Winter Mortality in Some Temperate Young-of-the-Year Fishes

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Abstract: We tested the survival and growth of three young-of-the-year (YOY) estuarine resident (mummichog, sheepshead minnow, winter flounder) and a southern migrant (silver perch) fish species to determine the influence of winter temperatures. Under ambient winter temperatures with daily feeding, mortality did not occur for mummichog and sheepshead minnow, was low for winter flounder (25%) and high for silver perch (100%). There was little or no growth for any species that survived during the winter. As expected, silver perch were least tolerant to cold temperature, supporting the hypothesis that this species needs to migrate out of Middle Atlantic Bight estuaries in the fall to avoid low winter temperatures and survive.

Keywords: winter mortality, young-of-the-year, fishes, estuaries, growth

INTRODUCTION

The ability of temperate young-of-the-year (YOY) fishes to survive the first winter of life may be an important determinant of recruitment success. Investigators have shown that winter survival of YOY may be size dependent and for some species may be dependent on a critical minimum winter temperature below which YOY cannot survive (Conover and Present, 1990; Hales and Able, 2001; Henderson et al., 1988; Kooka et al., 2007; Post et al., 1988; Sogard, 1997). A recent review noted that most research currently addresses winter mortality and enhanced recruitment to the adult population associated with climate change can result in warmer winters and reduced thermal refugia are possible for estuarine and marine fishes, but not for freshwater fishes (Hurst, 2007). Responses in these contrasting environments may differ, in part, because extensive migrations to thermal refugia are possible for estuarine and marine fishes, but not for freshwater fish (Hurst, 2007). In addition, the general warming associated with climate change can result in warmer winters and reduced winter mortality and enhanced recruitment to the adult population (Hare and Able, 2007; Hurst, 2007).

This study compares winter survival rates among the YOY of four species that have different patterns of estuarine use. Bairdiella chrysoura Lacepède (silver perch) are resident in the summer, but are not found in winter because they migrate out of estuaries and move south as temperatures cool in the fall (Able and Brown, 2005; Able and Fahay, 1998). We hypothesized that YOY silver perch would be intolerant of cold water temperatures. In contrast, three year-round, estuarine species, Fundulus heteroclitus Linnaeus (mummichog), Cyprinodon variegatus Lacepède (sheepshead minnow), and Pseudopleuronectes americanus Walbaum (winter flounder) (Able and Fahay, 1998; Smith and Able, 1994) were hypothesized to be tolerant of low winter temperatures because they are considered resident. We also determined growth rates for all these species as another index of their response to low temperatures in winter. Our goal was to determine the influence of winter temperatures on growth and survival rates for all four species.

MATERIALS AND METHODS

Winter Flounder and Silver Perch Experiments

Young-of-the-year winter flounder and silver perch were collected in Great Bay/Little Egg Harbor estuary in southern New Jersey from August to November 1995. All fish were held in the laboratory at ambient temperature in a flow-through seawater system and were fed a diet of chopped Menidia menidia Linnaeus (Atlantic silverside) and Artemia sp. (brine shrimp) daily until the start of the experiment. The flow rate of ambient sea water, which was filtered and UV treated, was approximately 0.6 l min⁻¹ and a drainage hole in the side of each aquarium maintained water volume at a constant level. The bottom of the experimental aquaria (50 × 26 × 33 cm) was covered with 1 cm of rinsed beach sand. Natural photoperiod was simulated in the laboratory using an artificial lighting schedule.

Twenty-four hours prior to the start of the experiment, fish were placed into their treatment aquaria. Winter flounder (n=31; 60-126 mm SL) were divided into size groups to keep biomass similar among aquaria and then randomly assigned to 15 rectangular aquaria (3 small fish or 1 large fish per aquarium). Silver perch (n=65; 52–109 mm SL) were randomly placed in 13 rectangular aquaria (5 per aquarium). Individuals of both species were fed daily as previously described. Uneaten food was removed later in the day. Temperature was also recorded every half hour by a temperature recorder (Ryan Instruments TempMentor) located in an identical aquarium in the same location that contained no fish. Mortality was assessed each day and dead fish were removed and measured to the nearest 0.1 mm SL using a dial caliper. At the end of the experiment on 22 April 1996 when ambient temperatures were consistently above 9°C, survivors were measured to the nearest 0.1 mm SL in order to determine growth rate during the experiment.

A control group of silver perch (n=16, drawn from same group as reported earlier) were placed in four aquaria under nearly constant warm temperature (mean daily average = 14.6°C) to monitor survival under non-winter conditions. A control was not deemed necessary for winter flounder because previous observations demonstrated that winter flounder survived similar temperatures under laboratory conditions.
Mummichog and sheepshead minnow experiments

Young-of-the-year sheepshead minnows and mummichog were collected from four marsh pools adjacent to the Rutgers University Marine Field Station from October to November 1996. All fish were brought into the laboratory and held at ambient temperatures in a flow-through system. A daily feeding regime of a mixture of ground Atlantic silversides and spinach was implemented until the start of the experiment. A natural photoperiod was maintained in the laboratory by timer-controlled lighting.

The experiment was conducted over a period of 105 days from 26 November 1996 to 5 March 1997. A total of eight rectangular aquaria (50 × 26 × 33 cm) were used for each species. Each tank also had approximately 1 cm of beach sand covering the bottom. Six tanks were kept on an ambient flow-through system and two were on a controlled temperature regime (15°C ± 2°C). Each tank had eight fish (YOY mummichog: 31–53 mm TL, or YOY sheepshead minnow; 21–48 mm TL).

During the experiment, all tanks of fish were fed a mixture of Atlantic silversides and spinach four times a week. Temperatures were recorded every half hour by a Ryan Instruments Tempmentor. Mortality was assessed daily. All fish remaining after the termination date of the experiment were measured to the nearest 0.1 mm (TL) to determine growth.

RESULTS

Mortality
Mortality varied with water temperature and species. Under ambient conditions (~1.8 to 14°C, winter 1995–1996), there was a lethal temperature limit for all YOY silver perch and for a small number of YOY winter flounder tested (Fig. 1). We observed 100% mortality of silver perch on 9–11 December 1995 when the temperature dropped abruptly from 7.5 to 0.5°C (Fig. 1). There was a 25% mortality rate (Fig. 1) of winter flounder on 5–6 February 1996 during a period of extremely low temperatures (0 to −1.8°C). There was no obvious size effect for those few winter flounder experiencing mortality. There was no mortality for the YOY of either mummichog or sheepshead minnow even though ambient temperatures reached as low as −1.4°C and ranged up to 11°C (winter 1996–1997). There was no mortality in the controls for any of the species tested.

Growth
There was very little growth for any of the four species at ambient temperatures. There was virtually no growth for both winter flounder and silver perch (0.003 and 0.073% respectively) under ambient winter conditions in 1995–1996. The silver perch maintained at a constant 15°C grew at a rate of (0.038% day⁻¹), which was not significantly different (p=0.2969) than the growth rate of fish exposed to ambient temperatures. The control fish maintained at the higher temperature ate regularly whereas the fish kept under ambient conditions did not. Also, there was minimal growth for mummichog and sheepshead minnow (both 0.01% day⁻¹).

DISCUSSION

Mortality
The response of the four species of YOY estuarine fishes from southern New Jersey varied between resident and migratory species and with temperature. As predicted, the seasonally migratory silver perch had a higher mortality rate (100%) than the resident species (i.e., winter flounder [25%], mummichog [0%], and sheepshead minnow, [0%]). The geographic ranges of these species may help explain their differing survival at cold temperatures. The three latter species have northern
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(Black sea bass) experienced 100% mortality when winter temperatures dropped to 2–3°C (Hales and Able, 2001). YOY *Paralichthys dentatus* Linnaeus (summer flounder) suffered a 42% mortality rate in 2–3°C water (Malloy and Targett, 1991). Further studies indicated that time until 50% mortality was dependent on the rate of temperature decrease for this species (Malloy and Targett, 1994).

There are other factors that can affect winter survival besides direct temperature effects (see Hurst, 2007 for a review). Disease and parasitism could also be factors, as suggested for sheepshead minnows (Coleman and Travis, 1998). Others have noted a relationship between thermal stress and reduced osmoregulatory abilities (Fullerton et al., 2000; Johnson and Evans, 1990, 1991). Of course, multiple interactions between all of these factors are possible as well (Hurst, 2007).

**Growth**

The winter growth rates for all four species were very low as expected for the YOY of many species in temperate estuaries (Able and Fahay, 1998). The slow growth rates during low winter temperature were consistent with anecdotal behavioral observations of reduced feeding in the laboratory. None of these species ate on a regular basis once temperatures dropped in early winter, indicating a reliance upon energy reserves to survive the winter season. Winter flounder and silver perch remained relatively inactive, and surviving winter flounder did not eat regularly until the onset of warmer temperatures. The low winter growth rates contrast sharply with values for the same species in the summer. Curran and Able (2002) noted winter flounder growth rates in Great Bay of up to 0.56 mm d⁻¹ (2.5% d⁻¹) in June, while Phelan et al., (2000) reported values during the same period but elsewhere in Great Bay of up to 1.2 mm d⁻¹ (5.7% d⁻¹). Sogard (1992) obtained a similar maximum value of 1.3 mm d⁻¹. The silver perch have been shown to grow an average of 0.75 mm d⁻¹ in this same area from August to October (Able and Fahay, 1998). Also, both mummichog and sheepshead minnow have positive growth rates during the summer (Able and Fahay, 1998).
CONCLUSIONS AND IMPLICATIONS

We conclude that winter mortality varied between species, and was correlated with the seasonal and geographic distributions of these species during the winter. For example, YOY winter flounder, mummichog, and sheepshead minnow remain in estuaries during cold temperatures (Able and Fahay, 1998; Collette and Klein-MacPhee, 2002) but silver perch leave estuaries and retreat to areas south of Cape Hatteras (Able and Brown, 2005). This pattern of migration to the south, to often below Cape Hatteras, is shared by all other sciaenids that typically occur in the Middle Atlantic Bight and many other species that occur in these estuaries during the summer (Able and Brown, 2005). This is apparently in response to the widely variable seasonal temperatures typical of the Middle Atlantic Bight (Grosslein and Azarovitz, 1982; Hare and Able, 2007; Parr, 1933). If species lack the ability or inclination to migrate from estuaries as temperatures decline in the fall, e.g. Chaetodon ocellatus Bloch (spotted butterflyfish) (McBride and Able, 1998), they may suffer 100% mortality and thus make no contribution to subsequent generations. At the latitude of New Jersey estuaries, these species may become annual expatriates (see Table 7.7.4 in Able and Fahay, 1998 for further possibilities).

The patterns of high winter mortality and very low growth rates during the winter may change in response to increasing temperatures as the result of climate change (e.g., Roessig et al., 2004; Strale and Stenseth, 2007). Our own observations in Great Bay in southern New Jersey have quantified annually variable winter temperatures during the period of 1976 to 2006. During that time there have been consistently milder winters, i.e., fewer minimum temperatures below 0°C, relative to the long-term average, since the late 1990s (Fig. 2). These changes, for example, have decreased winter mortality for Micropogonias undulatus Linnaeus (Atlantic croaker) (Hare and Able, 2007). The YOY of this species spend the winter in estuaries and, as such, are particularly susceptible to temperatures at that time. As a result, it is clear that recent milder winters have resulted in increased survival and profoundly influenced the distribution, population dynamics, and fishery for this species in the Middle Atlantic Bight because the increasingly mild winters are evident in multiple estuaries (Hare and Able, 2007). Thus, there is the potential that the moderating winter temperatures due to climate change may result in similar responses for more southern species if this warming continues (Sharma et al., 2007).

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LITERATURE CITED


