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Direct and indirect estimates of black crappie size selectivity to a common sampling gear: Potential biases and limitations for assessment

Greg R. Binion[a,*], Micheal S. Allen[b], Matt J. Catalano[b], William E. Pine III[b]

[a] University of Florida, Department of Fisheries and Aquatic Sciences, 7922 NW 71st Street, Gainesville, FL 32653, United States
[b] University of Florida, United States

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ABSTRACT

Reliable stock assessments require estimates of gear selectivity to separate selection from true changes in population structure, but true measures of selectivity are rare in the literature. We estimated size selectivity of bottom trawl sampling for black crappie *Pomoxis nigromaculatus* using capture–recapture methods to directly measure the effects of fish size on catchability (q, the fraction of a fish stock collected with a given unit of fishing effort) at Lake Jeffords, Florida, USA. Additional indirect estimates of selectivity were obtained with a population model applied to long-term data at four Florida lakes. Direct measures of selectivity indicated catchability was highest for the 90–119 mm length-group and lowest for fish greater than or equal to 180 mm, with q declining by a factor of 2 or 3 for large fish relative to small fish. The indirect age-structured modeling approach revealed dome-shaped gear selectivity patterns with relative selectivities peaking at age-1 for three of four lakes. Overall model trends indicated greater selectivity of younger fish (age-0 and age-1) to the gear followed by decreasing relative selectivity to older age-classes (age-2+). Trawl selectivity patterns suggested that otter trawls would be best for monitoring the abundance of small black crappie and useful for indices of recruitment. Our results showed that adult black crappie were underrepresented in bottom trawl samples which would influence age structure and growth rate estimates and the effectiveness of this gear as an assessment tool for tracking adult black crappie populations.

1. Introduction

Estimates of gear selectivity are important for fish stock assessment because they allow fisheries managers to assess population composition based on samples which usually are not a random sample of the fish population. Gear selectivity is commonly used to determine the effects of fishing on the size and age composition of a fishery and in assessment models to link size/age structure of catch data to the size/age structure of the fish population (Walters and Martell, 2004; Taylor et al., 2005). Accounting for selectivity in catch data allows managers to obtain a more accurate abundance index for the age composition and size structure of a fish stock. Stock assessment models need selectivity estimates to predict the effects of different harvest rates, calculate biological reference points like spawning potential ratio (SPR), and determining appropriate levels of sustainable yield for a fishery (Maunder, 2002). Thus, identifying gear selectivity allows biologists to adjust abundance indices to represent the true size/age composition which guides future management actions.

Measurements of the selective properties of fishing gears are often made utilizing direct and indirect methods (Pollock et al., 1990; Walters and Martell, 2004). Direct methods involve comparing catch composition against a known population structure. The most direct method for estimating selectivity is a mark–recapture experiment creating a known population, then calculating the proportion of fish caught by the gear in a given length category from the marked subpopulation (Hamley and Regier, 1973; Myers and Hoenig, 1997; McInerny and Cross, 2006). Indirect measures of selectivity require no prior knowledge about the age composition of a population. If catch-at-age data from the fishery are available, age-structured population models like virtual population analysis (VPA) can estimate the age/size selective properties of the fishing gear used. Other approaches incorporate the catch rates of various sizes of fish from different gear types and/or mesh size to compare relative gear selectivity between gears, but such studies do not identify the true selectivity of either gear (e.g., Boxrucker and Ploskey, 1989; Miranda et al., 1992; Millar and Holst, 1997).

Black crappie support one of the most popular sport fisheries in North America often ranking first or second among angler

* Corresponding author. Tel.: +1 361 547 9712.
E-mail address: greg.binion@tpwd.state.tx.us (G.R. Binion).

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preference, but can be difficult to manage. Sampling crappies to accurately describe vital rate functions (such as growth and mortality), abundance and size structure is often labor intensive requiring much sampling effort. Indexing black crappie abundance and size structure using common sampling gears is difficult due to unknown differences in gear performance and selectivity patterns. Trap nets have been useful in collecting large samples of crappie of all sizes (Gablehouse, 1984; Colvin and Vasey, 1986; Boxrucker and Ploskey, 1989), but true gear selectivity for these and other gears has rarely been measured (but see McInerny and Cross, 2006). Allen et al. (1999) compared the relative efficiency of trap nets versus otter trawls for sampling black crappie in two Florida lakes and reported that trawl sampling was superior to trap nets based on the size range of fish collected, accuracy of abundance estimates, required sampling effort, and expenditures associated with gear. Pine (2000) compared the relative selectivity of two different sized bottom trawls and found a smaller trawl was more effective at collecting juvenile black crappie than a larger trawl. However, otter trawl selectivity of black crappie relative to the population has not been measured. Our objectives were to (1) estimate size-specific catchability (q) of black crappie collected with otter trawls, (2) estimate relative age/size-specific selectivity of bottom trawl gears, and (3) use those selectivity patterns to evaluate the utility of otter trawls as an assessment gear for black crappie for Florida lakes.

2. Methods

2.1. Direct measure of selectivity

Capture–recapture sampling took place at Lake Jeffords, Florida during January 2007. Lake Jeffords is a 65 ha, meso-eutrophic (Pine, 2000) system located in Alachua County, North Central Florida. We selected Lake Jeffords because we could adequately sample the entire lake (i.e., sample all available habitat types) and create a large enough marked subpopulation to obtain reliable catchability (i.e., the fraction of the stock captured per unit effort) estimates.

Mark–recapture methods were used to create a tagged population using three gear types. Marking took place over a 10-day period in January 2007, with electrofishing gear sampled on day 1, otter trawls sampled on days 1–3, and hoopnets sampled on days 7–10. We sampled with three gears during the marking event to ensure all available habitat types of the lake were sampled. The recapture event took place over a 2-day period with bottom trawls 2 weeks after the first marking day. We only used bottom trawls during the recapture period, which allowed estimation of trawl size selectivity based on the known tagged population. The perimeter of the lake was sampled with electrofishing during both events to ensure fish had not moved into the shallow littoral zone where it is not possible to effectively trawl. Captured fish from all trawls were divided into subgroups by length. This division allowed estimation of q by size, providing a measure of actual trawl size selectivity. The length-groups (mm) approximated ages 0 (90–119), 1 (120–149), 2 (150–179) and adult fish three or older (180+). Abundance estimates were obtained using a Lincoln–Petersen estimator (Seber, 1982) which assumed that the crappie population was static over the mark–recapture time (closed population) and required a 2-stage mark-capture sampling event. The proportions of marked fish were calculated as the number of fish caught in the recapture events divided by the abundance estimate. All black crappie captured in the field during marking were measured for total length (TL) to nearest (mm) and pelvic fin clipped. Since only 2 weeks passed from mark to recap events and fish were fin clipped instead of using conventional tag types like a T-bar tag, we assumed tag loss to be negligible. All black crappie captured during the recapture where measured for total length to nearest (mm) and checked for fin clips.

Bottom trawls were pulled from a 7-m boat powered with a 70 hp outboard in all areas of the lake except in the shallow littoral zone to avoid fouling by vegetation. Effort was constant throughout the study at 3 min per trawl. The trawl net consisted of a 4.88-m long body and 4.6-m mouth and the body constructed with 38.1 mm stretch mesh and 31.8 mm stretch mesh in the cod end (Allen et al., 1999). Under tow, the mouth of the trawl is spread open with floats (25 mm × 50 mm) that are secured to the headrope of the trawl mouth. The sweep, or chain line, was attached to the footrope of the net. Wooden doors (38.1 cm × 76.2 cm) were secured to 146-cm leglines and a 15.3-m trawl bridle. The weighted doors served to open the trawl mouth and allowed the net to sample near the bottom.

Modified hoop nets were deployed in the middle of the lake at various sites. Hoop nets consisted of four similar-sized fiber-glass hoops either 0.9, 1.2 or 1.5 m in diameter and covered with 5.1 cm stretch nylon mesh webbing. A 23-m lead was used to connect two nets, which would direct fish toward a hoop net as they traveled along the lead. All hoop nets were set during the day, fished for 48 h, and retrieved. Hoop nets were only used for capture sampling event.

Electrofishing was conducted with a Smith-Root model SR18 electrofisher, equipped with a Smith-Root 9.0 GPP pulsator powered by a 9000 W generator. Approximately 7 A of DC current were produced at 120 pulses per second. The entire shoreline perimeter was sampled (as described above) with an experienced crew of one netter and one boat operator.

We estimated fin clipped mortality, defined as mortality from capture, handling, and fin clipping for each size-group to adjust the size of our marked population available for recapture. The subsamples of marked fish were held in aerated bait tanks and placed in holding pens as replicates ($n = 8$ replicate pens, Table 1) for 24 h to estimate associated fin clipping mortality for different length-groups. Holding pens were constructed out of PVC pipe which consisted of a rectangular frame that measured 3.0 m length by 1.25 m width. The body of the holding nets consisted of 19.3 mm stretch mesh webbing that extended to a depth of 1.1 m. The observed mortality rates for each size-group and holding pen were randomly resampled with replacement using a bootstrap to create 1000 Monte Carlo estimates (Haddon, 2001). The 95% confidence intervals were calculated at the 2.5 and 97.5 percentiles using the means of the resample from the bootstrap.

We used maximum likelihood methods to estimate how q varied with fish size. The Poisson log-likelihood function was approximated (dropping terms that did not include the data) as:

$$\ln L(O_i|q) = -\sum(P_i) + \sum(O_i) \times \ln(P_i)) \tag{1}$$

where P_i = (number available for recapture in size-group $i \times q \times$ effort) and O_i = (number of observed recaptures in size-group i). Catchability for each length-group was estimated by

Table 1
Summary of the number (N) of fish held in each replicate pen by length-group and the total number held in each pen

Replicate pen #	Length-group (mm)				
	90–119	120–149	150–179	180+	Total N
1	10	9	6	3	28
2	5	13	4	4	26
3	12	17	5	7	41
4	10	13	6	9	38
5	9	8	5	3	25
6	5	9	3	8	25
7	7	3	3	5	18
8	8	5	7	5	25