PENNSYLVANIA SEA GRANT
FINAL REPORT
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1. Cover Page

a. **Title:** *Quantifying seasonal movement dynamics and thermal habitat use of smallmouth bass in the Susquehanna River basin: implications for fish disease and fisheries management*

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2. Executive Summary

Smallmouth bass (*Micropterus dolomieu*) are both a socieconomically prized sportfish as well an apex predator. In the Susquehanna River basin, smallmouth bass populations declined in the 1990s through the early 2000's and although populations appear to be relatively stable in recent years, there are still concerns over what caused the initial decline. In addition, there remains uncertainty as to what has caused more recent incidences of disease and young-of-year mortality events. Several factors that may be affecting smallmouth bass health have been identified, including pathogens (e.g., bacteria, viruses, and parasites), contaminants (e.g., endocrine disruptors), and water quality conditions (e.g., elevated stream temperatures). Because the duration and frequency of exposure to these potential stressors is largely dictated by how smallmouth bass move and utilize different habitats, understanding the movement ecology of this species is critical. To address this issue, we used radio-telemetry to study movement and river and tributary habitat use of smallmouth bass in the Susquehanna River basin. Understanding movement patterns will provide insight on where fish could be spending large amounts of time, and therefore help understand where and when they might be exposed to various stressors. This study demonstrated key movement periods related to spawning and overwintering. Several fish utilized tributaries for spawning, but spent the majority of the time in the main-stem of the West Branch of the Susquehanna River. Overall movement varied substantially among individual fish, ranging from under a kilometer to over 90 km during the study duration (from May 2014 to June 2015). The results of this telemetry study have implications for studying disease and contaminant-related stressors in smallmouth bass and for fisheries management, including harvest regulations.

3. Report

a. Introduction

Smallmouth bass were introduced in the Susquehanna River basin in the 1870s (Stillwell et al. 1895) and since have become a revered and economically important sportfish. In addition, the smallmouth bass occupies the role of a top-predator in the system. The smallmouth bass population supported a popular and productive fishery throughout the basin, until population declines were noted in some portions of the system. For example, declining trends in adult smallmouth bass catch rates (catch per effort) began during the 1990s through the 2000s in the Susquehanna River main-stem (>90% probability of decline) and more recently the West Branch of the Susquehanna River (>65% probability of decline during the mid to late 2000s) (T. Wagner, U.S. Geological Survey, personal communication). Population declines have also occurred in tributaries of the Susquehanna River, including the lower Juniata River where declines occurred with over 90% probability for a period of time during the 1990s. In

addition to documented adult declines, reports of mortality and potential declines in young of the year smallmouth bass have also been noted in the Susquehanna River basin since 2005, raising concern for future recruitment (Arway and Smith 2013). The observed declines in smallmouth bass abundance, paired with the presence of disease, have resulted in efforts to study the system by a wide range of interest groups. Recently, there has been a large collaborative effort between state, and federal agencies, universities, and private interest groups (e.g., anglers). This study was part of that effort.

Not only are population declines a concern, smallmouth bass in the Susquehanna River basin are also being found with a wide range of concerning characteristics, including the presence of intersex in male fish (Blazer et al. 2014), melanistic spots, and external lesions. Several environmental stressors including pathogens (e.g., largemouth bass virus, Myxozoan and Trematode parasites, *Flavobacterium columnare*), poor water quality conditions (e.g., elevated temperatures), and contaminants (e.g., endocrine disruptors, Blazer et al. 2014) have been identified as potential risk factors. Smallmouth bass in the Susquehanna River basin are not the only smallmouth bass to have disease and intersex present in their populations. In the Potomac River drainage, adult smallmouth bass have been documented with both intersex and a wide range of pathogens, however differences also exist (i.e., mortality events of adults in the Potomac River, but not in the Susquehanna River basin) (Blazer et al. 2011). Yet in any environment, links between these risk factors and smallmouth bass ecology are difficult to understand. For instance, life history characteristics and seasonal habitat needs may influence where a fish inhabits and thus what it is exposed to environmentally. The Susquehanna River basin provides a wide range of both river and tributary habitats that smallmouth bass may utilize differently throughout the year.

Understanding movement and habitat use of smallmouth bass in the Susquehanna River basin will provide insight for when and where fish may occupy different parts of the river and tributary system, and how this relates to both population and disease management. Previous studies on smallmouth bass movement have been completed in their native range, including the Midwest and Great Lakes regions. Result from those studies demonstrated a high degree of variability among study systems and individual fish within the study systems (Lyons and Kanehl 2002, Gunderson VanArnum et al. 2004). Previous telemetry studies provided insight on potential movement periods, including spawning and overwintering associated movements, but given the variability in those studies and the fact they were done in very different systems, they do not allow extrapolation to movement patterns that may exist in the Susquehanna River basin (Lyons and Kanehl 2002).

In addition to relative range of movement, the habitat occupied could also be important for exposures to stressors including contaminants, pathogens, and poor water quality. For instance, during

low summer flow, smallmouth bass may be subjected to thermal habitat that is suboptimal (e.g., temperature preference for smallmouth bass is up to 31°C, Barans and Tubb 1973). Temperature thresholds above 34°C have been documented to have adverse effects on smallmouth bass (e.g., equilibrium loss: Smale and Rabeni 1995, spasms: Lutterschmidt and Hutchison 1997). Elevated temperatures in juvenile smallmouth bass habitat have previously been documented, with temperatures exceeding 31°C in the Juniata River during summer 2008 (Chaplin et al. 2009). Although adult smallmouth bass may not be routinely subjected to such extreme temperatures, exposure to elevated temperatures may result in physical stress, leading to an increase in disease susceptibility. Additionally, the amount of time spent in various habitats may correspond to important reproductive endpoints – including both overwintering, when gonad development is beginning, and spawning, where reproduction and the stress of reproduction occur. Previous research on nesting sites in the Potomac River basin found a wide range of chemical compounds in both water and sediment, including possible endocrine disrupting compounds (e.g., 17-alpha-estradiol and atrazine: Kolpin et al. 2013). Although direct exposure of juveniles to possible endocrine disrupting compounds may be an important factor affecting juvenile fish health, maternal egg composition and contaminants in yolk source for offspring may also play a role in determining the health and immunocompetence of young fish. As such, understanding where adults spend large proportions of their time (i.e. tributary versus river habitats) may have consequences for immunosuppression of adult and juvenile fish and reproductive success of adult fish.

Thus, regardless of the specific stressor or group of stressors that could be attributed to the population decline and concerning fish health characteristics of smallmouth bass in the Susquehanna River basin, understanding more about movement dynamics and thermal habitat use will be key in beginning to more fully understand the interaction between smallmouth bass and the stressors in the environment. The objective of this research was to investigate smallmouth bass movement dynamics and thermal habitat use in a portion of the Susquehanna River basin, the West Branch Susquehanna and two of its tributaries.

b. **Methodology**

Study Area and Layout

Prior to beginning the study, a suitable research area was selected in the Susquehanna River basin. The study area needed to include tributaries and main-stem river habitat that lacked barriers to tributary-main-stem movement. In addition the study area needed to be logistically feasible for radio-telemetry, which placed limits on both the depth and width of the water body and required access for tracking fish via land and water. The West Branch of the Susquehanna River and two tributaries, Pine Creek and Bald Eagle Creek, located in central Pennsylvania, were selected as the study area (Figure 1). Dams are present on both the West Branch of the Susquehanna River and on Bald Eagle Creek, but these barriers did not inhibit movement between the river and tributaries. Road access for tracking fish on land was available in several portions of the study area, and several canoe and boat launches were available for water access.

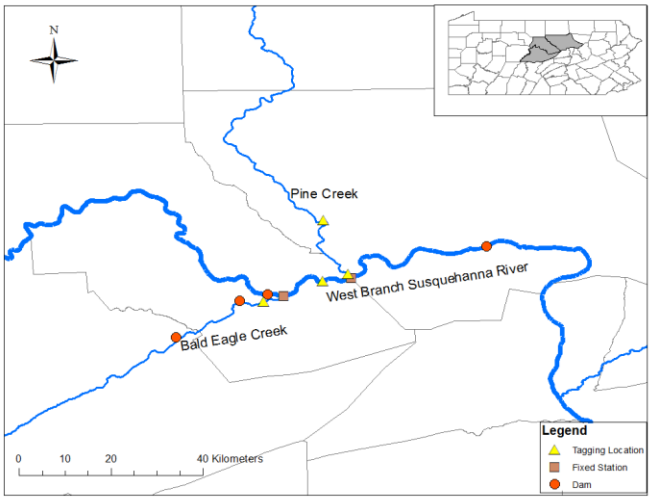

Figure 1: Map of the telemetry study area with four tagging locations (triangles) and two fixed stations (squares) for evaluating river and tributary movement of adult smallmouth bass. Dams in the study area are represented by circles.

A total of 40 adult smallmouth bass were tagged in the study area at four different tagging locations (10 fish at each location) (Figure 1). Fish were tagged during pre-spawn conditions spring 2014 when they would be in or near spawning habitat. Tagging locations included the mouth of Bald Eagle Creek, the mouth of Pine Creek, 16 km upstream from the mouth in Pine Creek (Ramsey, PA), and on the West Branch Susquehanna River in between Pine Creek and Bald Eagle Creek (McElhattan, PA) (Figure1). Fish were collected using towboat and boat electrofishing with the assistance of Pennsylvania Department of Environmental Protection (PA DEP) and Pennsylvania Fish and Boat Commission (PFBC). Electrofishing efforts were also supplemented by angling.

Radiotelemetry Procedures

Fish were surgically implanted with LOTEK MCBTF-2 temperature sensor radio tags (Lotek Wireless, Newmarket, Canada) weighing 8g with a trailing external antenna. Each tag had a unique identification number that allowed each fish to be identified every time it was detected. Radio-tags were surgically implanted in the body coelom posterior to the pelvic girdle using the shielded needle technique (Ross and Kleiner 1982). The antenna was allowed to trail out the side of the body (Figure 2). Sterile techniques were employed, using clean utensils, scalpels, and sutures for each fish. Non-absorbable monofilament sutures were used to close the incision, with interrupted sutures tied using a surgeon's knot. Fish were placed under anesthesia using MS-222 with a maintenance dose pumped through the gills during the entire procedure. Prior to release, fish were placed in individual instream net pens for 15-20 minutes to recover from the surgical procedure. Recovery was noted and fish were released once strong opercular movements occurred, equilibrium was regained, and regularly swimming motions are observed. The handling of fish followed protocols approved by The Pennsylvania State University Institutional Animal Care and Use Committee (IACUC # 42544).

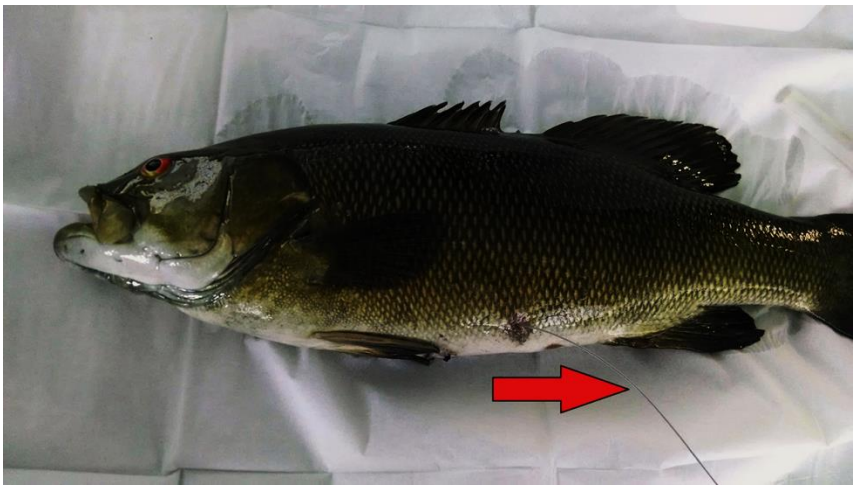

Figure 2: An example of a radio-tagged smallmouth bass with a trailing external antenna after the completion

Tracking Procedures

After tagging, fish were given at least two days before tracking began. Fish were located using both manual (LOTEK SRX 400A) receivers and data logging fixed stations (LOTEK SRX DL-3) located at the mouth of both tributaries (Figure 1). Fixed station setups included two antennas to determine directionality of fish movement and were solar powered to continually log fish movement. Due to the

size of the system and limited access, it was not possible to always get precise locations of all fish; however, GPS locations were within 100-200 meters of the actual fish location.

Manual tracking occurred as frequently as possible, beginning in May 2014 and ending after tags began to die (May-June 2015). Tracking effort was rotated between sample areas to ensure that effort was evenly distributed across the study area. Tracking efforts were reduced after fish moved into overwintering habitat in the West Branch of the Susquehanna River and ice began to form on the river and tributaries (November 2015). Overwintering areas were periodically checked with increasing intensity to weekly intervals in March 2015 in an effort to identify when movements began after winter ice-out.

Data Evaluation

Fixed station data – The multi-antenna system made it possible to determine when a fish crossed the fixed station and what direction it was coming from. A location was logged when the signal strength was highest on a given antenna or switched antennas when crossing. Low signal readings or few readings could make it hard to tell if a fish crossed. In these instances, future locations were used to support the type of movement made by an individual fish. If a fish remained in close proximity to a fixed station for extended periods of time, additional locations were logged after a few hours.

Manual tracking data – With each manual location the following information was recorded: fish id, temperature, and location (GPS reading). It is likely that some of the fish were harvested by anglers, died due to natural causes, or dropped their tags (i.e., the radio tagged fell out of the fish). To address the potential for dropped tags, each fish was assessed for movement to evaluate whether a lack of movement might be due to a fish not moving or that a tag had been dropped. Specifically, animation plots of each fish's movement patterns were created using program R (R Development Team 2008) through R Studio (R Studio Team 2015) and RGoogleMaps (Loecher and Ropkins 2015). Each animation was evaluated by two separate readers. Each reader documented if movement occurred, when movement ceased, and the probability of a drop tag. The readers then discussed and compared their assessments and any fish that were in disagreement were re-evaluated. Fish that moved and then movement ceased for extended periods of time and that did not show any spring movements were considered dropped tags. These fish were removed from movement evaluations beyond the point in time the tag was deemed dropped. Fish that did not move the entire time period were not considered dropped tags.

Summaries- Data were summarized to determine key movement periods, range of movement, locations during key life history events (e.g., overwintering and spawning), and temperatures occupied.

If fish were considered to have dropped a tag based on video diagnostics, they were removed from corresponding summaries. For example, if a fish moved until overwintering, but did not move for spawning, it was included in overwintering summaries, but omitted from spawning summaries. Movement and location patterns were evaluated for movement to overwintering, total movement, and locations both for overwintering and spring spawning. Thermal habitat use patterns were compared to stream temperatures from two fish which were tagged in the tributaries and moved throughout the entire study duration. During the yearlong duration, (2014-2015) in general both stream and fish temperatures did not exceed 31°C, limiting further investigation into potential avoidance of suboptimal temperatures. Therefore, temperature results are only reported from two fish that moved throughout the entire time period for demonstration of stream and fish temperatures over the entire study period.

c. **Results**

Overview

Smallmouth bass that were tagged ranged from 694-1747g (average = 1057g) in weight and from 373-505mm (average = 428mm) in total length. A total of 630 locations were collected between spring 2014 and spring 2015. After video review, 180 locations were omitted due to the possibility of dropped tags, which left 431 locations used in data summaries. A total of 16 fish were considered dropped tags by the end of the study, with 9 of the 16 drops having five months of data collected prior to the tag being dropped. One fish was harvested by an angler and reported to be caught during June 2014 and two fish were only located a couple times and then never located again, resulting in 21 fish remaining at the end of the study.

Movement

Total movement was variable, ranging from 0.5 - 97.7 km (average = 36.5 km) for fish that were not considered to have dropped their tags during the entire time period (Figure 3). Seven fish covered distances of greater than 50 km over the one year study period. Movement was also variable within and among the sites, with the West Branch having the largest proportion of fish that moved small distances (<20km, 4 out of 9 fish) (Figure 3). Distance moved to overwintering habitat also was variable ranging from 0.3 - 48.3 km (average = 19.5km) (Figure 4). The majority of the movement occurred during three time periods: 1) after spawning (late spring/early summer 2014), 2) overwintering (late summer/early fall 2014), and 3) transitions into spawning habitat (April 2015). Three sample movement videos from fish that moved and returned to spawning habitat can be downloaded and viewed at: https://www.dropbox.com/sh/dsdh5esafffevlm/AAADszchn0tgnChMwf7SG0rQa?dl=0. The three videos consist of one fish from each of the following: Pine Creek Ramsey, Bald Eagle Creek, and West Branch Susquehanna River. Scale bars were not provided on the video map, but the distance between Lock Haven and Williamsport is approximately 50 km.

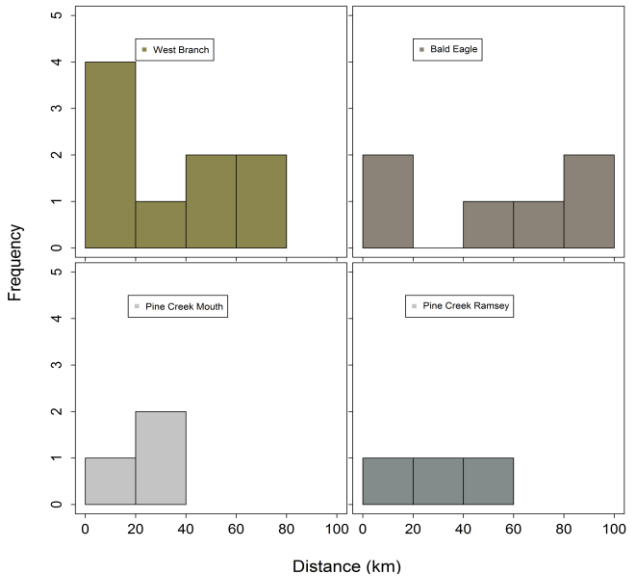

Figure 3: Distance moved during the entire study period by site. Fish included were only those that were not eliminated due to being potential dropped tags.

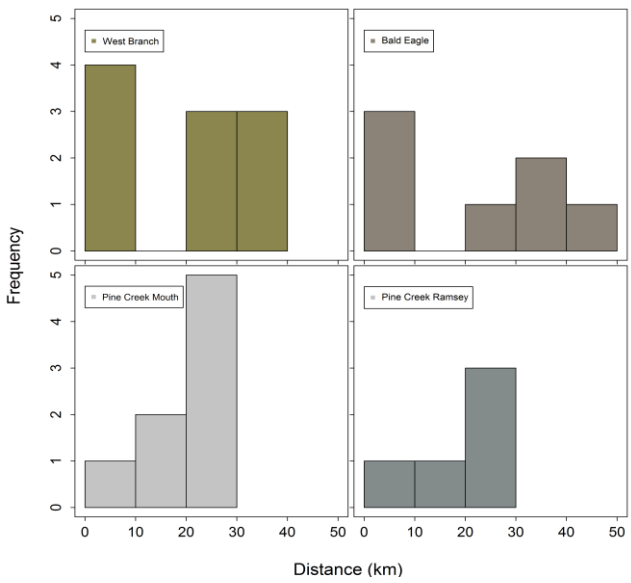

Figure 3: Distance moved to overwintering habitat. Fish included were only those that were not eliminated due to being potential dropped tags.

Tributary-River Movement

After the initial spring tagging (2014), 22 out of 30 fish tagged in the tributaries moved out into the West Branch of the Susquehanna River. Of the remaining fish in the tributary (8), four were later classified as dropped tags, in which fish were heading downstream towards the mouth of the tributary prior to dropping tags. During spring 2015, 7 fish tagged in tributaries returned from the river to the previous year's spawning location in the tributaries (4: Bald Eagle Creek, 3: Pine Creek), indicating some level of spawning site fidelity. None of the fish tagged spring 2014 in the river entered into either tributary during the duration of the study.

Locations by Season

Smallmouth bass, in general, occupied different habitat for seasonal life history requirements, including overwintering and spawning. Fish were congregated in river habitat for overwintering (Figure 5), primarily in deep pools upstream of a dam located in Williamsport, PA and near Linden, PA. Fish then dispersed throughout the system during the spring of 2015. Fish also returned to areas in close proximity to previous spawning locations (Figure 6); although, a small sample size (due to dropped tags) limits the ability to make inferences regarding spawning site fidelity.

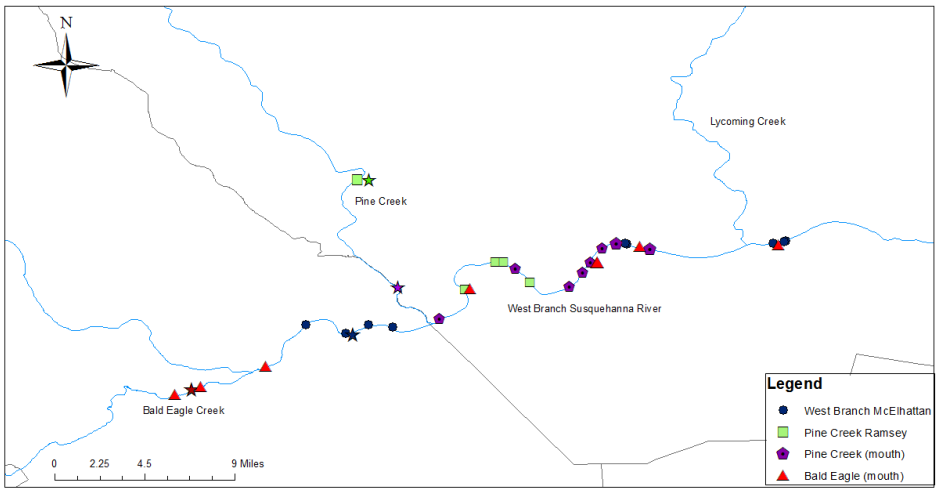

Figure 5: Locations of tagged fish at last location before winter 2014. Fish were congregated in river habitat near Linden, PA and Williamsport, PA.

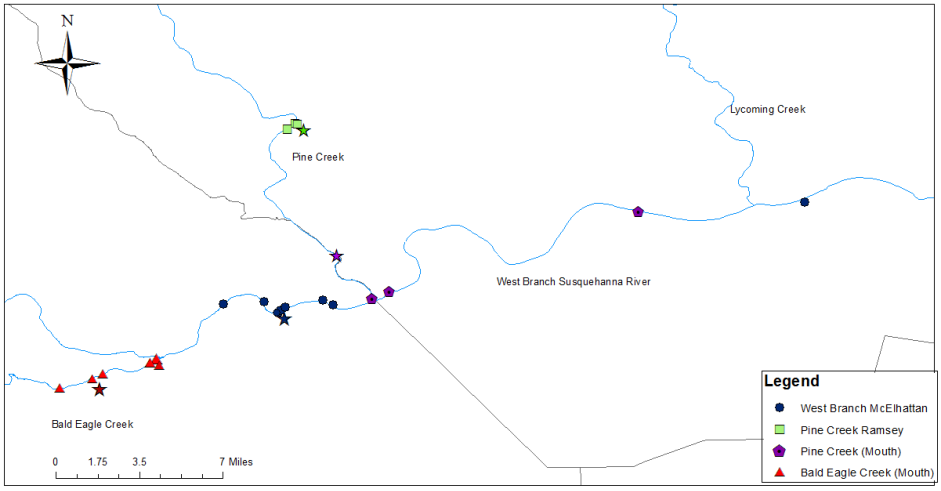

Figure 6: Locations of tagged fish during spring 2015 close to the time fish would be preparing for spawning.

Thermal habitat use

Because it was hypothesized that elevated water temperatures could play a role in thermally stressing smallmouth bass and make them susceptible to disease, internal temperature sensors were used to investigate temperatures that fish were occupying. However, temperatures did not exceed smallmouth bass preferred temperature (> 31°C) during the study period, with the warmest temperature a fish was located in was between 27.6 and 28.4°C during June and July 2014. Several tags (8 total) were located in waters above 31°C, but these were already considered dropped tags at the time

(likely out of water), gave the maximum sensor reading of 34°C, or were previously documented as erroneous in field notes. Water temperatures in Pine Creek were measured from the USGS Gage Station 01549700 located in Waterville, PA (U.S. Geological Survey 2015) and the highest temperature recorded at that gage during the study period was 28.8°C in July 2014. Because the preference temperature was not exceeded during the study period, no investigation into thermal habitat use during stressful thermal conditions was possible. For illustrative purposes, temperatures from two tagged fish were compared to stream temperatures on Pine Creek (Figure 7). The fish were tagged in either Pine or Bald Eagle Creek and moved into the river for overwintering before returning to their respective tributaries. Fish and stream temperatures were comparable throughout the study period regardless of whether the fish were located in the river or in the tributary.

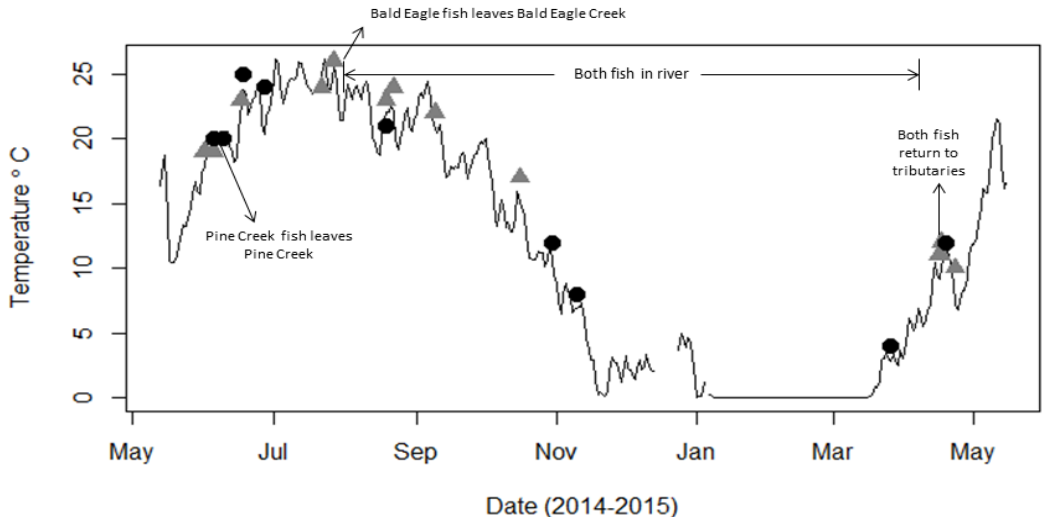

Figure 7: Pine Creek stream temperatures in comparison to sensor temperatures from two fish tagged in either Pine Creek (black circle) or Bald Eagle Creek (gray triangle). Both fish moved out of the tributaries and spent several months in the river prior to returning to tributaries for spawning.

d. **Conclusions**

There was large among-fish variability in movement distances, with some fish moving relatively long distances (over 90km) during this study. High among-fish variability in movements has been found for smallmouth bass in other studies and for other species (e.g., brook trout; Mollenhauer et al. 2013). In Elkhorn Creek, a tributary of the Kentucky River, movement by individual smallmouth bass tagged after spawning conditions was also variable, with some bass moving large distances (up to 24km) while others remained relatively stationary (Gunderson VanArnum 2004). However, only a small proportion of the early summer fish tagged in the tributary of Elkhorn Creek also used the larger river system –

Kentucky River (13%). In the current study, 22 out of 30 pre-spawn tributary fish (73%) moved out into the West Branch of the Susquehanna River after spawning, demonstrating a larger portion of fish, as compared to the Elkhorn Creek study, that are using the tributaries for spawning, but residing in the river throughout other seasons. Other studies have also demonstrated high among-fish variability in smallmouth bass movements – ranging from < 10km (Todd and Rabeni 1989) to 109km (Langhurst and Schoenike 1990).

Previous studies on smallmouth bass have also documented a wide range of movement patterns and habitat use in rivers (Lyons and Kanehl 2002). Movement patterns were shown to have a high amount of variability among studies, with evidence for large movements related to environmental conditions (e.g. high flow events; Lyons and Kanehl 1993) or movements into overwintering habitats (Langhurst and Schoenike 1990). In the West Branch of the Susquehanna River basin, two of the three movement periods, including overwintering and pre-spawn movements, are similar to those documented in the Embarrass and Wolf Rivers in Wisconsin (Langhurst and Schoenike 1990). The third movement period, post-spawn (late May-July), was not documented during the Embarrass and Wolf River study, likely due to the time of tagging (August) in that study. However, other studies have documented both movement (Elkhorn Creek, Kentucky: VanArnum et al. 2004) and restricted home ranges during the post-spawn timeframe (Middle Snake River, Idaho; Munther 1970, Huron River, Michigan; Beam 1990). Development of statistical models that include environmental factors, such as temperature and flow, will be important to further understanding movement patterns in the Susquehanna River basin. In addition, developing models to accommodate uncertainty in accommodating dropped tags will also be important. For instance, in this work, fish that moved very little (<1km) were still considered fish with active tags, but there could also be a probability that some of those were dropped tags. A way to accommodate some of this uncertainty will be important in developing more rigorous movement models.

This study highlights the fact that both tributaries and river habitat provides important habitats for smallmouth bass in the West Branch of the Susquehanna River. It is likely that smallmouth bass in other areas within the Susquehanna River utilize both tributary and main-stem river habitats, demonstrating the importance of river connectivity. Tributaries used for spawning may be the result of several underlying factors including 1) suitable habitat needs, 2) inter and intraspecific competition in-river habitat, or 3) site fidelity to natal spawning grounds. The tributaries in this study were much smaller than the river and provided ample spawning substrate (course gravel; Pflieger 1966), especially in the Pine Creek watershed where nests were highly visible. During times of overwintering, the majority

of the fish were located in deeper river habitat, some of which as created from the impounded section of the river above the Williamsport dam. It is important to understand the types of habitat that smallmouth bass are using seasonally to provide insight for protection and management of critical habitat.

The large movement potential (> 90 kilometers) and wide variety of habitat that could be encountered during that journey provides new perspective into what environmental risk factors for fish health and population level concerns could be encountered. When fish health investigations are conducted, a common goal is to gain an understanding of the fish health characteristics present and how that might relate to local environmental factors. A broader perspective may be needed, one that considers the potential for seasonal movements of smallmouth bass, when identifying environmental stressors and potential sources of those stressors. A riverscapes approach, where factors are considered at different scales, may be appropriate in these cases (Fausch et al. 2002). One way to begin to broaden the perspective is to think about land use or other factors that may impact fish at different scales. In the telemetry area in this study, land use varies depending on the scale investigated. At the catchment level, all sites are predominantly forested (>70%: NLCD 2006: Fry et al. 2011). However, at smaller scales (local level), the West Branch of the Susquehanna sites near McElhattan, PA (tagging location) and Linden, PA (overwintering location) have a higher percentage agriculture than Pine Creek and Bald Eagle Creek. Urbanization levels are also variable at the local level, suggesting the need to consider land use sources at different spatial scales may be important. If tributary fish are spending extended periods of time in the river, comparing both river and tributary landscapes and water quality may be important when trying to understand the characteristics that are being studied in the adult fish, such as contaminant concentrations or the presence of parasites.

Overall, the goal of this research was to begin incorporating movement ecology of smallmouth bass into understanding the potential role contaminants and pathogens play in the observed intersex, disease, and mortality events. By considering movement patterns, it is possible to start thinking about different scales of management that might be warranted. Several additional collaborative research projects (listed in part d. Additional Research Indicated) are currently underway to gain a more in depth understanding of smallmouth bass movement ecology in the Susquehanna River and how this relates to management of these populations. Additionally, although it was a goal of this project, it was not possible to study thermal habitat use in times of elevated temperatures due to the seasonal temperature patterns that occurred. Future research may be needed to evaluate temperature stressors and habitat selection by smallmouth bass if thermal stress becomes more frequent.

e. **Additional Research Indicated**

This telemetry study has been paired with a wide range of other ongoing research in the Susquehanna River basin including the following: 1) adult and juvenile fish health investigations, 2) an expanded telemetry investigation, 3) population genetics, and 4) contaminants research. The additional research is being completed through a collaborative effort with state and federal agencies, including the U.S. Geological Survey (USGS), U.S. Fish and Wildlife Service (USFWS), PFBC, PA DEP, Susquehanna University, Sea Grant, Susquehanna River Basin Commission (SRBC) and the PA Department of Conservation and Natural Resources (DCNR). Details of these investigations are provided below.

1.) ***Fish Health Investigations***: Fish health investigations of both juvenile and adult smallmouth bass occurred at the telemetry sites in 2014 and 2015, in addition to other sites in various parts of the states. This work is ongoing, but work in 2014/2015 included the collection of smallmouth bass for histological screening of tissue abnormalities and parasites. Additional work on parasites infecting young of the year smallmouth bass including the myxozoan parasite *Myxobolus inornatus* is also ongoing.

2.) ***Supplemental Telemetry Study***: The current telemetry project was expanded with a supplemental tagging of 45 additional fish during the fall of 2014. The same study area was used, but additional tagging locations were added both in the tributaries and river. The expansion of the initial study was made possible through support from Susquehanna University and the R.K Mellon, Freshwater Research Initiative. The additional telemetry work was recently completed and will be compiled with the findings from this study to develop a more robust evaluation of movement of smallmouth bass in the Susquehanna River basin.

3.) ***Population genetics research***: This movement study demonstrated movement of fish between river and tributary habitats for various seasonal needs (e.g., spawning and overwintering), but does not allow for a full investigation of what this means for genetic structuring of populations (i.e., are river and tributary spawning fish genetically distinct). To assess genetic population structure, 24 sites were selected for tissue collections that were located across the Susquehanna River basin, including river and tributary sites. The telemetry study sites (both river and tributary) were included in the genetics study. Genetic samples were collected during pre-spawn conditions (May – June 2015). The genetics research is currently ongoing. Sampling smallmouth bass for this research was a collaborative effort that included the PFBC, PA DEP, Susquehanna University, and SRBC. The laboratory research and analysis was funded through the R.K. Mellon, Freshwater Research Initiative through Susquehanna University.

4.) ***Contaminants research***: This telemetry research provided insight on movement patterns which could potentially relate to exposure for various environmental stressors, including contaminants. Little information is currently available regarding contaminants present in both adult and juvenile smallmouth bass within the telemetry study area. To begin to understand what movement patterns may mean for uptake of contaminants, background data are needed to determine what chemical constituents are present in fish, water, and river sediments. As part of a PA Sea Grant funded project, both juvenile fish and adult gonads were collected for contaminant analysis from both tributaries and the West Branch of the Susquehanna River. Bed sediment was also collected at nesting sites. This research has been expanded to include additional sites in the Susquehanna River basin and to also include water contaminant sampling. The field work and contaminant sampling has been concluded, but laboratory analysis is ongoing.

f. **Acknowledgements**

This telemetry research project was possible because of collaboration with a wide range of agencies and interest groups including U.S. Geological Survey (Pennsylvania Cooperative Fish and Wildlife Research Unit: Dr. Tyler Wagner, Leetown Science Center: Dr. Vicki Blazer), PA DEP (Tim Wertz, Josh Lookenbill, Dustin Shull, Mark Hoger, Rebecca Whiteash), PFBC (Geoffrey Smith, Jason Detar, Dave Kristine, Jordan Allison, Dan Ryan), Susquehanna University (Dr. John Niles, Mike Bilger, John Panas, Laurel Seemiller, Nathan Newton), Sea Grant funded technicians (Lydia Neal, Tyler Thompson, Stephen Sbrolla), Pennsylvania State University (Bryan Fergusen, Pennsylvania Cooperative Fish and Wildlife Research Unit: Josh Hickey, Evan Faulk, Alyssia Church, Tyrell Deweber, Steve Midway, Lori Smith, Shannon White), Pennsylvania Department of Conservation and Natural Resources (Tiadaghton State Forest), landowners (T.A. Seeds, Scott Munro), and anglers (Stan Wisniewski, local bass clubs, The Chapman Family).

g. **Citations**

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4. Appendix A

a. **Staff**

1.) **Number of individuals**

1.) 1 graduate student –Megan Kepler Schall (PhD candidate)

2.) 1-U.S. Geological Survey Scientist at the PA Cooperative Fish and Wildlife Research Center and Pennsylvania State University Adjunct Associate Professor – Dr. Tyler Wagner (advisor of M. Kepler Schall),

3.) 3 paid technicians funded by this grant including: Stephen Sbrolla, Lydia Neal, and Tyler Thompson.

4.) Assistance was also received from various partnerships including anglers, local landowners (T.A. Seeds and Scott Munro), and local universities (e.g., Susquehanna University). Management agency staff including Pennsylvania Fish and Boat Commission (PFBC), Department of Environmental Protection (DEP), and U.S. Geological Survey (USGS) also assisted with various parts of the research. The Department of Conservation and Natural Resources (DCNR) also provided assistance with access to study sites.

2.) **Number of full-time employees (as part of the grant**)- The money awarded in this grant supported technicians that assisted with this project throughout the duration of the project. Two separate full time technicians working at different times were supported: Lydia Neal – February 2014- August 2014 and Tyler Thompson: May 2015- August 2015. Two part time technicians were also hired to cover in between times including Tyler Thompson (August 2014-November 2014 , February 2015-May 2015, and September 2015-December2015) and Stephen Sbrolla (February 2015-May 2015).

3.) **Number of full-time employees (as part of match**) – No match provided

b. **Students Supported**

1.) **Number of Undergraduate Students** - Two undergraduates from Penn State University were hired as technicians from the money supplied by the grant to work on the project during their undergraduate career.

2.) **Number of Graduate Students** – 1- PhD student Megan Kepler Schall

3.) **Number of Ph.D. Students**- 1-Megan Kepler Schall.

4.) **Degrees Awarded (please indicate level)-** Megan Kepler Schall is currently working on her PhD with an anticipated graduation date of December 2017.

c. **Outreach/Extension**

1.) **Number of meetings, workshops, or conferences, and number of attendees**

1.) *Interagency Mining Workshop* – PFBC, DEP, Pennsylvania Game Commission (PGC). August 2015. Title: Investigation of risk factors affecting population status of Susquehanna River smallmouth bass. Approx. number attending: 20-30

2.) *Trout in the Classroom Workshop, PFBC.* June 2015. Title: Using Technology to study fish in the wild: A case study using smallmouth bass. Approx. number attending: 30

3.) *U.S. Geological Survey Chesapeake Bay Workshop.* May 2015. Title: Movement of smallmouth bass in the Susquehanna River with implications for disease and population management. Approx. number attending: 40-50

4.) *Joint Meeting of the Pennsylvania and Ohio Chapter of the American Fisheries Society Meeting*. February 2015. Title: Movement dynamics of smallmouth bass in the Susquehanna River basin. Approx. number attending: 50-60

5.) *PFBC Area Fish Management Meeting*. February 2015. Title: Investigating risk factors affecting population status of Susquehanna River smallmouth bass. Approx. number attending: 20

2.) Number of public or professional presentations, and number of attendees

1.) *Susquehanna University: Guest Lecture* – February 2015. Title: Investigation of risk factors affecting population status of Susquehanna River smallmouth bass. Approx. number attending: 20

2.) *Mansfield University: Guest Lecture* –March 2015. Title: Investigation of risk factors affecting Susquehanna River smallmouth bass. Approx. number attending: 20-30.

3.) *Penn State Ecology Graduate Student Organization –Science Café.* March 2015. Title: Wild animals get sick too! Approx. number attending: 30-40

4.) *Pine Creek Preservation Association* –September 2015. Title: Investigating movement dynamics of smallmouth bass in the Susquehanna River basin. Approx. number attending: 20

5. Appendix B: Impact Statement

Title: *Quantifying seasonal movement dynamics and thermal habitat use of smallmouth bass in the Susquehanna River basin: implications for fish disease and fisheries management*

1.) Relevance: This work was relevant to the large collaborative research effort underway to understand the potential drives of disease and recruitment failures in smallmouth bass in the Susquehanna River basin. This work is directly relevant to the recently (December 2015) completed Susquehanna River smallmouth bass CADDIS Report (http://www.dep.pa.gov/Business/Water/PointNonPointMgmt/WaterQuality/Pages/SusquehannaRiverStudy.aspx#.VpZC1vkrJaS) developed by the Pennsylvania Fish and Boat Commission, the Susquehanna River Basin Commission, the United States Geological Survey, and the PA DEP.

2.) Response: With the ongoing concerns regarding population abundance and recruitment of smallmouth bass in the Susquehanna River, this research provides information on smallmouth bass movement patterns and tributary-river usage in this system. When paired with other ongoing efforts, including fish health work, researchers can begin to integrate variables that may be of concern when it comes to managing smallmouth bass populations. This research was a collaborative effort with partners ranging from state and federal agencies to universities and anglers. The results of this research could benefit many of these groups, given the importance of smallmouth bass both as a sportfish and a top predator.

3.) Results: The results of this study are directly relevant to the aforementioned state and federal agencies attempting to understand a decrease in abundance of smallmouth bass in the Susquehanna River basin as a result of poor recruitment into the adult smallmouth bass population, as described by the aforementioned CADDIS report. The information derived from this study will be used by our state and federal partners to help inform (a) sampling strategies, (b) management options, and (c) the linkages between water quality (nutrients/contaminants), disease, and mortality in smallmouth bass populations in the Susquehanna River basin.

4.) Project Partners: Pennsylvania State University, U.S. Geological Survey, Pennsylvania Department of Environmental Protection, Pennsylvania Fish and Boat Commission, Susquehanna University, local landowners, anglers, and Sea Grant.