Management and Ecological Note

Reproductive investment drives capture probability in fish: an interspecific comparison

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Sustainable use of fisheries resources requires knowledge of how exploitation interacts with life history. Often, life history characteristics within a species can change across latitudes, resulting in population-dependent variations in growth rates, maturation schedules, reproductive effort, parental care and mortality (Winemiller & Rose 1992; Yamahira & Conover 2002). Despite this interpopulation variation, species and species complexes with wide geographic ranges are often managed with common approaches, ignoring life history variation (Quinn 2002). Recently, proposals to liberalise spring fishing for *Micropterus* at the northern extent of their natural range have gained interest with regulatory agencies (Jackson & Brooking 2004; Pearson 2008; Ontario Ministry of Natural Resources 2012). Year-round fishing for *Micropterus* is common in southern jurisdictions, while northern jurisdictions often restrict spring fishing to protect spawning individuals (Quinn 2002). In an effort to understand better potential consequences for homogenising regulations across broad spatial scales through liberalising fishing regulations, the present study compared how reproductive characteristics influence vulnerability to angling during parental care in largemouth bass, *Micropterus salmoides* Lacépède, and Florida bass, *Micropterus floridanus* (Lesueur), two phylogenetically related species (Near et al. 2003) inhabiting different latitudes.

Brood size and nest defence behaviour were compared between nest-guarding male Florida bass from northern Florida [Lake Susan (30° N, 82° W) and Devil’s Hole (30° N, 82° W)] and largemouth bass from south-eastern Ontario [Lake Opinicon (45° N, 76° W) and Elbow Lake (44° N, 76° W)] sampled at the beginning of the spawning season (early March, 2011 at Florida sites, mid-May, 2011 at Ontario sites). All four populations inhabited lakes with similar trophic states previously described as oligotrophic to mesotrophic (Carlson 1977; Canfield & Hoyer 1992) and had similar angling history (D. Philipp and M. Allen, personal observation). Nests with brood-guarding males were located by snorkel surveys in the littoral zone and marked with individually numbered plastic tags. Male total length (TL) was visually estimated under water as described by Suski and Philipp (2004). Following nest detection, the number of
potential egg predators in a 2-m circumference around the nest was assessed using a cumulative predator count over 2 min, similar to Gravel and Cooke (2009). Vulnerability to angling, a metric indicative of brood defence (Suski & Philipp 2004), was quantified by anglers in a boat who presented three fishing lures to an area within 2 m of each male’s nest (12-cm black/silver floating minnow bait, 6-cm white jig, 15-cm black plastic worm, in this order). Each lure was cast five times (15 casts in total) and the number of strikes recorded. Following the presentation of the lures, egg number (i.e. brood size) was quantified using a transparent 1-m² acrylic gridded sheet (Landsman et al. 2011). All activities were approved by the Institutional Animal Care and Use Committee of the University of Illinois at Urbana-Champaign (protocol #11036). Male TL, predator count and brood size were compared using a nested analysis of variance with lake nested within latitude (Wagner et al. 2006). The proportion of fish that struck the minnow bait on the first cast and the proportion of fish that hit any of the three lures during the 15 casts were compared using a nominal logistic model with the same hierarchical design described previously (Blanchette et al. 2002). Means were separated using a Tukey–Kramer test when the nested term [i.e. lake (latitude)] was significant (Zar 1999). Statistical analyses were performed with JMP 9.0.2 (SAS Institute, Cary, NC, USA).

Both males and brood sizes were significantly larger in Ontario compared to Florida, and brood sizes varied significantly between Ontario lakes (Table 1). Only bass from Ontario struck the minnow bait on the first cast (nominal logistic model: $\chi^2 = 14.65$, d.f. = 1, $P < 0.001$, Fig. 1). In addition, 84% of Ontario males struck at least one of the 15 casts presented, compared with 43% recorded for nest-guarding Florida bass (nominal logistic model: $\chi^2 = 12.18$, d.f. = 1, $P = 0.001$, Fig. 1). Males from the same species had similar probabilities of striking the first or any of the 15 casts, making differences between lakes within latitudes not statistically significant (nominal logistic model: $\chi^2 = 1.96$, d.f. = 2, $P = 0.56$ and $\chi^2 = 1.40$, d.f. = 2, $P = 0.56$, Fig. 1). Finally, predator densities showed a high variability across lakes within a latitude but not between latitudes (Table 1).

Results from the current study indicate pronounced differences in the response to angling across latitudes, with nest-guarding bass from Ontario much more likely to strike a lure than fish from Florida. Often, vertebrate populations from high latitudes show increased investment per brood, coupled with fewer reproductive events per year, resulting in large broods and high brood defence relative to low-latitude populations (Spencer & Steinhoff 1968; Leggett & Carscadden 1978; Chalfoun & Martin 2007). Multiple reproductive events per year have been reported for bass stocked into tropical reservoirs and for one of the Florida populations investigated here (Waters & Noble 2004; Rogers & Allen 2010; Shaw & Allen 2014), while northern bass populations often only achieve a single spawning event per season (Ridgway 1989). Besides a potential latitude/site effect, a number of additional factors have previously been shown to influence angling vulnerability for brood-guarding bass. For example, larger nesting male bass, typically with larger broods, are more aggressive nest defenders than smaller males, likely due to increased potential fitness returns, or

Table 1. Male size, brood size and number of predators near nests of brood-guarding largemouth bass (Lake Opinicon; $N = 27$), Elbow Lake; $N = 24$) and Florida bass (Devil’s Lake; $N = 17$, Lake Susan; $N = 28$) with results of the statistical tests comparing variables across lakes and latitudes

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Measured variables</th>
<th>Statistical analyses</th>
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<tr>
<td>Male size (mm)</td>
<td>Lake</td>
<td>Mean (SE)*</td>
</tr>
<tr>
<td></td>
<td>Lake Opinicon</td>
<td>355 (6)a</td>
</tr>
<tr>
<td></td>
<td>Elbow Lake</td>
<td>338 (24)a</td>
</tr>
<tr>
<td></td>
<td>Devil’s Hole</td>
<td>286 (10)b</td>
</tr>
<tr>
<td></td>
<td>Lake Susan</td>
<td>299 (8)b</td>
</tr>
<tr>
<td>Brood size</td>
<td>Lake Opinicon</td>
<td>6759 (623)a</td>
</tr>
<tr>
<td></td>
<td>Elbow Lake</td>
<td>4168 (930)b</td>
</tr>
<tr>
<td></td>
<td>Devil’s Hole</td>
<td>1831 (290)b</td>
</tr>
<tr>
<td></td>
<td>Lake Susan</td>
<td>1682 (267)c</td>
</tr>
<tr>
<td>Predators at nest</td>
<td>Lake Opinicon</td>
<td>4 (1)ab</td>
</tr>
<tr>
<td></td>
<td>Elbow Lake</td>
<td>0 (0)a</td>
</tr>
<tr>
<td></td>
<td>Devil’s Hole</td>
<td>7 (2)c</td>
</tr>
<tr>
<td></td>
<td>Lake Susan</td>
<td>3 (0)bc</td>
</tr>
</tbody>
</table>

* Dissimilar letters indicate significant differences between parameters at $\alpha = 0.05$ level (Tukey–Kramer HSD).
† $F$ ratios for analyses of variance (male size, brood size and predators at nest).

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a breeding event closer to the end of their reproductive lifetime (Suski & Philipp 2004; Steinhart et al. 2008). In addition, past harvest in heavily fished populations may remove vulnerable individuals and result in reduced response to angling (Philipp et al. 2009). To minimise the latter, effort was taken to standardise angling history across latitudes to the best extent possible (i.e. both Florida lakes and Elbow lake were private access and limited fishing, whereas in Lake Opinicon, fishing is not permitted during spring). Despite differences in angling history and predator abundances across lakes within a latitude, responses to angling did not differ across lakes within a latitude, suggesting only a minor influence of angling history and predator abundance on nest defence behaviour. Therefore, elevated angling vulnerability of Ontario fish may be due to a suite of factors related to larger (older) male sizes, coupled with larger broods and/or fewer reproductive opportunities per year, mediated by reduced breeding season length (Keast & Eadie 1985; Winemiller & Rose 1992; Suski & Philipp 2004). Species-specific differences and/or past angling history (i.e. harvest) across latitudes may have also played a role. Thus, while the exact mechanism for elevated aggression during the spawning period was not defined, results demonstrate that brood-guarding bass from Ontario were significantly more vulnerable to angling lures than were fish from Florida.

The more aggressive response to angling lures observed in largemouth bass relative to Florida bass highlights the potential for increased risk of angling-related disturbances for northern bass populations. Even short-term removal of a nest-guarding male (e.g. catch and release) can negatively affect reproductive success due to egg predation (Philipp et al. 1997). By contrast, the longer breeding seasons and potential for multiple broods in a year for Florida bass could be a partial explanation as to why decades of angling during the spring may have imparted little population-level impairment on southern populations of Micropterus (Gwinn & Allen 2010). Relationships between reproductive success and recruitment have not been well defined for Micropterus spp. and should be the subject of future investigations, ideally across broad latitudinal ranges.

Results from the current study emphasise that management needs to consider the long-term, evolutionary impacts of regulations. A number of recent studies have highlighted the potentially negative population-level consequences that can arise through harvest or improper management of fish and wildlife resources, resulting either from evolutionary or plastic changes to populations (Olsen et al. 2004; Darimont et al. 2009; Stenseth & Dunlop 2009; Sutter et al. 2012). Together, these studies, coupled with the present results, emphasise the need to consider potential population-dependent evolutionary responses to human resource use, and the need for a precautionary approach to reduce the risk of undesirable evolutionary population changes. The current study shows that populations of Micropterus can express significant differences in vulnerability to angling during brood defence, potentially as a result of local adaptation, which could be partially mediated by climatic factors, spawning duration or human influences. Due to the potentially negative impacts that may result, even under catch-and-release regulations (e.g. Philipp et al. 1997), managers should acknowledge population-dependent differences. Despite differences in male sizes, high-latitude environments offering limited reproductive opportunities could potentially result in more aggressive nest-guarding behaviour and, thus, more vulnerable bass populations; southern populations may be less vulnerable due to more reproductive opportunities per year. Because the current
study only examined individuals residing at the extreme ends of their natural range with a limited sample size, additional work needs to quantify population differences in reproductive tactics and their role in defining vulnerability to angling, ideally at mid-latitudes. Together, the findings of this study suggest managers should be cautious when extrapolating population-level trends across environments and species.

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References


