm were present in both years on the last sampling date in late July.

Coefficient of Condition

Significant declines in Fulton's *K* occurred from the start to end of the study in both years (2015: F=45.46, P<0.0001; 2016: F=16.97, P<0.0001)

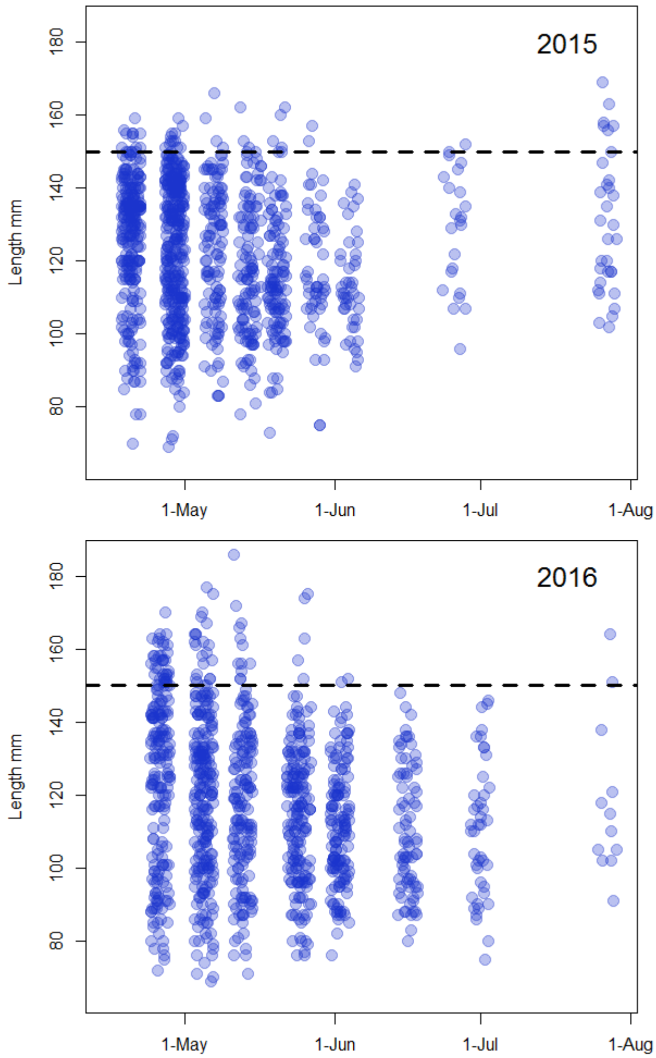

FIGURE 5. Individual lengths (mm) by sample date for combined Upper, Middle, and Lower primary sample sites of all marked steelhead caught in Chautauqua Creek, NY in 2015 and 2016. The dotted black line represents the 150 mm mark, which is the lower range of the recommended steelhead stocking size. Points for each sampling event are jittered to make individual points visible.

(Figure 6). Fulton's *K* at the initial sampling date post-stocking for all sites and groups combined was 1.01 in 2015 and 0.91 in 2016. By mid-May of both years, Fulton's K had dropped to 0.83, followed by a gradual increase into late-June (2015 = 0.89, 2016= 0.92). Declines in measures of condition were again evident by the end of July in both years.

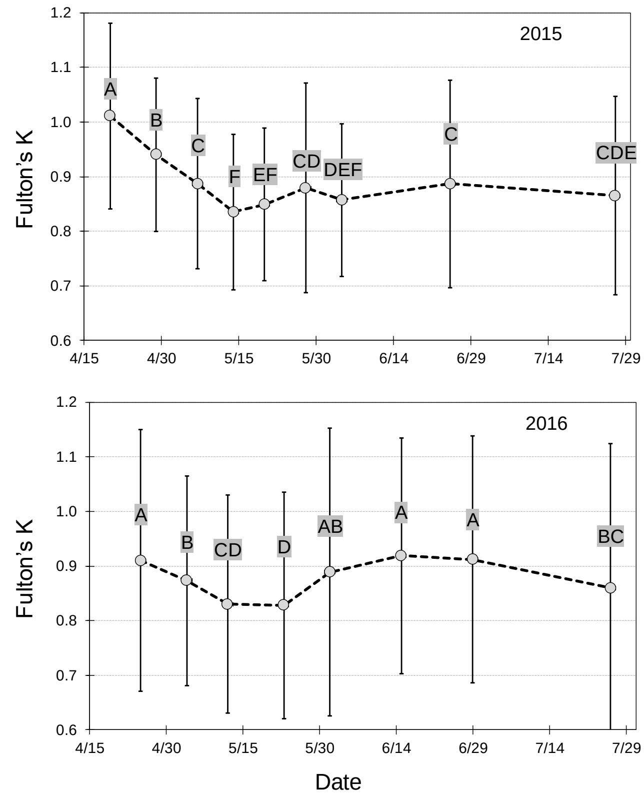

FIGURE 6. Mean Fulton's *K* by sample date of stocked steelhead caught in Chautauqua Creek, NY in 2015 and 2016. Vertical lines represent two standard deviations. Significant differences were found between dates not sharing a common letter.

Adult Sampling

Sampling of returning adult steelhead was conducted on six occasions in 2015/16 and 2016/17, and eight occasions in 2017/18 (Table 4). Altogether 406 steelhead that fit into the targeted size ranges were captured during sampling with a total of 60 (14.8%) exhibiting a mark from this study (Table 4). During the 2016/17 and 2017/18 sampling seasons, an average of 26 adult steelhead were sampled per trip with only 4 of them being marked.

The upper large stocking group was the most common mark encountered, representing 61.7% of all the marked fish, followed by the upper small stocking group (18.3%). Both lower stocking groups were detected the least and in relatively equal amounts (~10%). When corrected for the actual number of fish stocked and standardized (detections per 10,000 fish stocked), the upper large stocking group (13.29) was detected over four times more often than the upper small group (3.23) and six times more often than either of the lower stocking groups (Table 5).

TABLE 4. List of sampling dates, target size (mm), number of steelhead sampled, and number of fish with tags and/or clips from Chautauqua Creek, NY during the 2015/16, 2016/17, 2017/18 fishing seasons.

Date	Target Size (mm)	Sample Size	Lower Large	Lower Small	Upper Large	Upper Small	None
10/20/2015	<475	14			1		13
10/26/2015	<475	9					9
11/18/2015	<475	4			1		3
12/11/2015	<475	4					4
3/7/2016	<475	3			1		2
4/14/2016	<475	6					6
TOTAL 2015/16	<475	**40**	**0**	**0**	**3**	**0**	**37**
11/1/2016	>250 and <675	30			2		28
11/7/2016	>250 and <675	33	1	1	4		27
12/5/2016	>250 and <675	35	1		2		32
2/27/2017	>250 and <675	39	2	1	5	2	29
4/5/2017	>250 and <675	20		1	2		17
4/12/2017	>250 and <675	7				3	4
TOTAL 2016/17	>250 and <675	**164**	**4**	**3**	**15**	**5**	**137**
10/13/2017	>475	45			1	1	43
11/14/2017	>475	20	1		2	2	15
11/27/2017	>475	32			3	1	28
12/21/2017	>475	16			4		12
3/1/2018	>475	53	2	1	8	1	41
4/11/2018	>475	3					3
4/26/2018	>475	10					10
5/1/2018	>475	23		1	1	1	20
TOTAL 2017/18	>475	**202**	**3**	**2**	**19**	**6**	**172**
GRAND TOTAL		**406**	**7**	**5**	**37**	**11**	**346**

TABLE 5. Number of adult steelhead detected per 10,000 fish stocked by size group and stocking location from Chautauqua Creek, NY during the 2016/17 and 2017/18 fishing seasons.

Mark	Stocking Location	Size Group	Corrected Number Stocked	Number of Returns	Detections per 10,000 Stocked
CWT	Lower	Small	27,483	5	1.82
LV	Lower	Large	29,858	7	2.34
AD	Upper	Small	34,087	11	3.23
AD+CWT	Upper	Large	25,587	34	13.29

Research Conclusions

1. Larger stocked fish (>150 mm) were absent from the stream by the end of May.
2. Smaller stocked fish (<150 mm) were observed throughout the sampling period and tended to move upstream.
3. Fish that stayed in the stream lost condition over time.
4. NY stocked steelhead comprised only ~15% of adults sampled.
5. Stocking upstream as opposed to near the stream mouth produced the highest adult return rates.
6. Larger fish stocked upstream were detected at over four times the rate of smaller fish stocked upstream as adults.

Discussion

In any fisheries management strategy based primarily on stocking, the constraints of the hatchery product (i.e. quality and quantity) will have an impact on management outcomes. In this study we took an experimental approach to identify stocking practices (size and location) for steelhead that would maximize adult return rates in New York's Lake Erie tributaries using New York's hatchery product. This study builds on the work of several other researchers by examining the optimal stocking size and location to produce adult returns while taking the additional step of considering the interaction between stocking size and location. In addition, we examined instream juvenile behavior to understand the underlying mechanisms contributing to adult return rates. Our study results show that stocked steelhead greater than 150 mm generally left the stream while smaller steelhead remained stream residents, and that steelhead stocked several miles upstream returned at a much higher rate than steelhead stocked near the stream mouth. Results also indicated that stocked steelhead that remained in the stream tended to exhibit upstream movement and experienced deteriorating body condition over time, likely resulting in poor survival.

Juvenile steelhead stocked at upstream locations provided the best adult returns to Chautauqua Creek regardless of stocking size. This supports New York's long-standing Lake Erie policy of stocking steelhead upstream rather than near the mouth as the most effective strategy for maximizing adult returns (also see: Budnik and Miner 2017). However, adult returns of the upper large group were over four times higher than returns from the upper small group and nearly six times greater than similarly sized steelhead stocked near the stream mouth. This indicates an important interaction between stocking size and location—both management actions enacted simultaneously create a positive synergistic effect.

Our study findings are consistent with previous investigations that steelhead stocking size is positively correlated with adult returns (Seelbach et al. 1994, Slaney et al. 1993, Ward et al. 1989, Budnik and Miner 2017). The 150 mm minimum stocking size has been identified by many investigators as a target for juvenile steelhead to successfully smolt and emigrate (Bjornn et al. 1979; Budnik and Miner 2017, Chrisp and Bjornn 1978, Peven et al. 1994, Quinn 2005, Seelbach 1987, Wagner et al. 1963; Wallis 1968). Our results also indicated that stocked steelhead greater than 150 mm generally left the stream by the end of May. It is important to note that steelhead stocked in New York are uniformly smaller (typically average 127 mm or 5.0 in) than those stocked by other Lake Erie jurisdictions (average size = 190 mm (7.5 in); Coldwater Task Group 2018); a larger hatchery product would be expected to provide better adult returns. Typically, only around 15% of New York steelhead are greater than 150 mm when stocked (Lake Erie Fisheries Research Unit, NYSDEC, unpublished data).

Budnik et al. (2018) provided several hypotheses to explain the low contribution of adult New York stocked steelhead in the New York Lake Erie tributaries. The authors speculated that near-mouth stocking and rapid stream emigration in Ohio and Pennsylvania stocking programs were not producing strong stream imprinting to compel fish to return to their stream of stocking. The authors also suggested that the large numbers of juvenile steelhead stocked by both Pennsylvania and Ohio hatcheries may alone explain the large percentage of individuals from these jurisdictions in New York tributaries. They also theorized that odors from naturally reproduced steelhead in New York tributaries, where most of the natural production in Lake Erie occurs, may provide an attraction to adult steelhead from other systems. Each of these hypotheses infer that stray adult steelhead from other jurisdictions are being attracted to the New York tributaries and essentially "swamping" out the New York stocked fish. While we cannot rule out any of these hypotheses, our research offers an alternative and/or additional explanation for limited observed contributions by New York stocked steelhead: poor post-stocking survival leading to poor adult return rates.

This study has provided additional insights on the effects of stocking size on post-stocking residency. A large portion of the stocked steelhead less than 150 mm did not emigrate to the lake but instead exhibited upstream migration, remaining stream residents at least through mid-summer. These results were similar across both sampling years and consistent with earlier results from a two-year pilot emigration project conducted in 2013 and 2014 (Markham 2014; Markham 2015). While previous research on steelhead stocking size documented poor returns of small fish, none of these studies reported that small fish migrated upstream instead of downstream, essentially becoming stream residents. Stocked steelhead greater than 150 mm were present in both years on the last sampling date in late July, possibly indicating growth of fish that failed to out-migrate within its optimal window (Peven et al. 1994) or that some steelhead, regardless of size, never out-migrate (Wagner et al. 1963). This was also observed in Trout Run in Pennsylvania where individuals as large as 200 mm were present in June (Budnik and Miner 2017). In many New York tributaries to Lake Erie, low summer water levels prevent the potential for delayed emigration to the lake.

Most of New York's Lake Erie tributaries are low productivity streams and experience poor physical stream conditions during the summer months. Consequently, they likely cannot support a population of trout for more than a short period of time. The situation becomes even more problematic when the stocked fish do not emigrate and become stream residents for longer periods of time, potentially being detrimental to the stream's resident fish community. Stream temperatures in both years reached the mid-70's and higher as early as mid-June, which exceeds the temperature threshold where steelhead become stressed (68 ^{o}F) and is approaching their upper lethal limit (77 ^{o}F) (Cherry et al. 1977; Currie et al. 1998). In addition, summertime low flow conditions are typical of most New York Lake Erie tributaries, sometimes causing little to no surface flow into the lake, thus eliminating any potential for summertime fish emigration. Due to these poor physical habitat conditions and limited food resources, it is likely that any steelhead remaining in the stream after May experienced high mortality due to a combination of energy depletion (Josephson et al. 2012) and temperature stress. Even at sub-lethal levels, this combination of low food availability, low water, and high temperatures would make stocked steelhead increasingly susceptible to predation and disease (Haddix and Budy 2005; Peters et al. 2007).

A large decline in Fulton's *K* occurred over a relatively short period (3-4 weeks) post-stocking in both years indicating a rapid loss of energy reserves. While fish condition seemingly improves thereafter, research by Josephson et al. (2012) on rainbow trout condition indicates that increases in water content occur in food-limited environments, causing increases in Fulton's *K* and giving a false signal that fish condition improved. Increases in water content actually signaled energy reserve depletions due to rapid and sustained lipid losses. Consequently, the authors concluded that energy reserve depletion contributes to poor survival of stocked fish in food limited environments. We hypothesize that this same phenomenon is occurring in the juvenile steelhead examined in this study that remained in the stream past the end of May. In general, this result is indicative of a low productivity environment that provides low quality in-stream habitat for juvenile steelhead.

From a management standpoint, homing back to the stocked stream is the best outcome and supports the goal of our stocking program. Our results indicate that the majority (~ 85%) of the returning adults sampled in Chautauqua Creek were not stocked in Chautauqua Creek, supporting the findings of Budnik et al. (2018) that the vast majority of adult steelhead in Chautauqua Creek were of Ohio or Pennsylvania origin. However, it was beyond the scope of this study to determine if non-marked fish originated from stocking efforts in other jurisdictions or from another New York stocked tributary. These results do not necessarily demonstrate that stocking large fish upstream improved overall survival, only that it improved homing and return rates.

While we did attempt to directly measure tag loss in the AD+CWT (upper large) group, it was apparent that any steelhead in this group that lost its CWT would appear to belong to the AD group, which was in the same raceway. Therefore, to account for potential tag loss in the AD+CWT group, we applied the tag loss rate that occurred in the CWT only group. The conclusions of our study would not have changed regardless of how, or if, we accounted for tag loss in the AD+CWT group because the returns of these fish were so much higher than the other groups.

In the future, stocking steelhead several weeks earlier may be advantageous provided steelhead >150 mm are available. According to Wagner et al. (1963) and Hansen and Stauffer (1971), the greatest returns of adults can be expected from stockings made during the downstream migration of wild juveniles, which typically occurs from late-April through July (Stauffer 1972). Results from Budnik and Miner (2017) indicated that peak emigration in a Pennsylvania Lake Erie tributary occurred with photoperiods approaching 840 minutes (early May). Stocking currently occurs in the third week in April in New York's Lake Erie tributaries. An earlier stocking date may benefit appropriately sized New York fish by allowing more time to adjust to the stream environment and a longer period during which to imprint, smolt, and emigrate prior to water temperature increases and low-flow conditions that usually occur by June (Figure 3).

Based on this study and evidence provided by Budnik et al. (2018), we conclude that strays from other Lake Erie jurisdictions contribute a great deal to the success of New York's tributary steelhead fishery and have masked the low return rates of New York stocked steelhead. For example, if our fishery was solely dependant on NY stocked fish we would expect an average catch rate of only 0.08 fish/hr based on the 2017/18 angler survey (0.56 fish/hr; Markham 2019) and the conclusion that only 15% of adult steelhead are of New York origin. Our historical steelhead stocking practices put our hatchery product into a relatively sterile environment with the expectation that they will survive, imprint, emigrate to the lake, and eventually return to that stream as adults to provide a high-quality angling experience. However, our results indicate that most of New York's stocked steelhead are too small to emigrate and instead become stream residents, experience poor survival, and ultimately make minimal contributions to the adult steelhead fishery. Because New York's Lake Erie tributary steelhead fishery is so dependent upon stocking by other jurisdictions, any changes to their stocking practices could negatively affect the steelhead fishery in New York streams. As such, the resiliency of our fishery would be improved by maximizing the adult returns of the New York stocked fish through an improved hatchery product combined with upstream stocking practices.

Management Recommendations

To improve survival and adult return rates of New York's stocked yearling steelhead, and to ultimately improve fishery performance and stability, we recommend the following management actions:

1. Explore measures to increase the size of our stocked steelhead to a minimum of 150 mm through hatchery experimentation (e.g. rearing density reduction, grading, diet) and infrastructure improvements.
2. Continue the practice of stocking steelhead well upstream of the lake confluence to facilitate imprinting.
3. Provided steelhead >150 mm are available, stock these fish beginning in late March or early April to allow fish more time to acclimate and imprint prior to May temperature increases.

Some of these management actions are currently underway, however, increasing the size of our hatchery project may be more problematic due to the constraints of the existing Salmon River Hatchery infrastructure. Nonetheless, Salmon River Hatchery staff are experimenting with water flow adjustments and fish densities as a short-term solution, and hatchery infrastructure funds are in place to develop long-term solutions for improved water flow and temperatures which should result in a higher quality product.

The success of changes in management actions should be evaluated based on our angler survey and the relative contributions of New York stocked fish. Otolith microchemistry has proven to be a viable and affordable tool to establish the origin of steelhead in Lake Erie tributaries. Otolith microchemistry should be used in the future to evaluate changes in stocking policy and/or hatchery practices.

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