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Movement and Survival of Black River Strain Walleye *Sander vitreus* in Southern Missouri Rivers

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ABSTRACT
Limited research has been conducted on Black River strain (BRS) walleye *Sander vitreus* that occur in south-eastern Missouri rivers. In an effort to provide additional insight on stocking contribution to existing stocks and movement of juvenile and adult walleye in these systems, multiple evaluations were conducted examining stocking mortality, juvenile movement using biotelemetry, adult movement and exploitation using reward tags, and stocking contribution using chemically marked otoliths. Survival of walleye fingerlings 48-h post stocking was extremely high (range = 92-100%) during net-pen studies conducted in 2005, 2006, and 2007. In preparation for a biotelemetry study utilizing juvenile BRS walleye, a preliminary evaluation of walleye survival and tag expulsion rates was conducted using internal and externally-attached dummy tags. Internal radio tags were deemed the best option for tracking juvenile walleye movement due to high survival (100%) and low tag loss rates (10%) during the preliminary evaluation period. Beginning 13 April 2007, 15 juvenile walleye implanted with radio telemetry tags were stocked into both the Current and Black rivers and subsequently tracked for 17 weeks. On three different occasions during the 17-week study, diel tracking was also conducted on a sub-sample of walleye in each river. Final displacement from stocking location, total movement, and the rate (km/day) of movement of juvenile walleye were greater in the Current River than in the Black River. Movement in the Current River was generally upstream whereas upstream movement on the Black River was restricted by Clearwater Lake dam. Diel tracking sessions showed the majority of movement in both rivers occurred during nocturnal hours with very little movement occurring during diurnal hours. Walleye utilized significantly deeper depths in the Current River than in the Black River and the relative proportions of the types of structure with which walleye associated were also significantly different between the two rivers. However, walleye in both rivers generally utilized deep areas where structure provided a break in the swift current. Overall, 36.7 percent of radio-tagged walleye expired during the 17-week study, with a majority (33.3%) of the mortality in the Black River caused by great blue herons *Ardea Herodias*. The nocturnal movement patterns of BRS walleye within the large, shallow pool below Clearwater Lake dam provided effective foraging opportunities for great blue herons. Since 1991, reward tagging projects have been conducted on adult walleye in the study rivers thereby providing managers information on adult walleye movement, exploitation, and longevity. Some reward-tagged walleye exhibited extreme movement patterns and many remained in the systems for several years after initial tagging. Some past attempts have been made using oxytetracycline (OTC) to examine the contribution of stocked walleye to the fishery. The small sample of otoliths analyzed for OTC marks suggests that stocking contribution is relatively high in the Black River. Fishery managers now have a better understanding of the movement patterns and population dynamics of BRS walleye in these rivers allowing them to better manage this unique fishery.

Keywords: walleye, Black River strain, Current River, Black River, movement, nocturnal, telemetry, habitat use, stocking, tag retention.

INTRODUCTION

Walleye *Sander vitreus* are an increasingly popular sportfish among Missouri anglers (Mayers 2003); their numbers in southern Missouri streams, however, have decreased dramatically over several decades (Russell 1973; M. Boone, D. Mayers, and J. Ackerson, Missouri Department of Conservation, personal communication). Of particular interest is a genetically distinct strain of walleye found in southeast Missouri streams known as the "Black River strain" of walleye. Black River strain (BRS) walleye inhabit the St. Francis River and the Black River system of Missouri (including the Black, Current, and Eleven Point rivers and converging downstream with the White River drainage system) and possess an mtDNA haplotype unique to that system (Koppelman et al. In prep). According to the Missouri Department of Conservation's (MDC) Genetic Policy (Koppelman 2007), BRS walleye must be managed as a distinct genetic population. A previous Missouri state record walleye weighing 9.3 kg (20.5 lbs) captured from the St. Francis River was likely a BRS walleye, adding to the interest in this unique strain of walleye.

Stocking is a common technique used to enhance walleye fisheries, with over 1.17 billion stocked annually for sportfishing into North American inland waters (Heidinger 1999). Previous attempts have been made at enhancing BRS walleye populations in southeast Missouri streams by stocking. In the late 1960's the Current River was stocked with nearly six million BRS walleye swim-up fry and the St. Francis River was stocked with both swim-up fry and fingerlings. These efforts, however, were considered unsuccessful because the released walleye had very low survival rates and anglers did not report an increase in the numbers of walleye harvested (Russell 1973). From 1996 to 2004, over 545,000 BRS walleye fingerlings were produced and stocked into the Current, Black, Eleven Point, and St. Francis rivers in an attempt to bolster populations. Little is known about the fate of these fingerlings once stocked. Subsequent electrofishing surveys on the rivers produced very few, if any, fingerling or juvenile walleye (J. Ackerson, M. Boone, P. Cieslewicz, and D. Mayers, unpublished data). Only adult walleye (> 381 mm) are sampled in the springtime as fish move onto shoals to spawn but they are usually not observed in electrofishing surveys the remainder of the year.

High stocking mortality rates could be one reason that juvenile BRS walleye are not regularly observed during routine electrofishing surveys. Previous work has shown that mortality rates of stocked fish vary based on a variety of factors (Pitman and Gutreuter 1993). Brooks et al. (2002) noted size-dependent survival of walleye stocked in Illinois lakes with small fingerlings surviving better than fry. Fingerling walleye also survived better than smaller conspecifics when stocked into Wisconsin lakes (Madenjian et al. 1991; Kampa and Hatzenbeler 2009) and Iowa rivers (Paragamian and Kingery 1992). Clapp et al. (1997) suggested that both fish size at stocking and water temperature influenced survival of stocked walleye. Stocking-related mortality could influence the number of BRS walleye that survive to catchable sizes; therefore, understanding this source of mortality should allow for better estimations of the contribution of stocked BRS walleye to the fishery.

Sampling the appropriate habitat at the correct time for the targeted fish is an important component of an effective sampling protocol. Although information on movement patterns and habitat use by adult walleye is readily available (e.g., Holt et al. 1977; Kelso 1976; Paragamian 1989; DiStefano and Hiebert 2000; Rasmussen et al. 2002), very limited information exists on these parameters for juvenile walleye, especially in streams (e.g., Johnson et al. 1988). To date, sampling protocols in Missouri have been designed based on information available on adult walleye habitat selection and seasonal movements. Additional information on juvenile walleye movement patterns, including diel patterns, would improve the effectiveness of Missouri fisheries professionals when sampling juvenile walleye to evaluate annual BRS walleye stocking regimes.

One hypothesis regarding juvenile movement is that once they are stocked the young walleye may move out of the management zone. Fish movement after stocking is commonly observed in a variety of species (e.g., Brown 1961; Bjornn and Mallet 1964; Popoff and Neumann 2005). Because of the proximity to the Arkansas state line of rivers containing BRS walleye, fish could be moving downstream into Arkansas where they are not sampled by MDC fisheries personnel. Downstream movement would also decrease the likelihood of survival since walleye harvest in the Arkansas portion of these streams is not regulated with length limits as is done in Missouri. Understanding movement patterns would allow stocking locations to be modified, if needed, to limit movement out of Missouri by BRS walleye.

Tracking fish movements has been of interest to aquatic observers for hundreds of years (McFarlane et al. 1990). Although there is no ideal marking regime to track movement, each provides valuable specific information to the researcher (see Nielsen 1992). Three commonly used tagging options include external tags, chemical marks, and biotelemetry tags. The most widely used are external tags that consist of a multitude of styles (see Nielsen 1992). Transbody tags, such as the Carlin dangler tag, and dart style tags (e.g., t-bar tag) are two such tags that are easily detected, have good retention rates (Gutherz et al. 1990; Weathers et al. 1990; Walsh and Winkelman 2004), and have little effect on fish behavior or growth (Tranquilli and Childers 1982; Eames and Hino 1983). Further, information can be printed on both tags to facilitate information gathering by fisheries professionals.

Chemical marking involves florescent compounds fusing with calcium and becoming permanently deposited in the bones and scales of fish (Nielsen 1992). Chemical marks are advantageous over other marking techniques in that they can be placed on fishes of any size. Chemical marks also allow fish to be batch marked, increasing the efficiency of the marking process. The primary disadvantage of chemical marks is that, most often, individual fish must be sacrificed to collect important tissues for mark detection.

Biotelemetry tags allow remote sensing of individual tagged animals (Nielsen 1992; Cooke et al. 2004). Long detection ranges and directional signals allow the immediate locations of tagged animals to be determined (Nielsen 1992). When appropriate tag sizes are selected, internally implanted biotelemetry tags have little effect on the study organism's behavior (Brown et al. 1999; Paukert et al. 2001; Murchie et al. 2004). Until recently, tag sizes restricted their use to test subjects of larger sizes; however, recent technological advances in tag design now allow researchers to track movements of small subjects (e.g., Beeman et al. 1998; Benson et al. 2005). Combined, these technologies provide a means to evaluate the movement of individuals of varying sizes.

The lack of currently available information on survival rates and movement patterns of stocked juvenile (< 381 mm) and adult BRS walleye in southeastern Missouri streams limits the ability of fisheries management personnel to effectively manage this unique fishery. The objectives of our evaluation were to 1) monitor stocking-related mortality of hatchery-reared BRS walleye, 2) evaluate performance of implanted versus externally attached radio tags when used on juvenile walleye, 3) evaluate the habitat selection of juvenile BRS walleye stocked into two Ozark streams, and 4) evaluate the movement and survival of adult and juvenile BRS walleye in four Ozark streams. Results from this evaluation will provide management personnel with guidance for improving the current BRS walleye monitoring program and stocking regime.

STUDY SITES

This evaluation of BRS walleye was conducted in four south-flowing streams in southern Missouri and northern Arkansas (Figure 1). The Current River is a sixth-order open river system that is formed by the confluence of Pigeon Creek and the Montauk Spring complex near Montauk, Missouri. The Current River spans 283 river km and drains into the Black River near Pocahontas, Arkansas. The Eleven Point River originates in the eastern section of the Ozark Plateau in Howell County, Missouri. It flows south approximately 225 km before being joined by the Spring River in Arkansas. The Black River originates in Reynolds and Iron Counties, Missouri, but the river is impounded creating Clearwater Lake (660 ha) in Wayne County, Missouri. Clearwater Lake is primarily used for flood control; water flows in the lower Black River are regulated by releases from Clearwater Dam. The primary reach of the sixth-order Black River below Clearwater Dam totals 415 river km before its confluence with the White River in Arkansas. The St. Francis River originates in Iron County, Missouri, where it flows approximately 684 km south into Arkansas before converging with the Mississippi River. Black River strain walleye exist in the upper, fifth-order section of the river above Lake Wappapello.

METHODS

Stocking Mortality

Stocking mortality evaluations were conducted on the Current River and Eleven Point River during May 2005, June 2006, and April 2007 (Table 1). Concurrent with routine stockings, a subsample of BRS walleye were randomly chosen and placed into floating net pens positioned in backwaters adjacent to the main river channel near primary stocking locations.

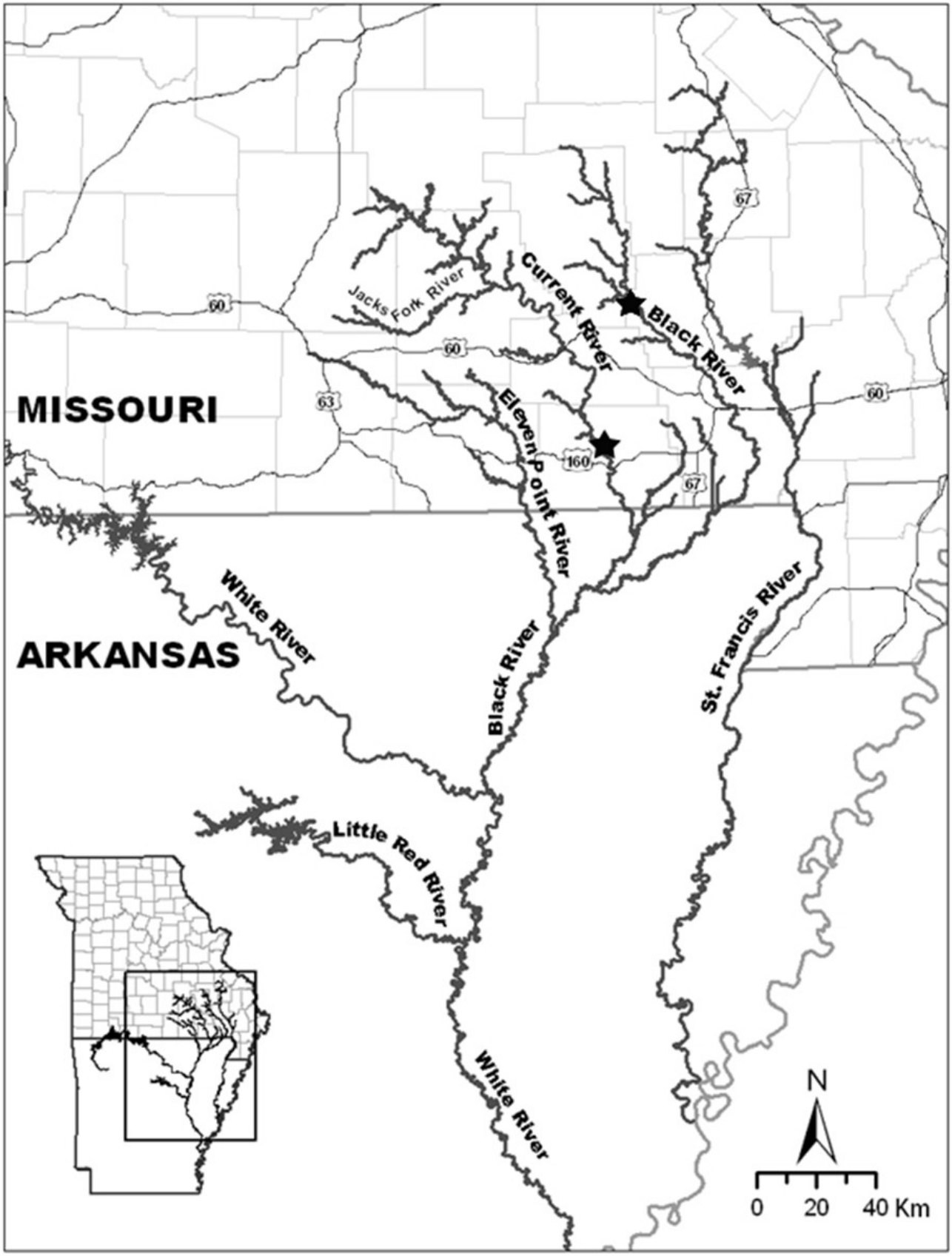


Figure 1. Map of the river systems in which research and management of the genetically distinct strain of walleye, the Black River Strain, has been conducted since the early 1970s. Stars indicate where the radio tagged walleye were released at on each river on April 12, 2007.

Fish total length (TL) varied by year (Table 1); therefore, numbers of fish placed in net pens also varied annually. Net pens (71 cm × 71 cm × 122 cm) were constructed of 3 mm bar mesh and extended from the water surface to near the bottom allowing fish to move freely within the entire water column. Net pens were checked 24- and 48-h poststocking and mortality was documented within each pen at those times.

Internal and External Tag Comparison

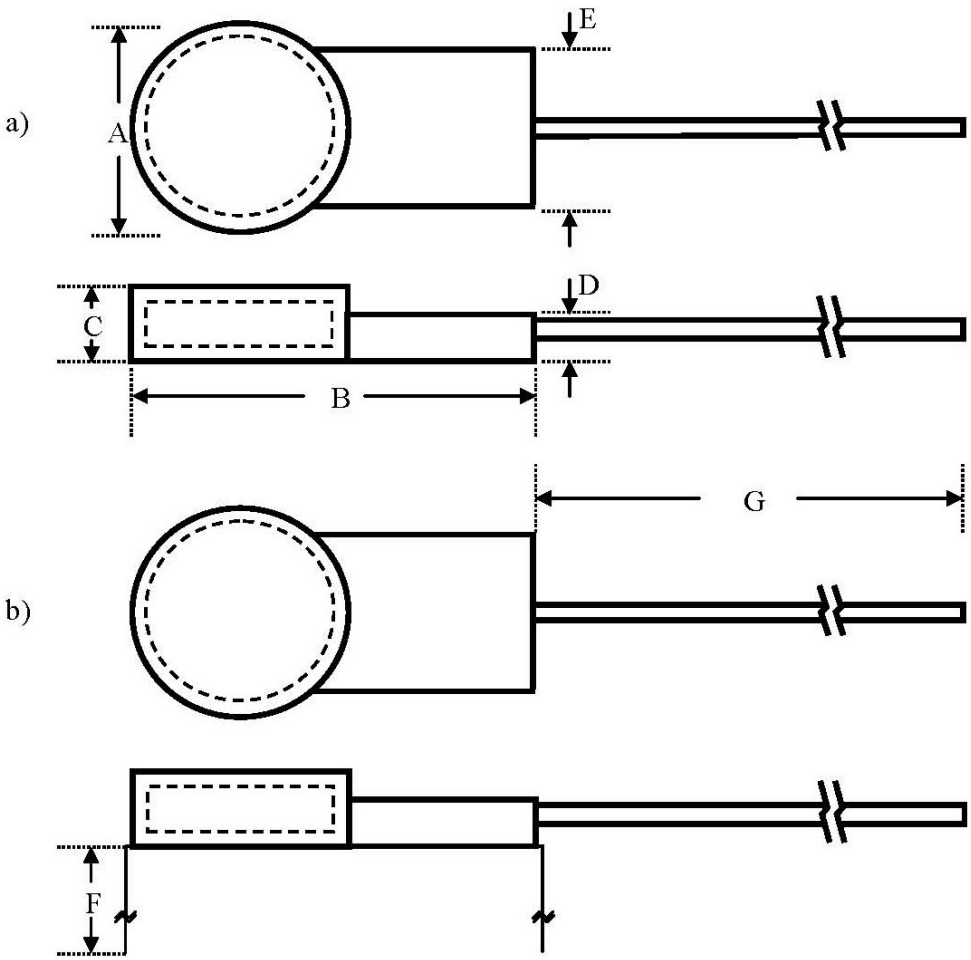
The evaluation of internal and externally-attached dummy radio telemetry tags was conducted at Indian Trail Hatchery near Salem, Missouri. Study fish were held in a concrete raceway (6.1 m × 1.2 m × 0.4 m water depth) with continuous flow and light levels that mimicked the natural photoperiod on that date. One-half of the raceway was covered with a black cover to limit light penetration. The raceway also received fathead minnows weekly to ensure study fish could feed ad libitum.

To determine a design suitable for use in our evaluation of juvenile walleye movement, two styles of dummy radio tags were constructed in March 2005 (Figure 2). An internal tag design was constructed using steel rod to emulate a battery and plexiglass in place of tag electrical components. Plastic-coated fine antenna wire was attached to the tag body. Once completed, two layers of synthetic plastic coating (Plastidip International, Blaine, MN, USA) were applied to the transmitter and allowed to dry. External tag construction was similar to the internal tags except that a stainless steel attachment wire (145 mm) was added to each end of the tag body prior to dipping. Care was taken to ensure that the average final transmitter weights of both the internal (mean weight ± SE, 1.2 ± 0.0 g) and external (1.7 ± 0.0 g) tags mimicked those of commercially available transmitters and were approximately 2 % or less of the total weight (range = 70 - 100 g) of the juvenile walleye tagged (Winter 1983).

Walleye were held in a raceway for six weeks and fed fathead minnows ad libitum except that all food was removed from the raceway 48-h prior to experimentation. Immediately prior to surgeries, juvenile walleye were removed from the raceway, anesthetized in a 101 mg/L solution of Finquel® (tricaine methanesulfonate; MS-222) for about 2 min or until equilibrium was lost, and dummy tags were sterilized by immersion in 100% ethanol for 60 s. Walleye were placed supine in a soft foam surgery tray and a TL was taken before a small ventral incision was made posterior to the pelvic girdle, just off the midline, using a scalpel (blade #15, rounded point). A 20 gauge hypodermic needle was then inserted externally in an anterior direction near the cloaca of the fish and the tip was pushed out through the incision. The antenna of the tag was inserted into the needle tip until the end of the antenna was protruding from the needle entry point. The tag was then pulled into the peritoneal cavity of the fish by pulling the antenna until the tag was firmly against the back wall of the body cavity and away from the incision. The incision was closed using PDS II violet monofilament suture (4/0, FS-2 cutting needle, Ethicon Inc.) in two simple interrupted sutures.

Stocking Date	River	Mean Length (mm)	Net Pen	N	Survival (%)
5/11/2005	Current	34	1	168	95
			2	162	94
			3	188	96
6/27/2006	Eleven Point	94	1	50	96
			2	51	96
			3	65	100
4/25/2007	Current	28	1	121	96
			2	132	92
			3	138	97

Table 1. Date stocked, stocking location, mean length, and number placed in each of three experimental net pens during 2005, 2006, and 2007 for BRS walleye used to determine stocking mortality in Ozark rivers. Survival at 48 h post-stocking is shown as a percentage of total fish held.



Model	Dimensions (mm)							Weight (grams)
	A	B	C	D	E	F	G	
Internal Dummy	8	15	5	4	6	*	170	1.2
External Dummy	8	17	5	4	6	145	170	1.7
ATS F1560	13	24	5	4	9	*	205	2.5

Figure 2. Schematic and table of measurements for tags used in the evaluation of BRS walleye movement. Internal (a) and external (b) dummy tag designs were developed to determine best tag designs for juvenile walleye. The actual radio tag design used was internally-implanted (a) and its measurements are also shown. Dimensions and weights in air of dummy and actual tags are shown.
** = not applicable measurement.*

Fish were then allowed to recover in an oxygenated holding tank before being returned to the raceway. Raceway water temperatures (mean ± SE = 13.9 ± 0.8 °C) were held constant and fathead minnows were maintained as prey throughout the experiment. Walleye mortality was monitored daily whereas tag loss and condition of the incision were checked at two and six weeks post-surgery.

Juvenile Movement

To assess movement and survival of age-1 BRS walleye within the Current and Black rivers, 50 walleye (TL range = 254 - 284.5 mm) were randomly selected from fish to be stocked into the rivers in 2006. These fish were held indoors at Chesapeake Hatchery near Mount Vernon, Missouri, and fed a diet of fathead minnows until April 2007. Using results from the dummy tagging trials, internal radio tags were chosen for the investigation. Radio transmitters (Advanced Telemetry Systems, Model F1560, 150-152 MHz, two-stage, battery capacity of 198 d) were body implant with a trailing whip antenna and were sized to not exceed 2% of the average walleye weight (Winter 1983). Transmitters weighed 2.5 grams in air, were 24 mm long and 13 mm wide, and had a 205 mm trailing whip antenna (Figure 2). Tags were sterilized via immersion in a 2% Chlorohexidine solution and rinsed in sterile water prior to implanting.

The radio telemetry portion of this evaluation was conducted on the Current and Black rivers. At

each river, 15 BRS walleye were individually inverted on a surgery board and provided with a continuous flow of water over their gills during surgery. Although walleye were not anesthetized before surgery, previous work has shown that restraint of fish in an inverted position leads to cessation of movement acceptable for surgical practices (Holland et al. 1999). Transmitters were implanted as described above. Walleye were then placed in a boat-mounted oxygenated holding tank and allowed to recover before being transported by boat to the designated stocking location (Figure 1). In the Current River, 15 walleye were stocked approximately three kilometers upriver of the Deer Leap Access in a large main channel pool. In the Black River, 15 walleye were stocked in the large pool approximately 600 m downstream of Clearwater Dam. All radio-tagged juvenile walleye were released on 12 April 2007 and tracking began 24-h poststocking. All radio-tagged walleye were located during daylight hours multiple times during the first week of the study and then weekly until 11 August 2007 (approximately 17 weeks).

Radio-tagged walleye were located weekly from a jet boat using a radio receiver (Advanced Telemetry Systems, Model 2100) fitted with a three-element Yagi antenna. Tracking personnel allowed the boat to drift with the current while scanning both upstream and downstream for radio-tagged fish at 4 s intervals. If no fish were detected, the boat was relocated 200 to 400 m downstream to repeat the scanning process. Later in the study, when fish movement slowed, tracking personnel would move continuously up or down river scanning for radio-tagged fish. Once the general location of a radio-tagged walleye was found, triangulations were used to determine the fish's location.

Once located, GPS coordinates, time of day, water depth, water temperature, and tag number were marked on a Garmin GPSMap 178C sounder unit (Garmin Ltd 2004). General descriptions of location and structure type were also recorded at each location. Boulder, open water, woody debris, aquatic vegetation or any combination of these variables were recorded as structure types. If water was too turbid or deep to determine structure types, it was recorded as unknown.

Snorkeling was conducted at random times throughout the study to verify fish location and structure type. Tracking personnel snorkeled until fish were found or deemed that it was unnecessary to continue searching. In deeper pools where snorkeling was not viable, SCUBA was used to verify fish locations. All underwater observations were done on the Current River because the Black River was too turbid.

Nocturnal tracking was also conducted three times (May, July, and August) on a subset of radio-tagged fish in the Black (N = 6 fish) and Current (N = 5 fish) rivers to document movement patterns. Afternoon locations of walleye were determined and fish were subsequently tracked every two hours beginning at 1800 hours and ending at 0600 hours the following day. Location, time of day, water depth, tag number, and structure types were recorded for each fish every two hours as described above.

At the conclusion of the study (i.e., when most tags had expired), an attempt was made to capture remaining fish with functioning radio telemetry tags within each river. Radio-tagged fish were located and electrofishing or gill netting was employed in an attempt to capture select individuals. Boat-mounted electrofishing was conducted in the general location where radio-tagged walleye were located until they were captured or deemed not catchable. Experimental gill nets were also set to either encompass the radio-tagged walleye or set just above and below each located fish before dusk when a majority of the movement occurred. Immediately upon capture, the TL (mm) and weight (g) of each individual was recorded. Relative weights (Wr) were calculated for all recovered fish using methods described by Wege and Anderson (1978) and Murphy et al. (1990).

All fish locations were uploaded weekly from the GPS unit into ArcMap Version 9.2 (ESRI 2006). Movement of each fish was then estimated by measuring along the thalweg the linear displacement between tracking events. Mean minimal displacement per day, total movement, and final displacement (distance from release point that the walleye was last located) was calculated for each radio-tagged walleye. Mean minimal displacement per day for walleye in each river was examined by graphing the medians by week to determine differences in movement on a temporal scale between rivers. To determine nocturnal movement patterns, minimum displacement per hour was calculated for radio-tagged walleye monitored during diel tracking sessions.

Differences in median weekly displacement between the two rivers were compared using a nonparametric Wilcoxon two-sample rank test

(Conover 1980). Differences between rivers in radio-tagged walleye final displacement, diel movement through time, and day and night time depths were examined using mixed model analysis of variance (ANOVA; SAS Institute 2001). Differences in the frequency that radio-tagged walleye associated with different structure types between the two rivers were tested using a chi-square test. Spearman correlation coefficients were used to examine the relationship between median weekly minimal displacement values and mean weekly discharge levels in both rivers. The significance level was set a priori at $\alpha = 0.05$ for all statistical tests.

Adult Reward Tagging

Since the early 1990s, in an effort to assess the exploitation, movement, and longevity of BRS adult walleye in these systems, reward tag studies have been conducted and are ongoing. From 1991 through 1994, all walleye captured while electrofishing during routine springtime monitoring on the Black River were tagged with T-bar style reward tags. Tags were inserted into the fish on the dorsal side directly underneath the soft dorsal fin (Nielsen 1992). Rewards on the tags ranged from $5 to $100 and a return mailing address was included on each of the tags.

In December 2004, a similar angler reward tagging study using Carlin dangler tags was initiated on the Eleven Point River. Carlin dangler reward tags were attached on the dorsal side of the walleye underneath the spinous dorsal fin in front of the last spine (see Nielsen 1992). Information on the tags included tag number and a return mailing address with rewards on the tags ranging from $10 to $100. All walleye collected during routine electrofishing samples (N = 149, range TL = 363 – 821 mm) and all stocked advanced fingerlings (N = 289, mean TL = 211 mm) were tagged.

A reward tag study was initiated in February 2009 on the Current and Black rivers. All walleye collected during routine spring monitoring were marked with similar tags using techniques described above. In 2010, all walleye collected were double marked with reward tags (Current River: Carlin dangler and T-bar; Black River: two T-bar tags) along with a distinct fin clip in order to obtain a more precise in-system tag loss estimate. This reward tag study is currently ongoing and this data will be used to further evaluate exploitation rates and movement of walleye in both of these rivers.

For each reward-tagged walleye recovered, displacement was calculated as the distance moved from point of release to where anglers recaptured the fish. Retention rates of the different styles of tags used were either estimated or evaluated in controlled systems for a short period of time (A.J. Pratt, unpublished data). Angler compliance was also estimated in order to adjust exploitation rates accordingly.

Oxytetracycline Marking

Some effort has been made to assess the relative contribution of BRS walleye fingerling stockings to the populations in these rivers using chemical marks. As part of a three-year supplemental stocking evaluation, the Black River was stocked with OTC marked walleye in 2000 (7,719 fingerlings), 2003 (41,505 fingerlings), and 2004 (7,732 fingerlings). In 2006, a subsample of walleye was collected for analysis of OTC markings using otoliths. All of the otoliths were aged and examined for marks by two independent readers. Ongoing research on the Current, Black, Eleven Point, and St. Francis rivers using OTC marked walleye continues to investigate the relative contribution of stocking to a specific year class.

RESULTS

Stocking Mortality

In May 2005, a total of 518 walleye (mean TL = 34.3 mm) were stocked into three net pens in a backwater of the Current River to assess mortality. Survival in the pens 48-h poststocking ranged from 94 to 96% (Table 1). In June 2006, 166 walleye (mean TL = 94 mm) were stocked into three net pens in a backwater of the Eleven Point River. Survival of walleye ranged from 96 to 100% 48-h poststocking (Table 1). In April 2007 a total of 391 walleye (mean TL = 28 mm) were stocked into three net pens in the same backwater of the Current River as they were in 2005. Walleye survival in the pens ranged from 92 to 97% 48-h poststocking (Table 1).

Internal and External Tag Comparison

A total of 40 walleye were tagged with either internal (N = 20; mean TL ± SE = 182.1 ± 1.6 mm) or external tags (N = 20; mean TL ± SE = 180.2 ± 2.3 mm). To serve as controls, ten additional walleye (mean TL ± SE = 179.6 ± 2.3 mm) were not tagged and held in the same raceway as the tagged fish. Fish

Tag Type	*N*	Fish Length (mm)	Tag Weight (g)	Surgery Time (s)	Tag Retention (%)	Mortality (%)
Internal	20	182.1 ± 1.6	1.2 ± 0.004	280.9 ± 22.1	90	0
External	20	180.2 ± 2.3	1.7 ± 0.005	117.2 ± 8.2	93	20
Control	10	179.6 ± 2.3	NA	NA	NA	0

Table 2. Mean lengths, tag weights, and surgery times for walleye subjected to the three different treatments for the tag retention study conducted in March 2005. Tag retention rate and mortality rate were also calculated for each of the treatments 6-weeks post surgery.

TL among tagging treatments did not vary (df = 2; F = 0.36; P = 0.70), however, surgery times for the external tags (mean ± SE = 117.2 ± 8.2 s) were significantly (df = 1; F = 44.4; P < 0.001) less than surgery times for the internal tags (mean ± SE = 280.9 ± 22.1 s). Although the dummy tags were similar in size to what was commercially available, the external tags required additional wire for attachment and therefore weighed significantly more than the internal tags (df = 1; F = 6307; P < 0.001).

Survival of walleye and tag retention varied across treatment groups. Six weeks post-surgery survival was 100% for all fish tagged internally and for control fish. For externally tagged walleye, survival was 80% for walleye six weeks post-surgery, however 5 externally tagged fish were not recovered at the end of the study. Tag retention was slightly higher for those fish tagged externally (93%) than those fish tagged internally (90%; Table 2).

Juvenile Movement

Weekly Movement

A total of 405 walleye locations (Current River = 232; Black River = 172) were recorded during the study. Extensive movement by radio-tagged walleye was observed early in the study with little movement occurring after the initial six weeks (Figure 3). A majority of the movement in the Current River was upstream, with only four walleye moving downstream of the release site. Only one of the walleye that moved downstream (approximately 33 km downstream into Arkansas and then back into Missouri) of the release site in the Current River survived the duration of the study. This was the only juvenile walleye that was located outside of Missouri waters. In the Black River, only six of the radio-tagged walleye moved downstream out of the large pool below Clearwater Dam. Movement was also more unidirectional in the Current River than in the Black River. Movement in the Current River was either upstream or downstream with very few walleye moving in both directions whereas in the Black River those walleye that moved into the river generally moved downstream great distances and then moved back upstream a significant distance to where they remained the duration of the study.

Large differences in total movement by walleye were documented between the Current and Black rivers. Mean total movement in the Current River was 52.4 ± 10.5 km (mean ± SE) and 18.2 ± 7.2 km (mean ± SE) in the Black River. The greatest total movement in the Current River was 123.3 km and 76.4 km in the Black River. In the Black River, substantial movements were only documented for those walleye that moved out of the large pool below Clearwater Dam and remained in the river the duration of the study. For instance, mean total movement of those walleye (N = 6) that moved into the river was 41.3 ± 13.6 km (mean ± SE) compared to 2.7 ± 0.5 km (mean ± SE) for those walleye (N = 9) that remained in the pool below Clearwater Dam.

Walleye movement rates varied among fish, between rivers, and through time. Daily movements of walleye varied considerably with minimal displacement ranging from as high as 5.2 km/day early in the study to as low as 0 km/day near the end of the study. Mean minimal displacement in the Current River was 0.39 ± 0.06 km/day (mean ± SE) and 0.25 ± 0.06 km/day (mean ± SE) in the Black River. Median weekly displacement was significantly greater throughout the telemetry study in the Current River than in the Black River (Wilcoxon test; P = 0.02; Figure 3). Median weekly displacement was also positively correlated with discharge levels in both the Current (r = 0.60; P = 0.01) and Black (r = 0.76; P < 0.01) rivers.

Final displacement was significantly different

between the Black (mean ± SE = 5.7 ± 2.5 km) and Current (mean ± SE = 32.7 ± 9.1 km) rivers (df = 1; F=8.23; *P* = 0.008). The furthest final displacement of a tagged walleye in the Current River was approximately 105 km upstream of the stocking location, only a few km below the confluence with the Jacks Fork River. The greatest final displacement of a tagged walleye in the Black River was 31.5 km downstream of the release site.

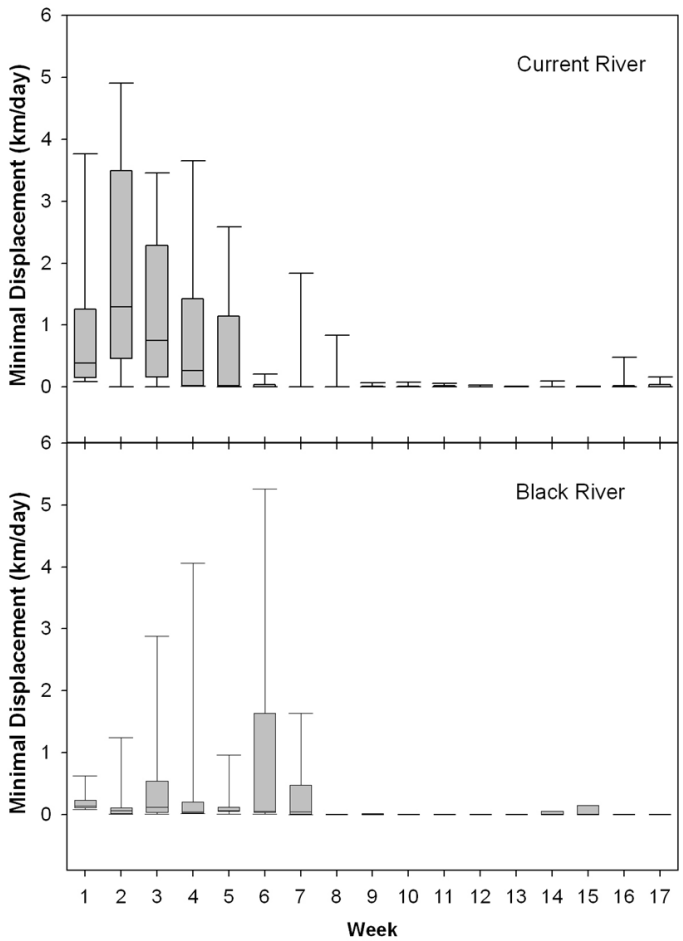


Figure 3. Box plots of weekly minimal displacement values for all juvenile walleye tracked in the Black and Current rivers during the telemetry study from April 12, 2007 to August 8, 2007.

Nocturnal Movement

Variable movements were witnessed during all three nocturnal tracking occasions with larger nocturnal movements (mean minimal displacement per hour) occurring in the Current River (mean ± SE = 76.6 ± 8.1 m/h) than in the Black River (mean ± SE = 23.3 ± 5.7 m/h; df = 1; F = 40.45; P < 0.0001; Figure 4). Mean minimal displacement of radio-tagged walleye differed (df = 5; F = 2.24; P = 0.05; Figure 4) among the six tracking periods. Most of the movement occurred during dusk hours (1800-2100) when walleye generally moved from their deeper daytime locations to shallower water where they were likely feeding. A majority of the walleye in the Current River would move out of their deep daytime locations to nearby shallow fast moving shoals. A slightly different behavior was observed in the Black River likely because a majority of the nocturnal trackings took place in the large pool below Clearwater Dam. At this location a majority of the tagged walleye remained in the spillway tailwaters in the large pool below the dam during the day and then moved into shallow low flow vegetated areas during nocturnal hours. Mean minimal displacement of walleye tracked in the large pool below Clearwater Dam (mean ± SE = 34.4 ± 13.0 m/h) was

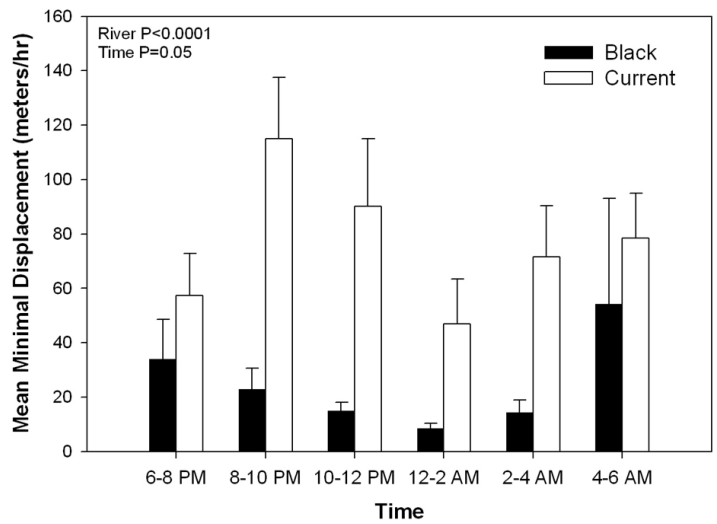


Figure 4. Mean minimal displacement values for the six different nocturnal time periods that the subsample of radio tagged walleye were tracked on three different occasions in both the Current and Black rivers. Error bars represent ± 1 S.E. of the mean.

greater than those walleye tracked in the river (mean ± SE = 15.2 ± 2.0 m/h). Movement back to within close proximity of their previous daytime locations or respective pools in both rivers occurred by dawn during almost every tracking instance.

Structure and Depth Associations

Radio-tagged walleye were generally located in different microhabitats in both rivers likely because the characteristics of each river are slightly different. Walleye in the Current River were generally located in the upstream portion of large deep bluff pools associated with structure (e.g. root wads, downed trees, or large boulders) that provided breaks from the swift current. Many of the walleye in the Black River remained in the large pool below Clearwater Dam for the duration of the study. Fish that remained in the

pool below the dam were generally located within the spillway tailwaters. Those walleye that moved downstream and out of the pool below the dam were generally found along current breaks created by root wads, downed trees, or vegetation adjacent to swift current.

Habitat in the pool directly below the dam is more characteristic of a lentic system; therefore, for comparison of the relative proportions of riverine habitat types walleye selected among rivers, all walleye locations from within the pool were excluded from the analysis. Structure types (i.e., boulders, root wads or downed trees, no structure, and vegetation) that walleye associated with differed between rivers (N = 242; df = 3; X2 = 14.43; P = 0.002; Figure 5). Root wads and downed tree habitats were most often selected by walleye in both rivers (Figure 5). Walleye were located in vegetated areas more often in the Black River (28.8 % of observations) than in the Current River (14.7 %). Walleye associated with boulders more in the Current River likely because boulders are more prevalent there than in the Black River.

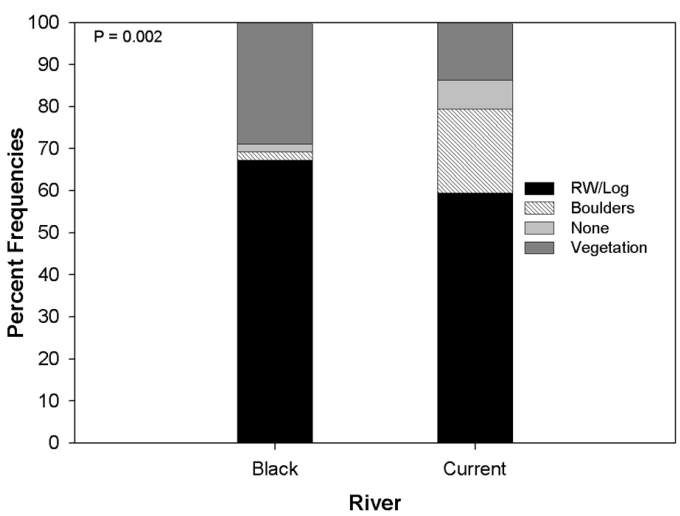


Figure 5. Percent frequencies of the structure types radio tagged walleye associated themselves with during the daytime locations in the Current and Black rivers. The percent usage of root wads/logs, boulders, no structure or vegetation by radio tagged walleye varied between rivers.

Overall, daytime depths selected by radio-tagged walleye in the Current (mean ± SE = 2.2 ± 0.05 m) and Black (mean ± SE = 2.4 ± 0.09 m) rivers did not vary (df = 1; F = 2.86; P = 0.09). When all depths from walleye locations in the Black River within the lentic pool below Clearwater Dam were excluded from the analysis, radio-tagged walleye were located at deeper (df = 1; F = 27.39; P < 0.001) depths in the Current River (mean ± SE = 2.2 ± 0.05 m) than in the Black River (mean ± SE = 1.53 ± 0.14 m). The subsample of walleye that were tracked during nocturnal hours were located in deeper depths during daytime hours than during nocturnal hours in both rivers (df = 1; F = 69.13; P < 0.0001; Figure 6). Mean daytime depth used by walleye in the Current River was 2.84 ± 0.10 m (mean ± SE) compared to the mean depth of 1.87 ± 0.10 m (mean ± SE) used during nocturnal hours. In the Black River, mean daytime depth used by walleye was 2.20 ± 0.11 m (mean ± SE) and decreased to 1.4 ± 0.10 m (mean ± SE) during nocturnal hours.

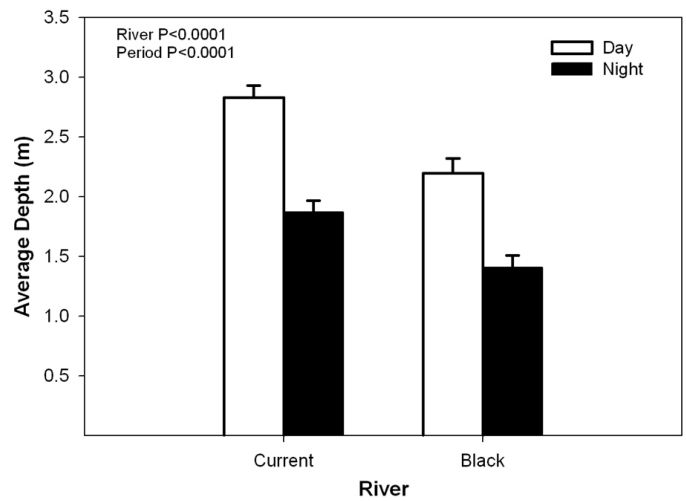


Figure 6. Comparison of daytime and nighttime water depths utilized by radio-tagged walleye that were tracked as part of the nocturnal movement study in both the Current and Black rivers. Error bars represent ± 1 S.E. of the mean.

Visual locations

Snorkeling and scuba diving were conducted randomly throughout the summer on a majority of the tagged walleye in the Current River. An attempt was made to locate the fish visually once a fish was located with the radio receiver. Many of the walleye were visually observed (Figure 7) in close proximity (within 5 m) to our estimated receiver locations giving us confidence in our triangulation ability. The juvenile radio-tagged walleye were often found with other walleye of a similar or larger size. However, during all of our visual inspections no young-of-year walleye were located with the radio-tagged walleye.

Mortality and Lost Fish

Mortality of tagged walleye occurred in both rivers during the telemetry study, and a majority (82%) of this mortality occurred within the first 60 d after stocking. Total mortality was 53.3% (8 of 15

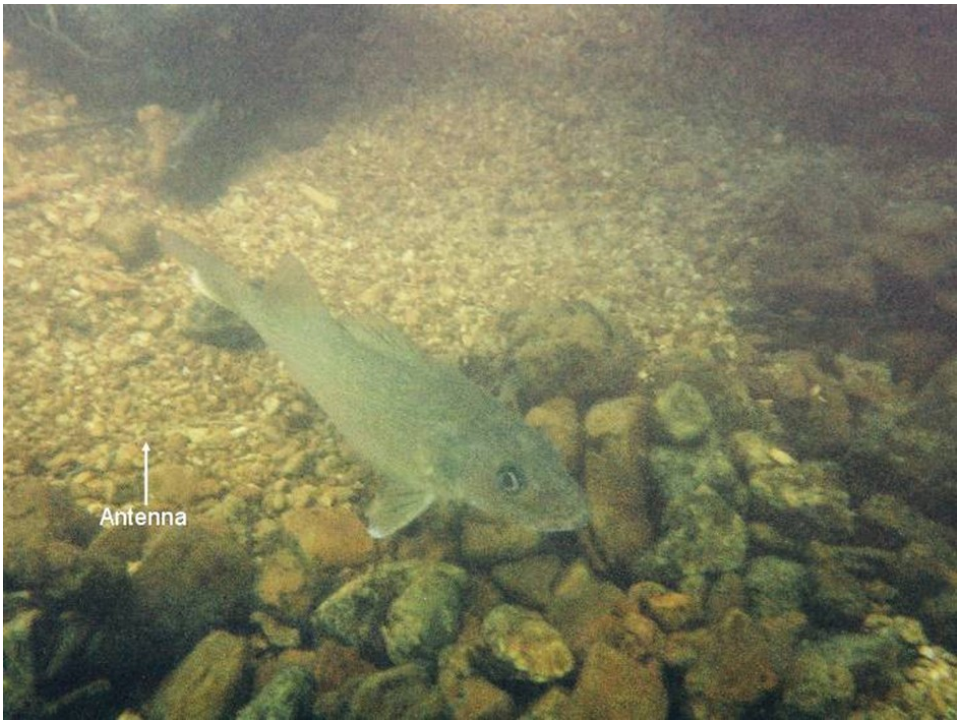


Figure 7. Underwater photograph taken of a radio tagged walleye while snorkeling in the Current River.

fish) in the Black River with five walleye being consumed by great blue herons *Ardea herodias*; this was confirmed by tracking tags to heron nests located in large rookeries. Three other walleye were determined dead, however, the cause of death was unknown. The majority of this mortality (7 of 8 fish) occurred in walleye that never moved downstream out of the large pool below Clearwater Dam. Total mortality in the Current River was only 20% (3 of 15 fish), and mortality due to great blue heron predation could be attributed to only one of those fish. Two other transmitters were recovered from a small tributary stream below the Doniphan, Missouri boating access and on a mowed path adjacent to the river, however, specific causes of mortality of these two walleye could not be determined.

Only two radio-tagged walleye were lost during the telemetry study. Both of those lost fish occurred in the Black River and were likely due to tag failure or illegal harvest since one of these radio-tagged walleye was later captured by Fisheries personnel during routine sampling. Tracker error was likely not the reason these fish went undetected during monitoring because all other fish in both rivers were located throughout the life of each tag. When fish were not detected, considerable effort was made to locate the fish by scanning upstream and downstream from the last known location.

Relative Weights

A total of seven radio-tagged walleye were recovered from the Black (N = 4) and Current (N = 3) rivers using electrofishing. Gill nets were not successful at capturing any radio-tagged individuals. Relative weights (Wr) of walleye recovered from the Black River and Current River ranged from 73.3 to 87.1 (mean Wr ± SE = 80.8 ± 2.9) and 86.3 to 108.7 (mean Wr ± SE = 99.2 ± 6.7), respectively (Figure 8). Dissection of all recovered walleye revealed high fat content in fish from the Current River and little to no fat in walleye from the Black River.

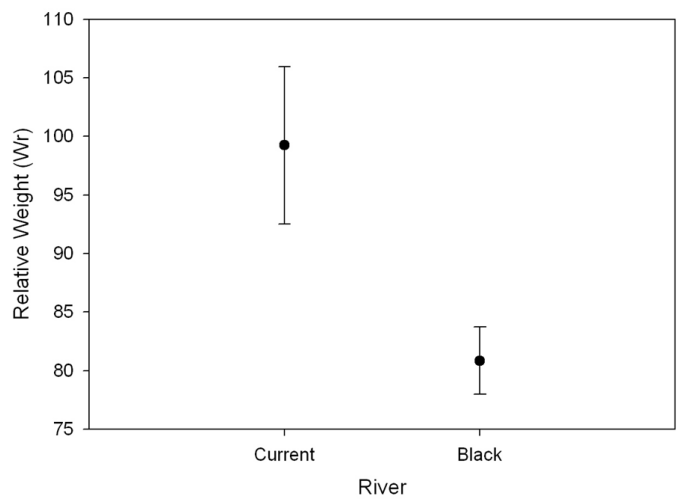


Figure 8. Mean relative weights calculated for tagged fish that were recovered from the Black (N = 4) and Current (N = 3) rivers at the conclusion of the telemetry study. Error bars represent ± 1 S.E. of the mean.

Adult Reward Tracking

From 1991 to 1994, Paul Cieslewicz (Missouri Department of Conservation, Fisheries Management Biologist) tagged 406 walleye (range TL = 305 - 840 mm) within the Black River. A majority of those walleye were tagged at two locations on the Black River (Clearwater Dam N = 326, Markham Spring N = 54). Since walleye tagging concluded in 1994 in the Black River, a total of 76 tags (18.7 %) have been returned and 65 of those fish were harvested. A majority (61.5%) of the walleye harvested were captured by anglers within a year of being tagged. Annual corrected exploitation rates using 80% angler compliance and 80% tag retention ranged from 4.3% to 15.9% (mean = 12.9%) for 1995 to 1998. A total of 24 walleye have also been recaptured multiple years during spring time electrofishing surveys on the Black River by MDC fisheries management biologists (two years N = 19, three years N = 3, four years N = 2). One of those fish was captured 8 years after tagging in the same location it was tagged.

Since 2004, a total of 438 walleye have been tagged with Carlin dangler tags in the Eleven Point River. Of these, 289 walleye were tagged and stocked as advanced fingerlings (mean TL = 211 mm) whereas 149 adult walleye (range TL = 363 - 821 mm) were tagged when collected while electrofishing. To date, anglers have returned a total of 30 tags, seven (2.4% of the advanced fingerlings tagged) of those walleye were stocked as fingerlings and 23 (15.4% of the wild fish tagged) were adult fish. In monthly walleye electrofishing samples, 49 tagged walleye have been recaptured (38 individuals once, 13 twice, 7 three times, and 1 four times). Many of the recaptured tagged walleyes were found from several months up to four years after initial tagging.

Reward tagging has provided some insight into the movements of adult walleye in these systems. A total of 64 tags were returned from walleye tagged at Clearwater Dam or Markham Springs during the 1991 to 1994 reward tagging project in the Black River. Twenty-nine (45%) walleye were captured in the same location they were tagged and the majority of the movement by other walleye was downstream (Table 3). Extreme movement patterns were exhibited by four walleye with three individuals being captured on the Current River near Doniphan, Missouri (approximately 341 km from the release site) and one walleye being caught in the Little Red River in Arkansas (approximately 541 km from the release site). Extreme movement patterns have also been exhibited by reward tagged walleye in the Eleven Point River (Figure 9). Only 4 of the 30 Eleven Point River tagged walleye caught and reported by anglers have been captured in the river within Missouri and 21 have been captured in Arkansas 14.5 to 73.2 km downstream of their release sites. Five other walleye that were tagged and released in the Eleven Point River moved to the mouth of the Eleven Point River, then up the Black River, and finally into the Current River (113.5 - 183.5 km; Figure 9).

Tagging Location	Capture Location	Displacement (km)
Clearwater Dam (*N* = 326)	Clearwater Dam (*N* = 26)	0
	Leeper, MO (*N* = 1)	- 10
	Mill Spring, MO (*N* = 4)	- 13
	Markham Spring Access (*N* = 1)	- 29
	Keener Spring (*N* = 10)	- 40
	Hendrickson Access (*N* = 4)	- 47
	Hickory Creek (*N* = 1)	- 64
	Sportsmans Access (*N* = 1)	- 74
	Current River, MO (*N* = 3)	-341
	Little Red River, AR (*N* = 1)	- 541
Markham Spring (*N* = 54)	Mill Spring, MO (*N* = 1)	13
	Markham Spring Access (*N* = 3)	0
	Keener Spring (*N* = 6)	-11
	Hendrickson Access (*N* = 2	-19

Table 3. Summary of movement by adult BRS walleye in the Black River derived from data obtained from angler-returned reward tags during the 1991 - 1994 reward tagging project. Sample sizes are shown for the number of walleye tagged at the two specific locations (left column) and those areas where walleye were caught by anglers (middle column). Displacement was estimated from tagging location to capture location.

Oxytetracycline Marking

In 2006, 35 walleye (range TL = 292 - 424 mm) from the Black River were sacrificed for OTC analysis. Thirteen of the 16 (81%) walleye collected from the 2003 year-class had an OTC mark whereas 8 of the 17 (47%) walleye collected from the 2004 year-class had an OTC mark. Though the sample size was relatively small, this suggests that stocking plays a substantial role in determining year-class strength of walleye in the Black River. Walleye otoliths from the Current River have also been examined for presence of an OTC mark to determine stocking contribution to the fishery; however, not enough conclusive data has been collected to determine walleye year class contribution to date in the Current River.

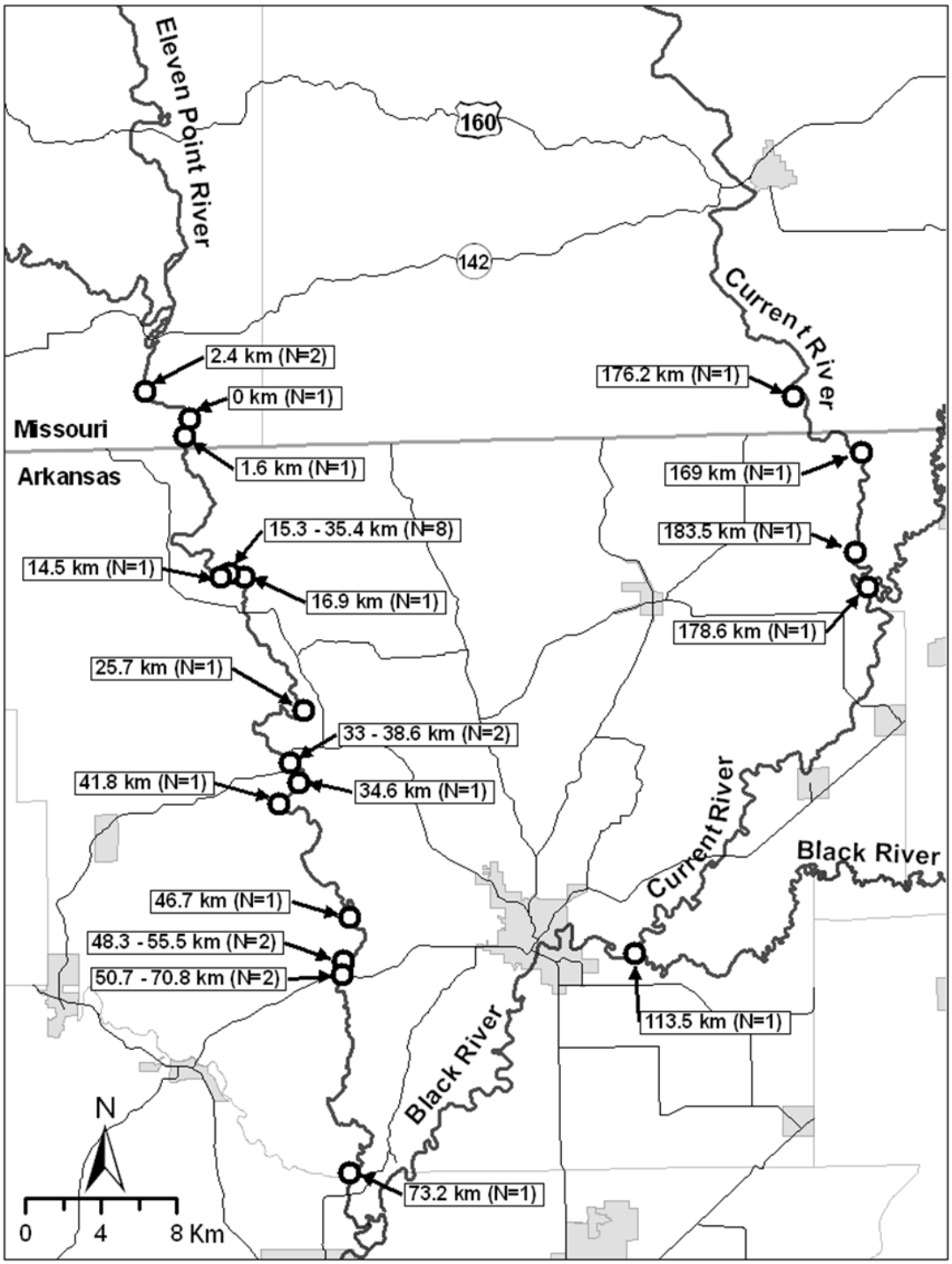


Figure 9. Capture locations (N = 30) of walleye tagged with Carlin dangler tags during the Eleven Point River walleye reward tag study (2004 to 2010). Fish were tagged and released at four different locations: Highway 160, Myrtle CA, The Narrows, and at the Missouri/Arkansas state line.

DISCUSSION

The Black River strain of walleye is a recreationally important fish in southern Missouri rivers. We took a multi-faceted approach to improve our understanding of juvenile and adult movement patterns and while doing so, discovered unknown predation pressures that exist within these river systems. We also examined current stocking procedures and began to assess their contribution to BRS walleye populations. Tracking the movements of age-1 walleye was unsuccessful in helping us determine the locations of young-of-year walleye although it did provide us insight into summertime holding areas of both juvenile and adult walleye in both rivers.

Stocking Mortality

Estimating the survival of newly stocked walleye fry or fingerlings is important information to gather in order to assess the usefulness of stocking programs and to assess potential contributions to year class strength. High survival (mean = 95.8%) of walleye fingerlings 48-h post-stocking during this study suggests that current stocking practices have little negative effect on survival of stocked walleye, and if poor contribution to a year class is observed, mortality is likely occurring later in life likely due to other causes. Several studies have investigated walleye fry or fingerling mortality occurring as a result of stocking practices by examining associated factors including water quality conditions, timing, chemical marking, and the stress associated with transportation (Madenjian et al. 1991; Pitman and Gutreuter 1993; Peterson and Carline 1996; Clapp et al. 1997). Peterson and Carline (1996) determined the relative effects of oxytetracycline marking, transport time, and hauling density on the survival of walleye fry 24-h post treatment. Mean walleye fry survival ranged from 87.0% to 97.3% regardless of the treatment levels tested and it was concluded that high post stocking mortality was not a result of the ranges in which the variables were tested. Pitman and Gutreuter (1993) had 0 to 34% survival of walleye fry 24-h poststocking and found survival decreased with increasing haul time. Black River strain walleye are generally stocked as fingerlings (25 -50 mm) and transport times and hauling densities are much less than those levels tested in both of these studies. The proper tempering of walleye before stocking is likely the most important factor and can greatly influence survival (Paragamian and Kingery 1992; Clapp et al. 1997). In our study, proper tempering practices ensured hauling tank water temperatures closely matched ambient river temperatures and this likely contributed to high survival 48-h poststocking.

High fingerling survival 48-h poststocking also suggests that fingerlings should continue to be stocked instead of fry. Although we did not examine fry survival after stocking in this study, previous attempts to stock walleye fry in these southern Missouri rivers in the 1960s had very poor results (Russell 1973). From 1967 to 1968, over 5.7 million walleye fry (TL < 25 mm) were stocked into the Current River; however, no juvenile walleye were sampled via drag seine, electrofishing, or SCUBA surveys and there was not an observed increase in angler catch rates (Russell 1973). It was concluded that survival of walleye fry was insignificant and, therefore, no contribution was made to the existing population. Other studies have also shown the benefits of stocking walleye fingerlings instead of fry. Not only is fingerling stocking survival higher, but higher contribution to a specific year class has also been documented (Clapp et al. 1997; Paragamian and Kingery 1992; Brooks et al. 2002).

Juvenile Movement

A standard practice during fish surgeries is the use of anesthetics (Hart and Summerfelt 1975; Summerfelt and Smith 1990; Mulcahy 2003). Currently, Finquel® (MS-222) is the only approved anesthetic for use on fish in the United States (FDA 2002) and the FDA requires that all fish that may be caught and eaten when released after the use of MS-222 be held for a minimum of 21 days prior to release (Anderson et al. 1997). The immediate release of radio tagged walleye in this study did not allow for the use of this anesthetic during surgery. The high survival upon release of tagged walleye suggests the use of the inverted technique described by Holland et al. (1999) is an appropriate technique for implanting radio receivers into juvenile walleye. This technique was also used on white sturgeon in the Klamath River because of similar constraints with the use of MS-222 (Welch et al. 2006).

Biotelemetry has been used to track walleye movements since the 1970s (Ager 1976; Holt et al. 1977); however, to our knowledge no one has attempted these techniques on yearling walleye. Past work examining walleye movements using biotelemetry focused on larger sized walleye

(range TL = 420 - 755 mm; Ager 1976; Holt et al. 1977; Kingery and Muncy 1988; Paragamian 1989; Palmer et al. 2005) compared to the age-1 walleye (range TL = 254 - 284.5 mm) monitored in our study. Although tag life was somewhat limited due to the small size, juvenile walleye could still be monitored for about four months.

Extensive movements were observed in both rivers over a relatively short period of time (within the first 6 weeks) during this telemetry study. Total movement, the rate of movement, and final displacement were all greater in the unimpounded Current River than in Black River where upstream movement was impeded by Clearwater Dam. A majority of the large movements in the Current River were upstream and only three of the walleye had final displacements below the release site at the end of the study. Upstream movement did not occur in the Black River due to Clearwater Dam, and only six walleye moved downstream out of the large pool below the dam.

Several different environmental and behavioral cues have been identified that may influence walleye movement in both river and lake systems, including discharge levels, weather, suitable spawning habitat, temperature, food availability, and habitat preferences (Smith et al. 1952; Auger 1976; Holt et al. 1977; Kingery and Muncy 1988; Paragamian 1989; Palmer et al. 2005; Hanson 2006). It was likely walleye movement in our study was influenced by a combination of some of these factors. The juvenile walleye in this study were likely not moving to search for suitable spawning habitat because they were stocked in both rivers as sexually immature fish after the spawning period. Discharge likely influenced movement in both rivers with increases in displacement following increases in discharge. Several other studies have shown that walleye activity is closely linked to changes in discharge levels (Kingery and Muncy 1988; Paragamian 1989; DiStefano and Hiebert 2000; Murchie and Smokorowski 2004). Large initial movements of some walleye may also be described as individualistic or a result of initial stocking dispersal (e.g., Brown 1961; Auger 1976; Kingery and Muncy 1988; Popoff and Neumann 2005). In this study it was difficult to know whether increases in discharge or initial stocking dispersal was the cause of most of the movement at the beginning of the study because they occurred during the same time period. Most of the tagged juvenile walleye observed during snorkeling were with similar sized or larger walleye suggesting walleye movement was probably a result of searching for suitable habitat with ample forage.

Nocturnal Movement

The majority of movement by radio-tagged walleye in this study occurred during dusk to dawn with very little movement by walleye observed during diurnal hours. On all three nocturnal tracking occasions in both rivers, we documented movement of tagged walleye out of their daytime locations to shallower habitat or nearby shoals probably to engage in feeding activities. This pattern of increased walleye movement during nocturnal hours has generally been attributed to both spawning and feeding activities and the absence of movement during daytime hours has been documented in several studies (Rawson 1956; Ager 1976; Holt et al. 1977; Kingery and Muncy 1988; Paragamian 1989; Hanson 2006). In our study, because the radio-tagged walleye were sexually immature, increased movement during nocturnal hours was likely attributed to foraging. We also observed the movement of walleye from the shallow shoals and vegetated areas they were utilizing during nocturnal hours back to within close proximity of their deeper daytime locations by dawn. This behavior of walleye closely resembles what Paragamian (1989) observed with adult walleye tracked in the Cedar River, Iowa. Although movement patterns in our study were similar to the Iowa study, they were examining the movement of adult walleye during the spawning season when they observed walleye returning to their respective pools from suspected spawning riffles just after dawn.

Structure and Depth Associations

Radio-tagged walleye in this study generally positioned themselves in areas where water was deep enough to provide sufficient overhead obscurity and where instream cover (e.g., vegetation, woody debris, or boulders) provided breaks from the swift current. The use of woody structure in summertime holding areas by walleye has also been observed in other river systems (Kingery and Muncy 1988; Paragamian 1989). Localities of tagged walleye were, however, slightly different between the two rivers. Walleye in the Current River were generally found in the upstream ends of large, deep bluff pools during all daytime locations whereas walleye in the Black River were located mainly in the spillway tailwaters. The spillway tailwaters provided suitable habitat (depth) for those walleye that had their upstream movement limited by Clearwater Dam. Daytime depths selected

by those walleye that moved out of the Clearwater Dam pool and into the Black River were slightly less than depths selected by walleye in the Current River. This could be a result of the Black River having fewer deep bluff pools and more turbid water than the Current River. Sufficient depth has been identified as an important characteristic of daytime summer holding areas for walleye in other systems (Kingery and Muncy 1988; Paragamian 1989).

Juvenile radio-tagged walleye were located in shallower depths during nocturnal hours than diurnal hours in both rivers. Shallower depths were selected nocturnally by walleye in the Black River than in the Current River. It is assumed walleye in both rivers are using shallower depths at night to engage in feeding activities during the summer. The use of shallower depths nocturnally by walleye has been observed in several other studies and has been attributed to spawning and foraging activities (Kingery and Muncy 1988; Paragamian 1989; Hanson 2006).

Walleye Mortality

Evidence has shown that piscivorous birds can have detrimental effects on fish stocks and can potentially cause large economic losses to fisheries in both natural systems and in rearing facilities (Glahn et al. 1999; Collis et al. 2002; Glahn and Dorr 2002; Hodgens et al. 2004). Great blue herons caused moderate mortality (20%) of radio-tagged walleye in this study. Much higher predation occurred in the Black River (33.3%) than in the Current River (6.7%). Relatively high mortality due to great blue herons in the Black River was likely a function of both stocking location and timing. The large deep pool below Clearwater Dam is more characteristic of a lentic system than a lotic system with shallow vegetated habitat along the entire perimeter. This type of habitat provided ample feeding grounds for the many great blue herons observed in the area. Since most of the walleye mortality occurred in the large pool below the dam and not in the riverine habitat, flow conditions may be influencing the ability of great blue herons to successfully forage. The nocturnal behavior of walleye moving to shallow waters in the large pool below the dam also likely made them more vulnerable to predation.

The stocking of the radio-tagged fish also closely coincided with the great blue heron reproductive season. Hodgens et al. (2004) documented in Bull Shoals and Norfork tailwaters of north-central Arkansas that heron daily energy demand peaked during the breeding season (March-May). Butler (1993) suggested that herons possibly match the peak energy demands of their chicks with a time of year that prey is most abundant at a certain location. Large heron rookeries likely exist near the pool below the dam because it is a shallow, productive system with abundant food and habitat for avian foraging.

The significance of nocturnal feeding habits of great blue herons has been a subject that has been debated in both tidal and non-tidal systems (Black and Collopy 1982; McNeil et al. 1993; Gawlik 2002; Hodgens et al. 2004). Nocturnal foraging activity has been shown to be equal to diurnal foraging activity in salt marsh habitat and has been correlated to tidal patterns (Black and Collopy 1982). In other systems nocturnal foraging by great blue herons is absent or considered to be not significant (Gawlik 2002; Hodgens et al. 2004). In this study, predation likely occurred during nocturnal hours with the nocturnal movement of walleye into shallower habitats and the observation of great blue herons feeding throughout the night within the study area.

Adult Reward Tagging

An understanding of angler utilization of walleye stocks in these rivers is important information to have in order to better manage these populations. Quantifying angler exploitation and natural mortality are necessary to successfully model a population. Annual exploitation rates in the Black River ranged from 4.3 to 15.9% (mean = 12.9%) over a three year period assuming 80% tag return compliance and tag retention rates. Although exploitation or angler return rates were relatively low during this tag study, our results are similar to what other studies have shown for walleye in different systems (Smith et al. 1952; Schoumacher 1965; Schneider et al. 1977; Dames and Brown 2010). Schoumacher (1965) indicated a minimum of 16% angler exploitation based on tag returns from 1,149 walleye and 1,836 sauger tagged during a three year period in the upper Mississippi River. Schneider et al. (1977) estimated 19.9% exploitation by anglers over an 18 year period from 4,400 walleye tagged in Lake Gogebic, Michigan, in 1947. These results are similar to what we found in the Black River with a total of 18.7% of the tags from walleye being returned by anglers. Angler tag returns in the Eleven Point River have only been 6.8% since the study was initiated in 2004. However, this may be a function of both tag loss and the mortality of the advanced walleye fingerlings tagged. This is suggested because a

higher proportion of tags were returned from adult fish (15.4%) tagged from the river than the advanced fingerlings (2.4%) that were stocked.

Exploitation rates that are uncorrected for precise estimates of both tag loss and angler compliance (i.e., tag return rate) can be extremely biased (Kallemeyn 1989; Muoneke 1992; Pollock et al. 2001; Miranda et al. 2002). Therefore, in an ongoing reward tag study in the Current and Black rivers, we are quantifying a more precise in-system estimate of tag loss using a double mark method (e.g., Kallemeyn 1989; Muoneke 1992). We will likely move towards more precise estimates of angler compliance during future reward tag studies in these rivers using a high-reward tagging program (Pollock et al. 2001).

Reward tagging studies have also provided insight into the mobility and longevity of BRS walleye in these rivers. Extensive movements were undertaken by walleye in both the Eleven Point and Black rivers during the recent reward tag studies. Movement of tagged walleye in the Black River was more representative to what other studies have shown for adult walleye where a majority of the angler returns occurred in close proximity to where walleye were tagged and only a few walleye exhibited extreme movement patterns (Smith et al. 1952; Schoumacher 1965). In contrast, a majority of the reward tagged walleye in the Eleven Point River were captured by anglers significant distances from where they were tagged. Since most of the tag returns were from the lower Eleven Point River in Arkansas, walleye in this river may only be using the upstream portions of the river during the spawning season. Most of the walleye in this river are collected from March through May while electrofishing at locations from the state line to 10 km above it, and many of the large females collected in the spring are already spent (John Ackerson Personal Com.). It is hypothesized that because most of the walleye were tagged during the spring and many of the electrofishing recaptures also occurred during the same time period in following years, walleye are being captured while migrating upstream to spawn or during post-spawning migrations downstream. During the summer months, walleye in the Eleven Point River are likely seeking deeper holding areas downstream and as a result are susceptible to angling for a longer period of time in Arkansas than in Missouri. Although we do not have detailed age and growth data for the walleye in these systems, it is likely that natural mortality of adult fish is low due to the longevity of some of the tagged fish in these rivers. Many of the reward tagged walleye in the Eleven Point and Black rivers have been recaptured multiple years while electrofishing during spring sampling. One walleye in particular was recaptured while electrofishing eight years after it was tagged in the Black River. Schneider et al. (1977) had tags from jaw tagged walleye returned by anglers up to 18 years after tagging.

Oxytetracycline Marking

Preliminary data suggests the contribution of stocked fingerlings to the existing BRS walleye population in the Black River is substantial. In the Black River, 33 walleye (age-2 and older) were examined for OTC marks from two different year classes and 64% of them were stocked walleye. Many of the stocking contribution studies done on walleye have been conducted in lakes, used age-0 fish collected in the fall, and have obtained large sample sizes for OTC analysis (Kayle 1992; Lucchesi 2002; Vandergoot and Bettoli 2003). In our study, walleye younger than age-2 are generally not collected during electrofishing surveys and it is difficult to collect enough walleye to have a sufficient sample size. Heidinger and Brooks (1998) found in an open system, contribution of stocked saugers to individual year-classes decreased each subsequent year after stocking, likely due to both immigration of wild saugers into and emigration of stocked saugers out of the sampling area. This study provides more evidence that it may be difficult to determine walleye stocking contribution in rivers due to the high mobility of walleye in an open system. Further investigation of stocking contribution in these rivers needs to be conducted, with more robust samples and efficient sampling techniques before we will be able to draw confident conclusions as to the success of stocking BRS walleye fingerlings.

MANAGEMENT IMPLICATIONS

Much progress has been made towards a better understanding of BRS walleye populations in southern Missouri rivers. Previous research on the benefits of stocking walleye fingerling instead of fry, in combination with the stocking mortality estimates reported here, suggest we should continue to stock BRS fingerlings to boost native stocks. Natural recruitment is considered low or nonexistent in all of the BRS walleye rivers, therefore stocking should continue in these rivers to maintain or improve this unique fishery. Great blue herons can have detrimental effects on the fisheries in these rivers, especially in the Black River. The Missouri Department of Conservation should be cautious when selecting stocking locations in small streams and rivers to reduce the likelihood that recently stocked fishes will be preyed upon by avian predators. Stocking locations near rookeries should be avoided, since an increased predation pressure on the local fishery could occur. If stockings must occur near rookeries, stocking during the peak of great blue heron nesting should be avoided if at all possible. The type of habitat that juvenile BRS walleye seek from spring through summer was also confirmed during this study. Since juvenile walleye are using the same habitat as adult walleye, managers can use this information to develop more efficient sampling methods for use on the rivers. More efficient sampling methods will be required if further sampling is undertaken to collect walleye of various sizes to model population dynamics.

Future Directions

One of the major pieces of information still missing is the movement and behavior of naturally-produced and stocked juvenile (age-0 or 1) BRS walleye in these rivers. Juvenile walleye are not observed by fisheries management biologists in significant numbers until they are age-2 and older. The ultimate goal of the telemetry study was to gather movement and location information on the smallest walleye (age-1) we could tag using the current telemetry equipment available with the hopes that juvenile walleye movements would lead us to other age-0 walleye. Although this study did not provide us the specific information we were seeking, it did provide us with a better understanding of the behavior and movement of juvenile and adult BRS walleye.

Future research will need to take a new approach for determining the fate of young-of-year walleye from stocking until they reach an age where they are collected in population surveys. It is hypothesized that young-of-year walleye seek much different habitat during the first year of life than adult walleye, and this reason is likely why we are not seeing many young-of-year walleye in these rivers. It is likely young-of-year walleye are moving or drifting in these rivers long distances downstream into Arkansas and utilizing lower flow and more productive, lentic-like habitats. Kuhn et al. (2008) observed this pattern of behavior in saugers in the Little Wind River drainage in Wyoming. In the Little Wind River system, juvenile saugers are not present in river samples although they have been found in a large downstream reservoir. Kuhn et al. (2008) hypothesized that larval saugers produced in the river system drift into the reservoir and remain there until they reach sexual maturity. At that time, large upstream movements occur and the saugers disperse throughout the Little Wind River drainage for the remainder of their life. It is possible this pattern of behavior is occurring with larval and fingerling walleye in BRS walleye rivers, where stocked or naturally reproduced fish are drifting downstream and then returning to upstream areas when they reach sexual maturity. Future sampling to determine young-of-year walleye localities should be directed towards addressing this hypothesis.

Additional research efforts should also be directed towards more precise estimates of walleye growth, exploitation, natural mortality, and recruitment in these rivers. To accomplish this, we will need more robust samples of bony structures for age, growth, and OTC analysis, more precise estimates of angler tag return rates, and in-system tag retention rates during reward tag studies. Efforts are already underway to determine in-system tag retention rates during our reward tag studies using a duel tagging method. Preliminary investigation has been initiated on the use of spines for analysis of OTC markings instead of otoliths, which may be a non-lethal way of determining stocking contribution. Many efforts have been made to understand BRS walleye in these systems, and with research goals moving towards a better understanding of walleye population dynamics in these rivers, fisheries management biologists will be able to more effectively manage this unique fishery.

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