North American Journal of Fisheries Management 25:640–645, 2005
American Fisheries Society 2005
DOI: 10.1577/M04-091.1

[Management Brief]

Effect of Baiting on Hoop Net Catch Rates of Endangered Humpback Chub

DENNIS M. STONE*

U.S. Fish and Wildlife Service, Post Office Box 338, Flagstaff, Arizona 86002-0338, USA

Abstract.—The effects of unbaited, scented (odor emitted by inaccessible hatchery feed), and baited (accessible feed) single-throated hoop nets on the catch rates of the federally endangered humpback chub *Gila cypha* (≥100 mm total length) were assessed in the Little Colorado River, Arizona, to determine how baiting affected the catch of these fish. Of a total of 1,297 unique humpback chub captured, 262 (20%) were caught in 179 unbaited nets, 330 (25%) in 179 scented nets, and 705 (54%) in 178 baited nets. Humpback chub retention in unbaited nets did not differ from a 50:50 chance event ($P = 0.075$) but probably peaked in baited nets where these fish were preoccupied with feeding (i.e., gorging themselves), which would explain the higher catch rates in baited than in scented or unbaited nets ($P \leq 0.001$). Moreover, humpback chub catch rates were not significantly higher in scented than in unbaited nets ($P = 0.779$), which suggests that elevating both ''fish attraction'' and ''fish retention'' are essential to substantially increase their captures in these nets. However, scenting may still be a viable option when used in conjunction with passive gears possessing higher fish retention capabilities or to target species less prone to escape. The findings of this study should provide valuable insight to anyone wishing to optimize catch rates by baiting or scenting passive entrapment gear.

The humpback chub *Gila cypha* was federally listed as an endangered species in 1967 (U.S. Office of the Federal Register 1967). Presently, the largest of six remnant populations occupy the Colorado River below Glen Canyon Dam within Grand Canyon National Park and lower Little Colorado River (LCR), Arizona (USFWS 1990; Douglas and Marsh 1996). The perpetuation of this population relies almost exclusively on LCR, which still contains hydrological conditions, water chemistry, temperatures, and suitable habitats conducive for these fish to successfully spawn, grow, and recruit to adulthood (Kaeding and Zimmerman 1983; Gorman and Stone 1999). Humpback chub are primarily restricted to the LCR corridor below the Atomizer Falls Complex, a series of travertine dams located from 13.6 to 14 river kilometers (rkm) upstream of the river's mouth (Kaeding and Zimmerman 1983; Mattes 1993).

For over a decade, hoop nets have been the primary gear used in the LCR because they inflict less stress and cause fewer injuries and mortalities than electroshocking (Ruppert and Muth 1997; Snyder 2003) or entanglement gear (Hopkins and Cech 1992), can be deployed in most LCR habitats (Gorman and Stone 1999), and are relatively efficient at capturing all postlarval humpback chub life stages (Stone 1999). Douglas and Marsh (1996) primarily used hoop net capture data to calculate monthly mark–recapture humpback chub population estimates in the LCR during 1991–1992.

Beginning in fall 2000, the U.S. Fish and Wildlife Service instituted a semiannual spring and fall mark–recapture census of the LCR humpback chub population. An idea was presented that baiting may lure more humpback chub into nets, which could increase the sample sizes and ultimately the precision of the population estimates. Baiting hoop nets in other systems resulted in higher captures of channel catfish *Ictalurus punctatus*, common carp *Cyprinus carpio*, smallmouth buffalo *Ictiobus bubalus*, bluegills *Lepomis macrochirus* (Mayhew 1973; Pierce et al. 1981; Gerhardt and Hubert 1989), and burbot *Lota lota* (Bernard et al. 1991). However, a major concern was that the distended intestines of humpback chub satiated with bait would be more susceptible to perforations upon abdominal insertions of passive integrated transponder (PIT) tags (Biomark, Inc.) than those of unfed individuals (M. Childs, Arizona Game and Fish Department, unpublished data). Therefore, it was suggested that we should rely solely on the scent from inaccessible bait to chum fish into nets. Jester (1977) found that perforated cans of dog food attracted channel catfish into gill nets, and Stott (1970) reported that adding copper sulfate to trap nets increased the catch of redfin perch (also known as the Eurasian perch) *Perca fluviatilis* and roach *Rutilus rutilus* 11-fold. The objective of this study was to assess humpback chub catch rates among unbaited, scented, and baited nets to pro-

* Corresponding author: Dennis_Stone@fws.gov

Received June 9, 2004; accepted October 21, 2004
Published online May 16, 2005

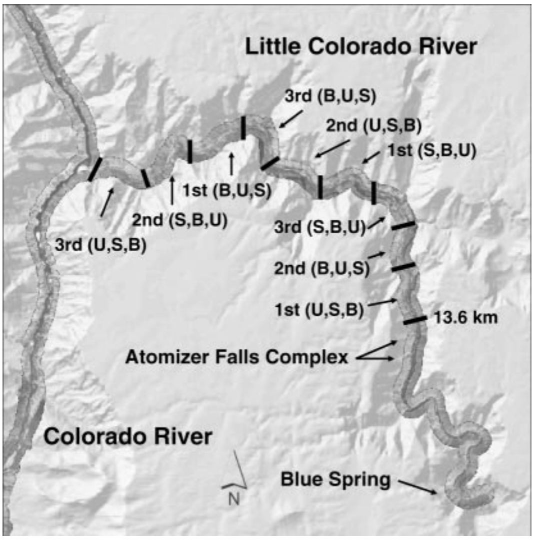

FIGURE 1.—Map and sampling design for the baiting experiment conducted in the Little Colorado River, Arizona. The river corridor below the Atomizer Falls Complex (13.6 rkm) was separated into nine (~1.5 rkm) stream sections. All nets deployed within each stream section were unbaited (U), scented (S), or baited (B) for the first haul, and then redeployed using different treatments for the second and third hauls. Stream sections sampled concurrently (1st, 2nd, 3rd) and corresponding treatments (e.g., U, S, B) for successive hauls are given.

vide guidance for future management activities in the LCR and elsewhere.

Methods

Hoop net treatments.—The miniature hoop nets used in this study were 50 cm in diameter, 100 cm long, had a single 10-cm throat, and were covered with 6-mm dark-green, nylon mesh netting. The three treatments included unbaited, scented, and baited hoop nets. Baited and scented nets were treated similarly whereby a single nylon mesh bag (30 × 30 cm, 6-mm mesh) containing approximately 160 g of bait (AquaMax Grower 600 for Carnivorous Species, Purina Mills Inc., Brentwood, Missouri) and one common white sock were hung near the cod end of each net. The bait inside of mesh bags was made inaccessible to fishes in scented nets by enclosing it within the socks and accessible to fishes in baited nets by placing it loose outside of the socks.

Sampling design.—The lower 13.6 rkm of the LCR was separated into nine (~1.5 rkm) stream sections (Figure 1). Three survey crews stationed at Boulder (1.9 rkm upriver from mouth), Coyote (5.0 rkm), and Salt (10.4 rkm) sampling areas were each responsible for first sampling an upper, followed by middle, and then lower stream section within their designated areas. Each stream section was sampled with 20 nets that contained one specific net treatment (i.e., either unbaited, scented, or baited) for the first ~24-h haul, then resampled by redeploying nets to new locations and applying a different treatment for a second and third haul. Net treatments varied daily among the three stream sections being sampled, which resulted in the deployment of 60 net sets of each treatment per haul (180 over three hauls). This sampling strategy was implemented to reduce potential biases associated with unbalanced treatments, catch rate differences among disparate habitats, and diminished catch rates over time.

This study was primarily designed to compare the net treatment effects on catch rates of unique (first captures only) humpback chub measuring 100 mm or greater in total length (TL). Because this trip was also the recapture event for the fall humpback chub population estimate, the typical procedure of marking fishes with PIT tags was replaced by clipping the right pelvic fin of each fish greater than or equal to 100 mm TL. Fin clipping allowed for analytical comparisons solely among unique individuals, still allowed for the ratio of marked to unmarked fish for the stock assessment, and alleviated concerns over PIT tagging well-fed fish. The study was conducted October 21–30, 2002, under base flow discharge (mean = 6.3 m^3/s near LCR mouth; Cooley 1976). Water temperature (°C) and nephelometric turbidity unit (NTU) measurements (Hach Model 2100P Turbidimeter, Loveland, Colorado) were obtained daily between 1300 and 1700 hours.

Analyses.—Three-way analysis of variance (ANOVA) was used to model the potential influences of net treatment, haul number, and sampling area (fixed factors) on unique humpback chub catch–set. Catch rates were not standardized by effort because effort remained largely consistent throughout the study (mean ± SD = 23 ± 2.2 h for 536 net sets). Although assumptions for a parametric test were violated, ANOVA was sufficiently robust under these large and nearly equal sample sizes (Ott 1993; Zar 1996). A second three-way ANOVA was used to examine for potential influences of net treatment, haul number, and sampling area on humpback chub mean TL. In addition, Pearson's correlation tests were used to examine for linear correlations between humpback chub TL and net treatment (ordered as follows: 1 = unbaited, 2 = scented, 3 = baited), haul number, and sampling area (ordered in an upriver direction as follows: 1 = Boulder area, 2 = Coyote area, 3 = Salt area).

The capacity of hoop nets to retain humpback chub overnight (i.e., fish retention) was examined October 24–28, 2003. Eighty-one PIT-tagged humpback chub (mean ± SD = 199 ± 38 mm TL; range = 102–342 mm TL) were returned to 30 unbaited nets. Twelve nets each held one individual, and the other 18 nets contained from two to six fish. These nets were redeployed in the same areas until the following day when remaining and newly captured humpback chub greater than or equal to 100 mm TL were tallied. A binomial test was conducted to examine whether the retained versus escaped proportions of previously returned fish significantly differed from a 50:50 chance event. A two-sample, pooled-variance *t*-test was used to examine for TL differences between individuals that remained and those that exited the nets; pooling variances was justified by Levene's homogeneity of variances test results ($F = 0.122$; df = 1, 79; $P = 0.728$).

A laboratory experiment was conducted December 13–16, 2002, to ensure that odors were dispersing from the bait-filled socks used for the scented net treatment. An unused white sock was filled with 160 g of bait and placed in a clean, covered container with 1,500 mL of tap water. The mean of three NTU samples were calculated initially and on three other occasions over the next 68 h. The remaining bait was dried and reweighed at the end of the experiment.

Statistical tests that resulted in *P*-values less than 0.05 were considered significant. All statistical tests were conducted using SPSS for Windows, Release 9, 1998 (SPSS, Inc., Chicago, Illinois).

Results

The LCR maintained relatively warm temperatures (mean ± SE = 18.4 ± 0.44°C) and high water clarities (4.8 ± 0.45 NTU) throughout the baiting study. Prior to the first haul, one unbaited, one scented, and two baited nets had collapsed and were therefore omitted from the data set. This resulted in sample sizes of 59 unbaited, 59 scented, and 58 baited net sets for the first haul, and 60 net sets of each treatment for the second and third hauls. Humpback chub constituted 68.8% of the overall catch, of which 1,297 were unique individuals (mean ± SD = 181 ± 69.5 mm TL; range = 100–467 mm TL), 264 were fin-clipped recaptures (100–389 mm TL), and 79 were age 0 (50–99 mm TL). Other native species (21% of total catch) included 304 speckled dace *Rhinichthys osculus*, 145 flannelmouth suckers *Catostomus latipinnis*, and 51 bluehead suckers *C. discobolus*. Nonindigenous fishes (10.2% of total catch) included 142 fathead minnow *Pimephales promelas*, 72 common carp, 21 black bullheads *Ameiurus melas*, seven rainbow trout *Oncorhynchus mykiss*, and one plains killifish *Fundulus zebrinus*.

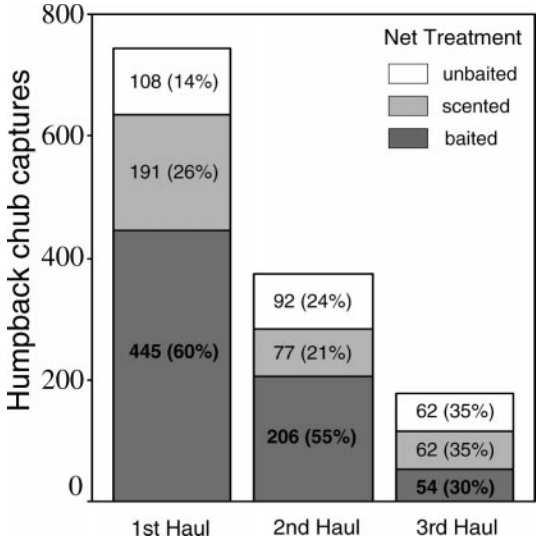

FIGURE 2.—Numbers and proportions of unique humpback chub greater than or equal to 100 mm TL captured in unbaited, scented, and baited hoop nets deployed for three separate 24-h hauls in the Little Colorado River, Arizona. Captures resulted from 59 unbaited nets, 59 scented nets, and 58 baited net sets during the first haul, and 60 net sets of each treatment for both the second and third hauls (536 total net sets).

The 1,297 unique humpback chub were disproportionately captured among nets possessing disparate treatments and deployed during different hauls (Figure 2). Total captures for each net treatment declined with each ensuing haul; the capture proportions among net treatments were most disparate during the first haul followed by the second haul, but very similar during the third haul. Overall, 262 fish (20%) were caught in 179 unbaited nets, 330 (25%) in 179 scented nets, and 705 (54%) in 178 baited nets.

The three-way ANOVA indicated that unique humpback chub catch–set was not affected by sampling area ($F = 0.147$; df = 2, 509; $P = 0.863$) or by its interactions with net treatment ($F = 1.601$; df = 4, 509; $P = 0.173$) or haul number ($F = 1.162$; df = 4, 509; $P = 0.327$); therefore, sampling area was omitted from the model. The re-

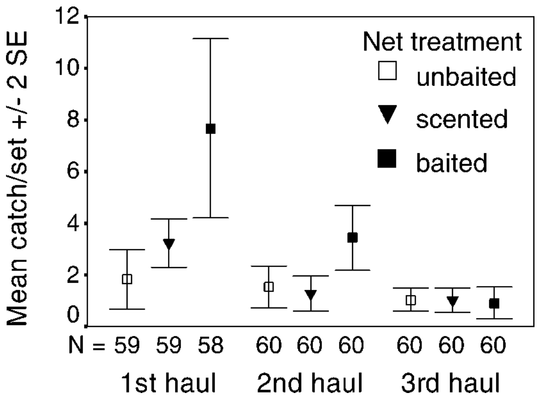

FIGURE 3.—Mean catch–set ± 2 SE of unique humpback chub greater than or equal to 100 mm TL from unbaited, scented, and baited hoop nets deployed for three separate 24-h hauls in the Little Colorado River, Arizona. The number of net sets (*N*) for each treatment of each haul is given.

sulting two-way model indicated that net treatment (F = 11.711; df = 2, 527; $P \leq 0.001$), haul number (F = 17.165; df = 2, 527; $P \leq 0.001$), and their interaction (F = 5.279; df = 4, 527; $P \leq 0.001$) were all related to humpback chub catch–set. Catch rates incrementally decreased from the first to third haul in a manner that direction of response was the same for all treatments; however, the magnitude of decrease was greatest for the baited treatment, intermediate for scented nets, and lowest for unbaited nets (Figure 3). Because the interaction was orderly, inferences made on the *F*-tests of the main effects were considered reliable (Ott 1993), and a posteriori Tukey's honestly significant difference tests were conducted on the main effects (Zar 1996).

Tukey's tests indicated that humpback chub catch rates were higher in baited nets than in either scented or unbaited nets (both $P \leq 0.001$), but were similar between scented and unbaited nets (P = 0.779). Overall, catch rates were higher during the first haul than either the second or third hauls (both $P \leq 0.001$), but did not differ between the last two hauls (P = 0.127). Therefore, catch rates from baited nets were only higher than those from scented and unbaited nets during the first two hauls, but were similar among treatments by the third haul (Figures 2, 3). The significant haul effect indicated that a relatively large portion of the population was being captured, which was expedited more by baited than by scented or unbaited nets.

Humpback chub mean TL differed primarily among the sampling areas from which they were captured. The three-way ANOVA model indicated that humpback chub mean TL was related to sampling area (F = 31.629; df = 2, 1,270; $P \leq 0.001$) and its interactions with net treatment (F = 2.632; df = 4, 1,270; P = 0.033), haul number (F = 3.443; df = 4, 1,270; P = 0.008), and net treatment–haul number (F = 3.193; df = 8, 1,270; $P \leq 0.001$), but revealed no effect of net treatment (F = 1.338; df = 2, 1,270; P = 0.263), haul number (F = 0.517; df = 2, 1,270; P = 0.596), or their interaction (F = 2.189; df = 4, 1,270; P = 0.068). Moreover, an increase of humpback chub TL was correlated with captures at consecutively upriver sampling areas (r = 0.304; df = 1,295; $P \leq 0.001$), which was also evident by the humpback chub mean TL (±SD) of fish captured at the Boulder (156 ± 49.4 mm; N = 444), Coyote (179 ± 72.2 mm; N = 409), and Salt (207 ± 74.6 mm; N = 444) sampling areas. In contrast, humpback chub TL showed no linear relationship to either the net treatment (r = 0.049; df = 1,295; P = 0.078) or the haul number (r = −0.033; df = 1,295; P = 0.230).

The LCR during the October 2003 fish retention experiment was 19°C and slightly turbid (50–82 NTU). Of the 81 humpback chub (102–342 mm TL) initially returned to the 30 nets, 49 were still present (60% retained) and 32 left (40% escaped) by the following day; the retained versus escaped ratio did not significantly differ from a 50:50 chance event (binomial test: P = 0.075). Retention of humpback chub was highly variable among nets. For example, 7 of 12 nets that harbored only one initially returned fish retained that individual. Moreover, none of six initially returned humpback chub escaped from one net, while four of six individuals escaped from another. Total lengths did not differ (t = 0.397; df = 79; P = 0.693) between individuals still present (mean ± SD = 198 ± 42 mm TL) and ones that exited the nets (201 ± 32 mm TL). Overall, 60 new humpback chub greater than or equal to 100 mm TL were captured in these experimental nets.

Results from the laboratory tests indicated that scent was escaping from the bait-filled socks. The mean NTU (±SE) were 0.85 ± 0.07, 41.5 ± 3.5, 416 ± 7.8, and 972 ± 7.4 at the beginning of the experiment, 4 h later, 21 h later, and 68 h later, respectively. By the second day the odor had permeated throughout the room. At the end of the experiment the remaining dried bait weighed 118 g, indicating that 42 g had dissolved in the water.

Discussion

My finding that baited nets captured significantly more unique humpback chub (≥100 mm TL) than unbaited nets was anticipated. Whereas hoop nets are deployed with their mouths facing downstream to the current, fishes must voluntarily choose to enter these passive entrapment devices (Stott 1970) and accessible food provides a good incentive. Baiting entrapment gears has been a common practice among commercial fishermen for over 50 years (Starrett and Barnickol 1955) and is essential for capturing certain species (e.g., burbot; Bernard et al. 1991). However, the significantly lower humpback chub catch rates in scented than baited nets, and similar captures between scented and unbaited nets was unexpected. Scent has also been shown to increase fish captures in entrapment gears (Stott 1970) and, as my laboratory study indicated, the odor from bait must have been dispersing from scented nets in the LCR. Presumably, humpback chub (particularly adults) rely heavily on their olfactory senses to procure food, especially at night when they are most active (Stone 1999) and vision is impaired (Hara 1993). Apparently, however, more is required to substantially increase humpback chub captures in these nets than merely relying on scent to elevate fish attraction to these devices.

The higher humpback chub catch rates from baited nets was likely related to fish retention. The fish retention experiment indicated that there was a 50:50 chance of humpback chub escaping these unbaited, single-throated hoop nets overnight; however, it is unknown whether those ‘‘retained’’ individuals were unable to find the mouth opening to escape, could have escaped but chose to remain, or escaped then returned (Patriarche 1968). In addition, as some individuals were escaping, others were entering these nets. However, humpback chub were clearly feeding in baited nets whereby many individuals became so gorged that they would immediately defecate upon handling. Moreover, the feeding process would have been prolonged because they had to extract food material through a 6-mm-mesh bait bag. Therefore, those humpback chub feeding in baited nets were likely remaining longer than those occupying unbaited or scented nets, which would result in an overall increase of fish retention and higher catch rates.

Baiting hoop nets could improve mark–recapture stock assessments of humpback chub in the LCR and elsewhere. The findings that baited nets captured over twice as many unique humpback chub as either scented or unbaited nets in the first two hauls, and expedited a significant catch rate decline between the first and later hauls, suggest that baiting could be used to either improve the precision of ensuing mark–recapture stock estimates without increasing sampling effort or to allow for less sampling effort to achieve the same precision as that from unbaited or scented nets. The 262 unique humpback chub caught in unbaited nets, 330 in scented nets, and 705 in baited nets constituted 5, 7, and 15%, respectively, of the estimated 4,807 individuals (≥100 mm TL) existing in the population (Van Haverbeke 2003). It was also encouraging that unique humpback chub did not exhibit size-related capture differences among disparate treatments nor did they differentially escape nets, as either of these suggest that the assumption of equal capture probability was being violated and, therefore, the accuracy of population estimates may be biased (Pine et al. 2003).

Scenting hoop nets or any other passive entrapment gear may still be a viable option under different circumstances. Interspecific fishes possess different propensities to enter and remain in nets (Patriarche 1968; Stott 1970) and differential attractions and repulsions to assorted baits (Mayhew 1973; Jester 1977). Thus, scenting may still increase captures of those fishes less prone to escapement if they are attracted by the emitted odors. Conversely, scenting for fishes that are prone to escapement may necessitate using passive entrapment gears that possess higher fish retention capabilities (e.g., multithroated devices).

Management Implications

The findings of this study should provide valuable insight to anyone wishing to optimize catch rates by baiting or scenting passive entrapment gear. Studies that use passive devices possessing low fish retention capabilities, such as single-throated hoop nets, may need to use accessible bait unless the target species have a low propensity to escape. The deleterious ramifications of abdominally PIT tagging well-fed fish may be avoided by holding fish, intramuscular PIT tagging, fin clipping, using external tags, or possibly using scent rather than bait in conjunction with other passive devices possessing higher fish retention capabilities. Either method, if successful, will bias relative abundance comparisons with historical data collected from unbaited gear and may attract undesirable piscivorous fishes into nets with the target species. Conversely, both methods may improve fishery management activities, such as population estimates, presence–absence surveys, translocations, and removals before stream renovations.

Acknowledgments

I thank D. Wesley, R. Van Haverbeke, P. Sponholtz, C. Nelson, E. Kohagen, C. Giuaque, A. Martinez, L. Johnstone, A. Pate, and M. Melnychuk for field assistance; B. Burch and C. Walters for statistical support; M. Santee for helicopter transport; T. Gushue for creating the LCR map; and three anonymous reviewers for remarks that greatly improved this manuscript. Permits to conduct this research and handle endangered fish were provided by the Arizona Game and Fish Department, Navaho Fish and Wildlife Department, U.S. National Park Service, and U.S. Fish and Wildlife Service (USFWS; Federal Endangered Species Permit TE676811–8). Funding was provided by the U.S. Geological Survey's Grand Canyon Monitoring and Research Center (Interagency Agreement 01–3022-R1009). The views expressed in this article are mine and do not necessarily reflect those of the USFWS or other federal agencies. Reference to trade names does not imply endorsement by the U.S. Government.

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