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Long-term impacts of introduced flathead catfish on native ictalurids in a north Florida, USA, river

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Abstract Introduction of flathead catfish, *Pylodictis olivaris* (Rafinesque), in waters of the USA has been widespread and often with negative impacts. Flathead catfish have been collected in Florida waters since the 1980s, and this study documents their impact on native fishes shortly after establishment. Four sites in the Choctawhatchee River, Florida, were sampled from 1997 to 2011, a time period spanning several years before and after the presence of flathead catfish at all sites. Flathead catfish expanded more than 91 river km in 2 years. The population increased rapidly and became the numerically dominant ictalurid at each site within 3 years of first detection at the site. Concurrent with the increases in flathead catfish was the precipitous decline of the native spotted bullhead, *Ameiurus serracanthus* (Yerger & Relyea). Electric fishing catch rates of flathead catfish significantly increased ($P < 0.03$) over time at all sites, while spotted bullhead catch rates significantly declined ($P < 0.03$) at three of four sites. Catch rates of flathead catfish and spotted bullhead were negatively correlated at all but the last site to be colonised by flathead catfish. This study provides evidence that introduced flathead catfish can quickly and significantly impact native ictalurids.

KEYWORDS: Chochtawhatchee River, introduced species, *Pylodictus olivaris*, range expansion, spotted bullhead.

Introduction

The flathead catfish, *Pylodictis olivaris* (Rafinesque), is native to the Mississippi, Rio Grande and Mobile Bay drainage basins in North America (Lee & Terrell 1987; Jackson 1999). Flathead catfish is a large predator that becomes almost exclusively piscivorous between 300 and 500 mm total length (TL; Layher & Boles 1980; Jolley & Irwin 2003). The potential to reach large size (up to 50 kg) in conjunction with the high quality of its flesh and popularity with anglers in its native range (Mayhew 1969; Layher & Boles 1980; Moss & Tucker 1989; Jackson 1999) has resulted in widespread introduction of flathead catfish outside its historical range. Introductions, both authorised and unauthorised, have frequently been followed by rapid population increases and range expansion (Kaeser *et al.* 2011). Within 15 years of a single stocking of 11 adult flathead catfish into the Cape Fear River, North Carolina, USA, the species had spread over 230 river km (Guier *et al.* 1984). Rapid population increases in Georgia were also reported by Quinn (1989), Bonvechio *et al.* (2011) and Kaeser *et al.* (2011).

Native catfishes can constitute a major part of flathead catfish diets (Hackney 1966; Nelson *et al.* 1985; Ashley & Buff 1987). Introduced flathead catfish have negatively impacted native fish species, particularly ictalurids (Guier *et al.* 1984; Mickey & Simpson 1988; Thomas

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1995; Moser & Roberts 1999), and have been stocked to control overcrowded bullhead *Ameiurus* spp. populations (Davis 1985; Odenkirk *et al.* 1999).

Flathead catfish in Florida, USA, waters were first collected from the Apalachicola River in 1982 (Cailteux *et al.* 2002) and from other nearby north Florida rivers shortly thereafter. Flathead catfish were first collected in the Choctawhatchee River in 2002 (Cailteux *et al.* 2002). North Florida rivers differ in geomorphology and unique species assemblages from locations of other flathead catfish introductions. For example, the Chochtawhatchee River flows over the Doughtery Karst Plain, contains 13 known fissure-type springs (Barrios 2005) and has many endemic species (Blalock-Herod *et al.* 2002; Blaustein 2008), such as the spotted bullhead, *Ameiurus serracanthus* (Yerger & Relyea), Okaloosa darter, *Etheostoma okaloosae* (Fowler), and southern sandshell mussel, *Lampsilis australis* (Simpson). To date, impacts of flathead catfish on native fishes have not been assessed in north Florida rivers.

One native fish species of particular concern is the spotted bullhead. Spotted bullhead has a limited distribution in Alabama and Georgia and in Florida is found only in the Suwannee, Ochlockonee, Choctawhatchee, Apalachicola and Yellow rivers (Cailteux & Dobbins 2005). The spotted bullhead is among the smaller of the bullheads, and the genus has been the focus of flathead catfish impacts in other cases of introduction (Guier *et al.* 1984; Pine *et al.* 2005).

The objectives of this study were (1) to quantify the colonisation and rate of expansion of the introduced flathead catfish population over a 15-year period in the Choctawhatchee River, Florida, and (2) to evaluate concomitant changes in the river's native ictalurid populations.

Methods

The Choctawhatchee River is an alluvial coastal plain river, rising in south-eastern Alabama and flowing southwest through the Florida Panhandle to Choctawhatchee Bay. The Choctawhatchee River is 227-km long and drains a watershed of 13 856 km². Approximately 70% of the watershed is forested with the remainder primarily agriculture. The river carries a heavy silt load and is considered the muddiest in Florida (Bass & Cox 1985). Historically, the Choctawhatchee River supported the populations of several native ictalurid species, particularly spotted bullhead, but also white catfish, *Ictalurus catus* L., and channel catfish, *Ictalurus punctatus* (Rafinesque) (Cailteux *et al.* 2002).

Routine annual ictalurid sampling by the Florida Fish and Wildlife Conservation Commission began in 1997 at Curry Ferry (rkm 125), Caryville (rkm 97) and Ebro (rkm 34); a fourth site at Hinson (rkm 76) was added in 1998 to increase spatial resolution (Fig. 1). Sampling was carried out by electric fishing in August or September when water temperatures exceeded 22 °C and were considered optimal for electric fishing (Quinn 1986; Justus 1996). Sampling during August–September helped standardise river conditions, and capture probability was assumed constant among years and sites. Sampling in 2005 was limited to the Curry Ferry and Caryville sites owing to river conditions. Sampling concluded at all sites in 2011.

Sampling protocol involved six 15-min continuous-pedal-time electric fishing transects equally distributed above and below the access point. The same boat-mounted electric fishing units (Smith-Root models GPP 5.0 and 7.5, Vancouver, WA, USA), operated at 15 Hz (Justus 1996; Cailteux & Strickland 2009) and 1000 V pulsed-DC output with two Wisconsin rings as the anodes were employed in all sampling. Sampling was conducted in a downstream direction at approximately the speed of the current (Cailteux *et al.* 2002). No chase boat was used in any sampling.

All catfish collected were weighed (g), measured (total length; mm) and released. Differences in catch rates

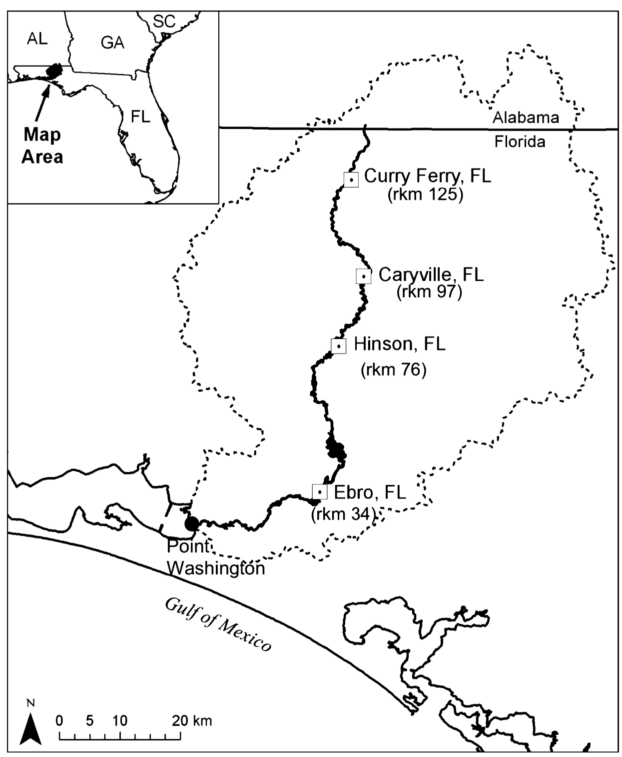

Figure 1. Location of study sites in the Choctawhatchee River, Florida. Distances are river km from the mouth of the River at Point Washington, Florida.

(fish per minute) between species, site and year were assessed with a linear mixed model (SAS 2008). Catch rates were square-root transformed (Zar 2010), after which they satisfied parametric test assumptions. Year was included as a covariate, and species, site and their interaction were included as fixed factors. The interaction between species, site and year was included as a continuous factor, which allowed testing for unique trends for each species at each site. A first-order autoregressive covariance structure was used to account for repeated observations at each site across years. This model allowed determination of the overall trend in catfish catch rates across time and comparison of differences between species and sites. Because the trend is based on LS means, regression parameters were calculated from untransformed data to better show the fit to actual estimates when the test results did not differ from the model with transformed data. This allowed meaningful rates of change in catch rates over time to be calculated. A mixed-effects model with site as a fixed effect and year as a continuous variable was used to test for potential differences in the lengths of the flathead catfish caught over time. Relationships between catch rates of spotted bullhead and flathead catfish were evaluated using Spearman's rank correlation.

Results

Sampling occurred in 13 of 15 years from 1997 to 2011; no sampling occurred in 2000 and 2010. Additionally, Ebro was not sampled in 2005 and Hinson was not sampled in 1997 or 2005. A total of 6847 ictalurids were collected during 3940 min of electric fishing and included 3626 spotted bullhead, 793 white catfish, 956 channel catfish and 1472 flathead catfish. Flathead catfish was first observed at Curry Ferry (the upstream-most site <16 km from the Alabama reach of the river) in 2002 and was first collected from all four sites in 2004 (Fig. 2). Flathead catfish colonised the entire Florida portion of the Chochtawhatchee in 3 years. Flathead catfish became the numerically dominant ictalurid at the Curry Ferry site by 2005, comprising 64.9% of all catfish collected there. Flathead catfish became the numerically dominant ictalurid at the Caryville site by 2006 (41.1%), the Hinson site by 2007 (73.8%) and the Ebro site by 2011 (55.2%).

The average length of flathead catfish did not differ among years ($F_{4,25} = 1.37$, $P = 0.2442$). The linear mixed model for catch rates detected significant interactions between species and sites ($F_{16,408} = 17.51$, $P < 0.01$) as well as a significant interaction between species, site and year ($F_{16,408} = 17.51$, $P < 0.01$), indicating that the trends in catch rates across time differed

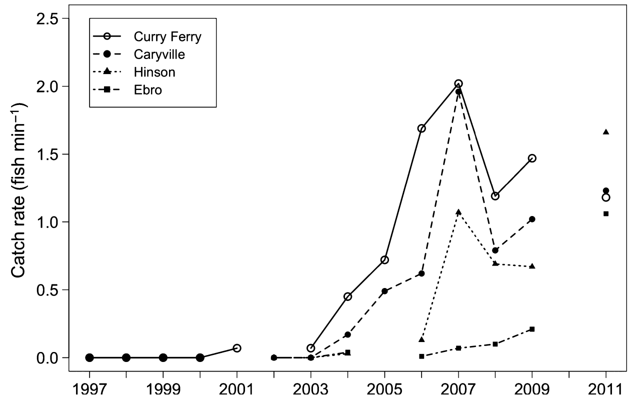

Figure 2. Mean catch rates of flathead catfish at four sites in the Choctawhatchee River, Florida, 1997–2011.

between species and sites. At the Curry Ferry, Caryville and Hinson sites, flathead catfish catch rates significantly increased over time, while spotted bullhead catch rates significantly decreased through time (Fig. 3). At Ebro, the site most recently colonised by flathead catfish, catch rates of flathead catfish and channel catfish increased over time, but spotted bullhead catch rates did not differ significantly over time. Catch rates of channel catfish did not differ over time at the other three sites, and catch rates of white catfish did not differ over time at any site. Spotted bullhead and flathead catfish catch rates were negatively correlated at Curry Ferry ($r_s = -0.785$, $P = 0.001$), Caryville ($r_s = -0.636$, $P = 0.019$) and Hinson ($r_s = -0.515$, $P = 0.105$), but not at Ebro ($r_s = 0.254$, $P = 0.426$).

Discussion

Rapid range expansion and population growth of introduced flathead catfish is well documented (e.g. Dobbins *et al.* 1999; Fuller *et al.* 1999; Kwak *et al.* 2006), but long-term impacts on native fish assemblages are less studied. Flathead catfish have expanded their range throughout the Florida portion of the Choctawhatchee River and are considered established. While first documented in the upstream portions of the river, this study found increasing abundance through time at each site and substantiates the downstream expansion of the flathead catfish population. Accompanying the flathead catfish range expansion was the significant decrease in spotted bullhead at three of four sites. Considering the recency of colonisation of the fourth sampling site (Ebro, most downstream site) by flathead catfish, it seems likely that this site will eventually experience similar declines in spotted bullhead abundance. Although white catfish and channel catfish showed little or no change in abundance, continued

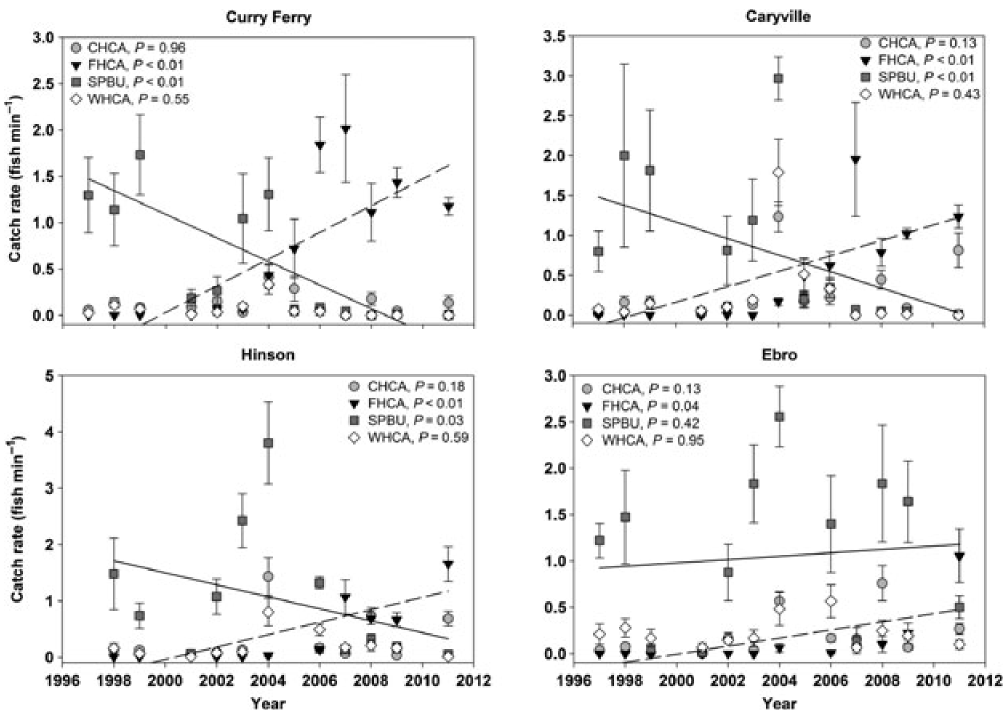

Figure 3. Mean catch rates of channel catfish (CHCA), flathead catfish (FHCA), spotted 410 bullhead (SPBU) and white catfish (WHCA) at four sites on the Choctawhatchee River, 1997–2011. Vertical lines are the SE. Linear trends in catch rates are shown for flathead catfish and spotted bullhead. *P* value after each species designation is the probability of a linear trend in catch rate.

monitoring is recommended, as white catfish have shown evidence of decline in the presence of other introduced ictalurids (Jordan *et al.* 2004) and channel catfish have been documented in flathead catfish diets (Weller & Robbins 1999; Baumann & Kwak 2011).

The dynamics of flathead catfish abundance were similar at all four sites: the time of colonisation was followed by 2–3 years of low catch rates, and then a period when catch rates increased. At Ebro, lower catch rates persisted for 5 years, but by 2011 flathead catfish catch rates were similar to those at the other sites. The period of time from which an immigrant species becomes an invader (also known as establishment or lag time) varies widely and is difficult to predict (Mack *et al.* 2000). Often, studies documenting introduced species are biased towards those species that establish successfully, and of those, the species that establish quickly and with the most impact are often disproportionately studied. Regardless of the quantitative expectations of establishment, flathead catfish demonstrate several characteristics that have been identified with establishment success of introduced or colonising species, in particular being a superior competitor, exhibiting high growth rates and a history of invasion (Sakai *et al.* 2001; Kolar & Lodge 2002).

Although the lack of differences in flathead catfish lengths among years could be demographic differences in habitat use or selectivity of the electric fishing equipment, rapid individual and population growth rates after introduction could mask any initial demographic or size-based differences in the population. Additionally, movement between sites over time could also homogenise the abundance of adults. One conclusion that can be drawn from the length distributions is that even within the first year of flathead catfish detection at all sites, electric fishing captured a high proportion of large (>500 mm *TL*) individuals, a size that presumably corresponds to sexually mature individuals.

The rapid increase in flathead catfish at Curry Ferry suggests that range expansion into the Florida portion of the Choctawhatchee River was not the result of a single isolated introduction in the immediate vicinity but rather recruitment from an existing reproducing population upstream. Population expansion and growth by the flathead catfish in the Choctawhatchee River has been relatively rapid, about 3 years to colonise the Florida portion of the river. Thomas (1995) reported flathead catfish increasing from ‘sparse existence to predominant status’ in approximately 10 years in the Altamaha River, Georgia, but did not report distance between sampling stations, and therefore, rates of establishment cannot be calculated. Similarly, Guier *et al.* (1984) found that flathead catfish became a ‘significant population’ within 10 years of introduction in the Cape Fear River, North

Carolina. Although Guier *et al.* (1984) reported that a single introduction of flathead catfish was able to populate a 201-km section of the Cape Fear River, results were drawn from data collected more than 10 years after flathead catfish introduction, limiting any estimates of expansion rate. Results of the present study indicate flathead catfish expansion in the Choctawhatchee River occurred at rates similar to or more rapid than in other south-eastern US rivers.

Guier *et al.* (1984) concluded that introduced flathead catfish severely impacted white catfish in the Cape Fear River, North Carolina. This study did not document a significant decline in white catfish catch rate after flathead catfish expansion, but detection of changes in white catfish abundance was constrained by low catch rates. Collection of only three white catfish from the Curry Ferry and Caryville sites in the final 4 years of sampling suggests that flathead catfish may have adversely impacted white catfish. Channel catfish appear to have been the only native catfish not negatively impacted by the introduction of the flathead catfish in the Choctawhatchee River; but, as noted for white catfish, the low catch rates may have precluded detection of a trend.

Fish assemblages in the south-eastern United States are presently considered the most threatened in the United States (Jelks *et al.* 2008); and benthic species, which includes native ictalurids, are often among the first groups to be impacted by habitat loss, pollution and introduced species (Angermeier 1995; Warren *et al.* 1997). While these impacts are often found in combination, introduced species alone have a clear, negative and often large impact on native species assemblages (Sakai *et al.* 2001). Most studies documenting the impacts of introduced flathead catfish on native ictalurids have been limited to comparing pre-introduction data to data collected relatively late in the expansion stage of the flathead catfish population. Bullhead declines in the presence of introduced flathead catfish have been previously documented (Guier *et al.* 1984; Bart *et al.* 1994; Thomas 1995; Odenkirk *et al.* 1999), and while this information is important in itself, it does not give insight into the rate of decline of native fish. This study has demonstrated that expansion of an introduced flathead catfish population in numbers and in space can happen in <10 years and that a native ictalurid population can be significantly reduced in a similar time period.

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