Identifying Movement Patterns and Spawning Areas of Invasive Lake Trout *Salvelinus namaycush* in Yellowstone Lake

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Introduction

Yellowstone Lake once supported what was believed to be the largest genetically unaltered population of Yellowstone cutthroat trout *Oncorhynchus clarkii bouvieri* in the world. Lake trout were initially reported in Yellowstone Lake in 1994, and subsequently, Yellowstone cutthroat trout have become the major prey of lake trout in the lake (Ruzycki et al 2003). Although other stressors (prolonged drought conditions and the exotic parasite *Myxobolus cerebralis* that causes whirling disease) may be additional contributing factors (Koel et al. 2005, 2006), recent evidence suggests that this aggressive predator has substantially altered the abundance and demography of Yellowstone cutthroat trout in the lake and currently threatens its long-term presence (Gresswell 2009; Syslo 2010).

The National Park Service has been actively attempting to reduce the numbers of lake trout in Yellowstone Lake since 1995, primarily by passive capture using gill nets (Gresswell 2009; Syslo 2010). Up to 20 km of gill nets may be used at one time, and by 2010, almost 610,000 lake trout had been removed since the suppression program was initiated (USNPS, unpublished data). The number of lake trout caught annually continues to increase (≈ 70,000 in 2007 and 2008, >100,000 in 2009, and 146,000 in 2010). Models based on removal estimates suggest more than a doubling of current gillnetting effort may be required to initiate a decline in lake trout abundance (Syslo 2010). Beginning 2009, a commercial research fisheries company was contracted to increase suppression effort, and by 2012, total effort is expected to reach, or exceed the proposed level.

Although the number of lake trout removed annually remains high, juvenile lake trout comprise the majority of the catch. Adult lake trout are more difficult to capture and are most vulnerable during the spawning season. Therefore, from late August to early October each year, some gillnets are set to specifically target mature lake trout as they move to the spawning area. In fact, approximately 96% of lake trout caught in these spawning season sets were removed from the lake prior to completion of spawning. Identification of spawning areas could potentially increase catch efficiency of adult lake trout substantially. Given the reproductive potential spawning lake trout and the direct positive relationship between lake trout body size and consumption of Yellowstone cutthroat trout, targeting adults may produce numerous indirect benefits.

Because currently there are no methods to destroy the potentially large numbers of developing embryos, research has been initiated to develop techniques specifically for destroying lake trout embryos on spawning grounds. For example, previous research has demonstrated that experimentally applied electrical current will cause mortality to trout eggs, but equipment necessary to use this technology has not been designed and tested (Gross et al. 2011). Numerous additional techniques that might be effective for destroying lake trout embryos in natural settings (e.g., controlled application of a variety of chemicals and sonic shock) have been identified (Gross et al. 2009), and efforts to develop the means to deploy such techniques in situ are ongoing (Gross et al. 2011). Of course, these methods should not be viewed as a substitute for gillnetting, and any successful technique should be used synergistically with methods that target free-swimming individuals (e.g., gill nets or electrofishing) in order to maximize suppression of lake trout.

Efforts to increase direct removal and utilize innovative techniques for destroying lake trout embryos and larvae require knowledge regarding lake trout movement patterns and accurate information concerning the location of spawning areas. In fact, recommendations of a scientific review of the lake trout suppression program on Yellowstone Lake strongly emphasized the need to locate lake trout spawning areas in the lake (Gresswell 2009). Although one spawning area was identified in West Thumb of Yellowstone Lake by tagging studies in 1998, recruitment is spreading to other areas of the lake as the population continues to grow and new spawning areas are pioneered (Patricia Bigelow, USNPS, Personal communication). In fact, models based on wave energy theory and information about the geomorphology of Yellowstone Lake suggest that about 4% of the lake has high potential for supporting lake trout reproduction (Bigelow 2009). For example, gillnets set in areas that may have a high potential for spawning have provided evidence of five additional sites where gravid lake trout congregate during the fall, but without further information, it is not possible to verify spawning in these areas.

To this end, we propose to utilize acoustic transmitters implanted in adult lake trout to document movement patterns in Yellowstone Lake to assist with active netting activity and identification of spawning areas that can subsequently be targeted for embryo destruction and adult removals. These data are critical for expanding management options for suppressing invasive lake trout.

Objectives

1) Locate spawning areas of lake trout in Yellowstone Lake.

2) Identify movement patterns of lake trout in Yellowstone Lake.

Approach

The successful and accurate location of lake trout spawning areas will require a multi-stage approach that will occur across three spawning seasons. The approach will not only provide necessary information on the activity and movement patterns of lake trout, but it will also have the greatest probability of accurately locating all spawning areas in Yellowstone Lake.

In August of *Year 1*, an array of stationary receivers will be strategically distributed in Yellowstone Lake, and acoustic transmitters will be implanted in prespawning lake trout. Data collected by the receivers will be regularly downloaded throughout the year. After 1 year of data collection, new information about areas of Yellowstone Lake frequently inhabited by lake trout will be documented, and potential spawning shoals will be identified based on movement patterns and congregations of fish during the fall.

In *Year 2*, additional stationary receivers will be deployed (bringing the total to 50) if funding becomes available. The existing stationary receivers will be repositioned for two main purposes: (a) receivers will be removed from areas of the lake that show no lake trout presence during fall spawning periods, and (b) receivers will be moved to suspected spawning shoals and arranged in a way that generates a small degree of overlap in the listening radius of each receiver. In this way, we will be able to use the 3-dimensional positioning capabilities of the hydrophone array to accurately quantify the movement, activity, and presence of tagged lake trout over suspected spawning areas. This approach will allow us to verify the presence of lake trout at suspected spawning areas identified in *Year 1* of the study, and we will be able to quantify movement and activities of lake trout involved in spawning to confirm reproduction.

By *Year 3*, we anticipate positive identification of several potential lake trout spawning areas where suspected spawning activity has been documented in two successive years. As such, activities in *Year 3* will consist of a combination of (a) additional fine-scale monitoring, potentially involving repositioning of the array around suspected spawning areas, and (b) targeted night gillnetting activities to remove adults from spawning areas, coupled with snorkeling and/or SCUBA to document the presence of lake trout eggs and larvae.

Significance

Information gained from this study will greatly increase the efficiency of gillnetting for suppression of the invasive lake trout, especially as individuals congregate near spawning areas. Furthermore, when coupled with visual location of developing embryos or sac-fry, these data will support the use of innovative technology that is emerging for the destruction of lake trout eggs and developing embryos in lake substrates. Overall effectiveness of suppression activities will be greatly enhanced by combining traditional approaches for removing free-swimming lake trout (e.g., gillnetting and electrofishing) with the direct destruction of eggs and embryo, but this integrated approach is directly dependent on the location of lake trout spawning areas. The results of the project could substantially improve efforts to protect the native Yellowstone cutthroat trout and preclude the necessity of listing the subspecies U.S. Endangered Species Act.

Methods

Stationary receivers (n = 26) will initially be deployed in August 2011. They will be located in areas currently believed to have lake trout spawning activity, at choke points within the lake, and at additional locations to ensure adequate coverage of the lake with minimal overlap of the listening radius of each receiver. Final locations will be determined following discussions with National Park Service personnel and contract fishers. Receivers have a listening radius of approximately 1 km.

Prior to deployment, depth will be measured and the GPS coordinates will be recorded at each site. Anchors will consist of cement blocks, and receivers will be mounted on a rope approximately one-third the distance from the bottom. A float will be located at the top of the anchor rope approximately 3 m below the lake surface to preclude interference with boating and fishing by park visitors.

Acoustic transmitters (tags) will be implanted in approximately 140 prespawning lake trout in August 2011. These transmitters (V13-1L, Vemco Inc., Halifax, Nova Scotia, Canada) will be 36 mm in length and weigh 11 g in air or 6 g in water. The power output of the tag is 147 dB, and a pulse or ‘ping’ is transmitted randomly every 60-180 seconds. Pings are then decoded by a hydrophone (i.e., underwater microphone) located on a receiver and recorded on an internal memory device. Data include date and time of detection, transmitter ID, and receiver serial number. Expected battery life for these tags will be approximately 1,100 days.

Lake trout for transmitter implantation will be collected with trap nets in conjunction with routine suppression activities conducted by the contract fishers. Initially, the number of the transmitters implanted at each site will be in proportion to the number of lake trout captured at those sites; however, up to 15% of the transmitters may be implanted in lake trout captured in gill nets set in other locations in the lake. A separate vessel operated by a National Park Service employee will be used to carry researchers, technicians, and gear to and from each sampling site.

Surgeries to implant tags will be performed by experienced surgeons using sterile, approved surgical techniques (Summerfelt and Smith 1990). In order to assure that tag weight in water will not exceed fish body weight, only lake trout > 500 g will be used in this study. Although is impossible to conduct surgical procedures under sterile conditions, care will be exercised to prevent the introduction of additional infective agents and to minimize the physiological stress of such procedures. All surgical instruments and transmitters will be disinfected in a Betadine bath prior to, and following surgery, and Betadine will be used to sterilize the surgical area on each lake trout. Latex or nitrile surgical gloves will be worn by the surgeon and changed frequently.

Prior to surgery, lake trout will be held in a holding pen (122 cm x 122 cm x 183 cm) constructed of 3.1-mm mesh (Memphis Net and Twine Company, Inc) framed by 50-mm PVC. Bottom members of the frame will be weighted, and the top portions of the frame will be wrapped with floating material. The net pen will be secured to the boat. Pen design provides continuous flow of oxygenated water, and fish are able to respire and move normally. The total weight of fish in the holding pen will not exceed 43 kg (Piper et al. 1982) at any time. Holding pens will be sterilized and decontaminated with chlorine solution daily.

Anesthesia and surgery will be performed on one lake trout at a time. Each fish will be anesthetized with 100 mg/L MS-222 buffered with 200 mg/L NaHCO3. After reaching stage 4 anesthesia (total loss of muscle tone and equilibrium; slow but regular opercular rate; loss of spinal reflexes), lake trout will be placed ventral side up on a V-cut foam pad. During surgery, anesthesia will be maintained constantly irrigating the gills with a solution of 50 mg/L MS-222 buffered with 100 mg/L NaHCO3 using a water-recirculation pump to maintain a flow over the gills from the mouth (Summerfelt and Smith 1990). A 15-mm incision will be made parallel to and off the midline, anterior to the pelvic girdle, into the peritoneal cavity using a #10-scalpel blade. The transmitter will be placed inside the body cavity, and two sutures, each consisting of two knots with four double throws, (Mono-Dox absorbable synthetic monofilament 3/0 NFS-1, CP Medical, Portland, OR, USA) will be used to close the incision (Summerfelt and Smith 1990). Following surgery, the fish will be placed in a recovery tank for post-surgical monitoring and subsequently released. All surgical equipment will be sterilized in a Betadine bath following surgery.

Although MS-222 is registered for fishery use, there is a mandatory 21-d withdrawal period (Summerfelt and Smith 1990), and during that time, they are not to be consumed by humans. Therefore, all lake trout that are implanted with a sonic transmitter will have the adipose fin removed. Signs will be placed at boat launches and fish cleaning stations instructing anglers not to consume lake trout with missing adipose fins prior to the specified date (to be posted following completion of surgeries). Information sheets with details about the study will also be available where fish licenses are sold. Given the small number of study fish (140) and the large population of lake trout (hundreds of thousands), the probability of a study fish being captured by an angler is not great. All marked lake trout captured in gill nets or trap nets will be released alive if possible, or the transmitter will be removed and saved for future implantation.

Downloading of data from stationary receivers will occur at least once every 2 weeks. Upon arrival at each receiver location, the float will be visually located if possible, and the anchor rope will be snagged with a grappling hook. Once the rope has been grasped, the anchor will be lifted until the receiver can be retrieved. Downloading consists of a wireless (Bluetooth) connection between the receiver and a laptop computer; data are sent from the hydrophone to the laptop for storage and subsequent processing. At the time of data retrieval, the location of each receiver will be noted and compared to the location at which it was deployed. If the location of the receiver has significantly changed, it will be moved back to its original location. Hydrophones will also be inspected for damage, and any damage will be noted in logbooks. Damaged hydrophones will be repaired or replaced as necessary.

If data suggest concentrations of lake trout in a given area, a portable receiver may be used to obtain precise locations and guide suppression efforts. The portable receiver may also be used periodically to search areas that are not being effectively monitored by the fixed-station receivers. These mobile surveys have limited effectiveness, however, because of potential bias related to time of day and search pattern, and the cost and labor requirements of these surveys can be prohibitive. Equally spaced transects with varying daily starting points are recommended (Winter 1996). Furthermore, the distance between transects will need to be less that the transmitter signal range (≈ 500 m) to insure detection (Winter 1996).

Products

Data will be processed immediately after the downloading is complete for all receivers, and a summary of movement patterns and fish locations will be delivered to the National Park Service as soon as possible (1-3 days). Comprehensive analysis and interpretation will be initiated after the final data acquisition of the year (mid-October), and a draft annual report will be submitted by January 4, 2012.

We intend to extend this project for 3 years if funding support can be obtained for FY12 and FY13. In addition to periodic data summaries that will be transferred to the National Park Service, there will be an annual report at the end of each field season, and a final report January 1, 2014. Ultimately, we plan to submit 1-2 manuscripts for publication to peer-reviewed journal.

Partners

The study will be conducted in close collaboration with the US Geological Survey, US National Park Service, East Yellowstone Chapter of Trout Unlimited, Greater Yellowstone Coalition, National Parks Conservation Association, Montana Trout Unlimited, and Trout Unlimited (national organization).

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