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Tradeoffs between physical captures and PIT tag antenna array detections: A case study for the Lower Colorado River Basin population of humpback chub (*Gila cypha*)

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ABSTRACT

A key component of many monitoring programs for special status species involves capture and handling of individuals as part of capture-recapture efforts for tracking population health and demography. Minimizing negative impacts from sampling, such as through reduced handling, aids prevention of negative impacts on species from monitoring efforts. Using simulation analyses, we found that long-term population monitoring techniques, requiring physical capture (i.e. hoop-net sampling), can be reduced and supplemented with passive detections (i.e. PIT tag antenna array detections) without negatively affecting estimates of adult humpback chub (HBC; *Gila cypha*) survival (*S*) and skipped spawning probabilities (γ'' = spawner transitions to a skipped spawner, γ' = skipped spawner remains a skipped spawner). Based on our findings of the array's *in situ* detection efficiency (0.42), estimability of such demographic parameters would improve over hoop-netting alone. In addition, the array provides insight into HBC population dynamics and movement patterns outside of traditional sampling periods. However, given current timing of sampling efforts, spawner abundance estimates were negatively biased when hoop-netting was reduced, suggesting not all spawning HBC are present during the current sampling events. Despite this, our findings demonstrate that PIT tag antenna arrays, even with moderate potential detectability, may allow for reduced handling of special status species while also offering potentially more efficient monitoring strategies, especially if ideal timing of sampling can be determined.

1. Introduction

Monitoring populations of threatened or endangered species is central to informing fulfillment of recovery goals. To evaluate population status and trends, monitoring efforts often focus on abundance estimation (USFWS, 2002). However, assessment of changes in additional demographic parameters, such as survival and spawning probability, can provide insight into drivers of population change. Generating unbiased and precise demographic estimates presents challenges, primarily due to limited biological understanding, as well as funding, personnel and time constraints. Although, improved parameter estimability may be possible, using technologically advanced and less invasive techniques.

When monitoring special status species, it is ethically and statistically important to minimize human induced negative effects, especially when those effects are a direct result of the monitoring program (Rahel et al., 1999). Handling-induced stress, leading to decreased fitness or mortality, is of utmost concern when population abundance is low. Although handling may not result in direct mortality, stress in fishes has been shown to have cumulative negative effects, including reduced growth and condition (Wedemeyer et al., 1990; Paukert et al., 2001). Research by Paukert et al. (2005) reveals an inverse relationship between growth rate and handling in bonytail chub (*Gila elegans*). Because changes in growth have been found to affect mortality, recruitment dynamics, susceptibility to environmental alterations and trophic interactions (Quist et al., 2012), these findings evoke concern for numerous

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fish species. For example, the congeneric humpback chub (HBC; *Gila cypha*) is a long-lived, federally endangered species (USOFR, 1967; USFWS, 2002) that has been intensively studied via traditional, capture based sampling programs since the mid 1980's (Van Haverbeke et al., 2013). Hoop-netting data from the Little Colorado River (LCR), Arizona reveals from 1991 to 2013, 67% of all HBC ≥ 200 mm total length (TL) had been previously handled (GCMRC unpublished data). Based on the current level of handling for assessing HBC population status and trends in the Lower Colorado River Basin (LCRB), concern arises for the long-term health of the population. Thus, minimizing human-induced negative effects should remain a priority for the LCRB monitoring program, while also improving understanding of HBC life history strategies and population dynamics (USFWS, 2002).

Current monitoring for the LCRB population of HBC has focused on repeated hoop-net sampling within their primary spawning ground, the LCR. Due to strong site fidelity (Paukert et al., 2006) and minimal breeding outside the LCR (Valdez and Ryel, 1995; Gorman and Stone, 1999), it is believed the LCR provides a reasonable location for monitoring the majority of the LCRB population (Paukert et al., 2006). Therefore, the U.S. Fish and Wildlife Service (USFWS), in cooperation with the U.S. Geological Survey, Grand Canyon Monitoring and Research Center (GCMRC), has annually conducted hoop-net sampling in the LCR, to estimate HBC abundance and recruitment (Coggins and Walters, 2009; Van Haverbeke et al., 2013). These same data can be used to monitor the other drivers of spawner abundance, which include adult survival and spawning probability (Pearson et al., 2015). During each sampling event, HBC are evaluated following standard handling procedures, unmarked fish are uniquely marked with Passive Integrated Transponder (PIT) tags, and recaptures are recorded (Persons et al., 2013).

Using a passive detection system for detecting PIT tagged individuals may increase the potential efficacy of monitoring programs. Advantages of supplementing physical recaptures with passive detections include: increased precision of demographic parameter estimates from extra detections and increased understanding of fish dynamics and movement outside of traditional sampling periods. Potential advantages of partially replacing capture effort with passive detections include: decreasing impacts on fish due to handling and reducing sampling costs while maintaining statistical performance.

To assess the efficacy of passive detection in the LCRB, the GCMRC installed a full duplex PIT tag antenna array (Biomark Inc., Boise, ID), within the LCR, just upstream of the confluence with the Colorado River (CR), to passively detect the passage of tagged fish migrating into and out of the LCR. Placement of the array near the mouth of the confluence suggests the majority of detections will likely consist of migratory HBC, as they move into and out of the LCR to spawn (Douglas and Marsh, 1996; Gorman and Stone, 1999), and tagged juveniles transitioning to the CR (Limburg et al., 2013). Because the majority of assumed resident HBC are thought to reside in the upper reach of the LCR (Douglas and Marsh, 1996; Gorman and Stone, 1999; Van Haverbeke et al., 2013), the array was not anticipated to be a reliable method for monitoring resident HBC. However, based on work by Pearson et al. (2015), Yackulic et al. (2014) and Limburg et al. (2013), resident adult HBC (i.e. ≥200 mm TL) likely account for only a small portion of the adult population.

Installation of the array afforded an opportunity to assess the effectiveness of using a passive detection system in part to evaluate HBC demographic parameters. However, tradeoffs in sampling effort between physical captures and passive detections may only be possible if demographic parameter estimation is not negatively affected (USFWS, 2002). Therefore, we evaluate tradeoffs between hoop-netting alone versus multiple levels of hoop-netting effort in combination with array detections. We compare bias and precision of survival and skipped spawning probability estimates, as well as spawner and total adult abundance, using a simulation analysis that represents the range of scenarios of current interest. We also evaluate the detection potential of the array by empirically estimating detection efficiency. Lastly, we discuss the implications of reduced hoop-net sampling effort on abundance estimation for the specific case of HBC in the LCR, where reduced tagging effort would imply foregoing one of two monthly spring sampling trips into the LCR, based primarily on LCR detection data from Pearson et al. (2015).

2. Methods

2.1. Little Colorado River HBC monitoring

Although, repeated hoop-net sampling within the LCR began in the 1980s (Coggins et al., 2006), it was not until fall of 2000 that the current standard sampling protocol was implemented. Since that time, the USFWS has consistently conducted four annual hoop-net sampling events. Two events occur in the spring (i.e. April and May), to estimate HBC spawner abundance and two in the fall (i.e. September and October), to estimate HBC recruitment. During each sampling trip, three crews are deployed to the lower 13.57 km of the LCR, simultaneously sampling three adjoining reaches (Salt, Coyote, and Boulders; Fig. 1). Each adjoining reach has been divided into three sub-reaches such that the entire lower 13.57 km of the LCR is sampled. Twenty hoop-nets (0.5–0.6 m diameter, 1.0 m long, single throat, 3–4 hoop, and covered with 6 mm mesh) are deployed in each sub-reach for three consecutive nights. This sampling design results in 180 net nights of sampling effort per adjoining reach for a total of 540 net nights of sampling effort per event (i.e. 2160 net nights annually). Upon capture, fish are measured, sexed, checked for gametes and parasites, uniquely marked with a 12 mm full duplex PIT tag and released (Van Haverbeke et al., 2013; Biomark Inc., Boise, ID).

The PIT tag antenna array, originally installed in May of 2009, is comprised of multiple individual antennas working in concert with one another (Fig. 2). The array was designed to cover the full wetted width of the LCR under base flow conditions (~220 cfs) and operate year-round. However, spring and summer high flow events, which routinely exceed 2000 cfs, reduce coverage of the array. Since installation, the array has experienced variable functionality, initially due to an insufficient solar power system used to keep the array functional during winter months as well as high flow events washing out individual antennas. However, the solar power system was upgraded in 2010 and all damaged arrays have since been replaced. Thus, in recent years, the array has been operational year-round.

2.2. Tradeoffs in sampling effort

To address possible tradeoffs between hoop-netting effort versus array detections, we considered the following monitoring objectives and practical considerations. First, a priority of the USFWS and GCMRC spring monitoring effort is to assess HBC spawning in the LCR. Second, abundance estimates are key to assessing population status, while recruitment, survival and skipped spawning probabilities are important for interpreting the causes of population change. Thus, we sought to understand whether reducing hoop-netting effort and supplementing with array detections would negatively affect estimability of abundance, survival or skipped spawning probabilities (because we evaluate only adult HBC (i.e. ≥200 mm TL), for this evaluation, we ignore recruitment).

Reduction in monitoring effort can be achieved by fewer net nights of effort per sampling event, or a reduced number of events. Given the fixed monetary costs of transporting crews and equip-