ARTICLE IN PRESS

JGLR-01237; No. of pages: 8; 4C:

Journal of Great Lakes Research xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Journal of Great Lakes Research

journal homepage: www.elsevier.com/locate/jglr

Novel aspects of stocked juvenile steelhead emigration patterns as revealed using dual-frequency identification sonar

Richard R. Budnik *, Jeffrey G. Miner

Department of Biological Sciences, Aquatic Ecology and Fisheries Laboratory, Bowling Green State University, Bowling Green, OH 43403, USA

ARTICLE INFO

Article history:
Received 24 March 2017
Accepted 18 July 2017
Available online xxxx

Keywords:
Oncorhynchus mykiss
Salmonids
Stocking
Dual-frequency identification sonar
DIDSON
Emigration

ABSTRACT

We used a Dual-Frequency Identification Sonar (DIDSON) near the mouth of a small Lake Erie tributary to monitor juvenile steelhead emigration. Data were recorded continuously over two stocking seasons (April–May 2014; April–June 2015) and total emigration counts were determined every hour. Fish lengths at time of emigration were estimated using the DIDSON fish measuring tool and quantified through time. Percent survival to emigration was high with >71% of individuals reaching the river mouth in both years. Photoperiod was the best predictor of peak emigration timing, and steelhead were most likely to emigrate at night. Larger individuals were more likely to emigrate shortly after stocking; however, the size range of fish that emigrated throughout the study period was wide. Residual population estimates performed after the DIDSON sampling period revealed that in both years <6% of the steelhead that were stocked remained in Trout Run by the end of June, >2 months after stocking. Most of these fish (63%) were <150 mm TL, below the typical size threshold for steelhead to emigrate. These findings provide useful information on the survivorship and residence time of stocked juvenile steelhead and indicate that multiple factors, including photoperiod and length at stocking, should be considered when determining best practices.

Introduction

Each year approximately 2 million juvenile steelhead (*Oncorhynchus mykiss*) are stocked into Lake Erie tributaries to sustain a valuable sport fishery in which tributary angling is the focus (CWTG, 2015). Because natural reproduction is minimal (Thompson and Ferreri, 2002), stocked individuals are primarily released with the expectation that they will emigrate to Lake Erie, grow to a size desired by anglers, and then return to the tributary in which they were stocked during spawning runs, where they become available for anglers. Ideally, stocked individuals emigrate shortly after release because juvenile salmonid mortality increases with increased emigration time (Melnychuk et al., 2007; Seelbach et al., 1994; Welch et al., 2004, 2008). Although increased tributary residence time increases mortality, imprinting of juvenile salmonid species to an olfactory cue can take 10–14 days (Dittman et al., 1996; Nevitt et al., 1994; Yamamoto et al., 2010). Thus, to maximize return rates optimal stocking strategies would limit residence time, while allowing sufficient time for tributary imprinting.

In addition to timing, stocking steelhead at the optimal size is important to maximize adult returns. Size-biased survival has been identified in stocked juvenile steelhead in Lake Michigan (Seelbach et al., 1994), and on the Pacific Coast the percent recovery of adult steelhead has been shown to be positively correlated with size at stocking (Slaney et al., 1993). Survival of wild steelhead in the Pacific Ocean is also positively correlated with juvenile size, and 200 mm steelhead have an 8-fold increase in survival compared to 140 mm individuals (fork lengths: Ward et al., 1989). Steelhead stocked at a minimum size of approximately 150–160 mm total length (fish sizes in remainder of manuscript are reported as total lengths) will usually emigrate shortly after release, while smaller individuals are more likely to delay emigration for a year or more (Bjornn et al., 1979; Chrisp and Bjornn, 1978; Peven et al., 1994; Quinn, 2005; Seelbach, 1987; Wagner et al., 1963). This delayed emigration increases mortality when fish are exposed to low water levels and high water temperatures during summer months (Chrisp and Bjornn, 1978). Delayed emigrants can also face additional challenges including increased predation risk, decreased food availability, and competition with other stocked individuals (Cada et al., 1987; Chrisp and Bjornn, 1978; Ward and Slaney, 1990; Wood, 1987a, 1987b). The average size at stocking for most agencies in the Lake Erie region is above 150 mm (In 2014: Michigan-193 mm, Pennsylvania-177 mm, and Ohio-171 mm). However, not all individuals are able to reach this size after a year of hatchery life, and the Salmon River State Hatchery (New York), which raises steelhead for release into New York's Lake Erie tributaries, consistently produces individuals with an average size at stocking of <150 mm (118 mm in 2014; CWTG, 2015).

Besides influencing survival, size at stocking may also affect the timing at which juvenile steelhead emigrate. Earlier downstream

* Corresponding author.
E-mail address: rbudnik@bgsu.edu (R.R. Budnik).

http://dx.doi.org/10.1016/j.jglr.2017.07.004
0380-1330/

Please cite this article as: Budnik, R.R., Miner, J.G., Novel aspects of stocked juvenile steelhead emigration patterns as revealed using dual-frequency identification sonar, J. Great Lakes Res. (2017), http://dx.doi.org/10.1016/j.jglr.2017.07.004

movements have been identified in larger young-of-the-year brown trout (*Salmo trutta*; Holmes et al., 2014), and a weir study performed on Godfrey Run, a small Lake Erie tributary, suggests larger juvenile steelhead emigrate earlier than smaller individuals (CWTG, 2014). Juvenile salmonid emigration usually peaks in autumn or spring (Bjornn, 1971; Hayes, 1988; Hvidsten et al., 1995; Jonsson, 1991), and environmental variables such as photoperiod, temperature, and flow can initiate juvenile salmonid migration (Jonsson and Jonsson, 2011). Salmonid smolts also time emigration movements based on diel patterns, a strategy believed to be related to predator avoidance (Leduc et al., 2010; Poe et al., 1991; Rieman et al., 1991), turbidity (Gregory and Levings, 1998), and flow (Greenstreet, 1992).

Here, we quantify emigration patterns of stocked yearling steelhead using Dual Frequency Identification Sonar (DIDSON) in a Lake Erie tributary that experiences elevated water temperatures in mid-summer typical of most tributaries in Lake Erie. DIDSON allows fish emigration to be measured in real time without tagging and can be effective under most environmental conditions (i.e., high flow, high turbidity, nocturnal conditions). DIDSON is multi-beam sonar that records near video quality images in underwater environments using sound. In high frequency mode (1.1–1.8 MHz), fish as small as 50–60 mm have been observed and measured (Boswell et al., 2007; Doehring et al., 2011; Holmes et al., 2006). DIDSON has been used to effectively observe large numbers of salmon in Alaska (Brazil and Buck, 2011; Maxwell and Gove, 2004), Idaho (Kucera and Faurot, 2005; Kucera and Orme, 2006), Washington (Galbreath and Barber, 2005), and British Columbia (Cronkite et al., 2006; Holmes et al., 2006), and to provide accurate escapement estimates for a small steelhead population in central California (Pipal et al., 2010, 2012). Although salmonid migration has been studied using DIDSON, most work has focused on the movement of adults. Our main objectives were to: 1) determine the viability of using DIDSON to monitor the emigration patterns of juvenile salmonids in a small study stream, 2) estimate survival of juvenile steelhead stocked into a small Lake Erie tributary in the first 7–8 weeks after release 3) quantify patterns of emigration timing, and 4) assess the role that environmental factors and individual fish size have on emigration timing.

Methods

Study area

Trout Run is a small Lake Erie tributary located in Erie County, Pennsylvania (Fig. 1). The stream is 10.4 km in length with an average width of 4 m, average channel depth of 0.5 m, and pools as deep as 1.2 m are present. Trout Run is protected from angling year-around because it serves as the primary source of broodstock for Pennsylvania's steelhead stocking program. Approximately 150 m from the mouth of the tributary is a manmade weir structure that serves to aggregate spawning adult steelhead. The structure has four concrete blocks (two on each side of the structure) that streamline flow and create a 4.2 × 6.1 m pool with a concrete bottom. The lower end of the structure (closer to the mouth of tributary) creates a small waterfall that is impassable to any fish that are unable to jump over the barrier which is approximately 2 m high (Fig. 2). Although steelhead spawning occurs in Trout Run, very little natural reproduction is successful due to high summer water temperatures during summer months (Thompson and Ferreri, 2002). Common fish species present in Trout Run include blacknose dace (*Rhinichthys atratulus*), blue gill (*Lepomis macrochirus*), central stone roller (*Campostoma anomalum*), creek chub (*Semotilus atromaculatus*), emerald shiner (*Notropis atherinoides*), fantail darter (*Etheostoma flabellare*), johnny darter (*Etheostoma nigrum*), northern hogsucker (*Hypentelium nigricans*), rainbow darter (*Etheostoma caeruleum*), yellow bulldhead (*Ameiurus natalis*), and white sucker (*Catostomus commersonii*) (R. Budnik, personal observation).

Trout Run was divided into three sections; a lower section that was characterized by slate-shale bedrock bottom, along with a middle and upper section where substrate was predominantly sand, silt, and small to medium-sized gravel. The lower section began at the weir location and extended 1.75 km upstream. The middle section extended 0.25 km from the end of the lower section to the stocking site, and the upper section extended 0.21 km from the stocking site to a barrier where additional upstream migration was unlikely (Fig. 1).

Annually, juvenile steelhead stocking into Trout Run takes place in early April and occurred on April 4, 7, and 10 in 2014, and April 8 and 9 in 2015. Stocking occurred approximately 2 km upstream of the tributary mouth (Fig. 1), and a total of 46,250 individuals were released each year. The total length (TL) of a sub-sample of fish was measured prior to stocking in both 2014 ($n = 50$) and 2015 ($n = 50$), and the mean TL ± S.E. was determined for all fish measured.

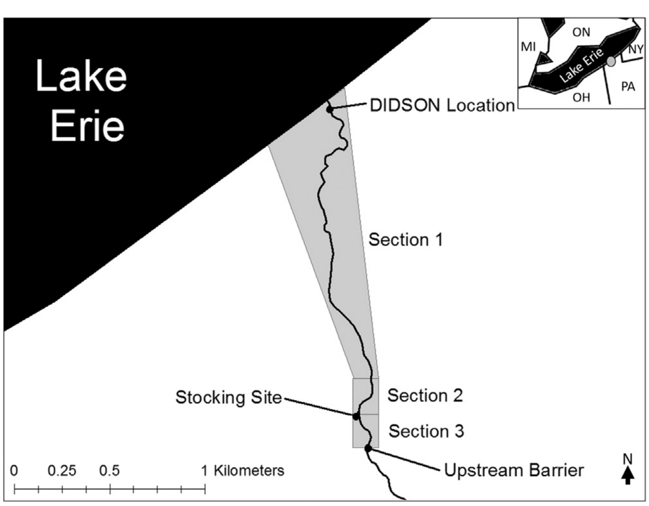

Fig. 1. Trout Run in Pennsylvania. Black circles (●) indicate DIDSON location, location of upstream barrier, and point of stocking by PA Fish and Boat Commission. Shaded gray areas highlight tributary sections used for population estimates.

Field methods and equipment

A DIDSON (Sound Metrics, Lake Forest Park, Washington) operating in high frequency mode (1.8 MHz) was placed 150 m from the mouth of Trout Run within the manmade structure described above (Figs. 1 and 2). In this mode, an image was created with a 29° horizontal and a 12° vertical field of view. A window length (length of the ensonified view) of 5 m was used with a window start of 0.42 m (i.e., any targets that passed within 0.42 m of the DIDSON were undetectable). Data were captured at 7 frames per second and focus and receiver gains were automatically set. The DIDSON was connected to a laptop running DIDSON software (Version 5.25.33) and was cradled in a small chassis. The chassis was attached to a large metal frame that kept the DIDSON stationary but allowed depth, positioning, and tilt to be manually adjusted. We aimed the DIDSON at a downward angle relative to the water surface (5–10°), so that the upper edge of the ensonified area followed the water surface, while the bottom edge ensonified the stream bottom. Inside the manmade structure, stream width did not change, however depth varied from 0.3–1.3 m depending on flow. The vertical and horizontal zones of detection were checked regularly using a fish shaped lure (152 mm), and adjustments to the depth, positioning, and/or tilt were made as needed.

DIDSON data were recorded in 60-min date- and time-stamped files from April 3–May 12, 2014 and April 7–June 22, 2015. During the first six days of the study in 2014, two non-optimal DIDSON configurations were used. The first configuration positioned the DIDSON in the middle of the pool, along the eastern wall, parallel to stream flow, and the second configuration positioned the DIDSON at the southern end of the pool (opposite end of waterfall) perpendicular to stream flow. The first configuration limited the amount of water column coverage, and