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Habitat-specific growth, survival and diet of late juvenile hatchery-reared spotted seatrout (*Cynoscion nebulosus*)

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ABSTRACT

As a key recreational fishery species throughout the Gulf of Mexico, the spotted seatrout (*Cynoscion nebulosus* Cuvier) requires sound management practices (VanderKooy and Muller, 2003; Fulford and Hendon, 2010). Accordingly, it is imperative to fully understand the ecology of spotted seatrout (Lorio and Perret, 1978), especially factors affecting the successful recruitment of this estuarine-dependent carnivore. Considering the large gap in knowledge about the ecology of late juvenile stage spotted seatrout, as well as the need to evaluate current stock enhancement practices for this species, the objective of this study was to assess the growth, survival and diet of late juvenile hatchery-reared (HR) spotted seatrout within three prospective nursery habitats in a shallow bay system: submerged aquatic vegetation (SAV), non-vegetated shoreline (NVS), and non-vegetated open water (NVO). While caged under natural conditions for 4 weeks, relative growth was significantly greater for fish caged in SAV and NVS habitats compared to NVO habitat. Mortality was relatively high in the first week of the study during acclimation. Stomachs of HR fish contained prey, and the diet composition of HR fish included common prey types consumed by comparable sizes of wild fish. Findings indicate that habitats within or in close proximity to SAV or marsh shoreline offer more favorable conditions than deeper open water habitat for late juvenile HR spotted seatrout. Moreover, HR fish can acclimate to natural conditions and successfully transition to a natural diet, in the absence of predators and competitors.

1. Introduction

As a key recreational fishery species throughout the Gulf of Mexico, the spotted seatrout (*Cynoscion nebulosus* Cuvier) requires sound management practices (VanderKooy and Muller, 2003; Fulford and Hendon, 2010). Accordingly, it is imperative to fully understand the ecology of spotted seatrout (Lorio and Perret, 1978), especially factors affecting the successful recruitment of this estuarine-dependent carnivore. Because this economically important species exhibits considerable fidelity to its natal estuary (Callihan, 2011), the availability of nursery habitat for spotted seatrout is particularly vital to its recruitment success (Baltz et al., 1998). Indeed, structured estuarine habitats, including seagrass, emergent shoreline vegetation, and subtidal shell substrate, provide key nursery conditions for post-settlement early life stages ranging in size between 3 and 10 cm SL (Rakocinski et al., 1992; Baltz et al., 1998; Rooker et al., 1998; Smith et al., 2008; Neahr et al., 2010). In Florida Bay, Hettler (1989) reported seagrass as the most valuable feeding habitat for juvenile spotted seatrout. Likewise, Peebles and Tolley (1988) suggested that lower mortality of pre-settlement larvae was related to the more extensive seagrass cover in Fakahatchee Bay compared to Naples Bay, Florida. Rapid growth of small juvenile spotted seatrout also coincided with structured organic detrital sediments in Louisiana, where submerged aquatic vegetation (SAV) habitat is limited (Baltz et al., 1998).

Although habitat use by adult spotted seatrout, which involves the seasonal use of seagrass beds in the warm months (Blanchet et al., 2001), is also well documented (Baltz et al., 2003), much less is known about the ecology of late juveniles (>10 cm SL). In Mississippi, late-juvenile spotted seatrout were significantly more abundant in SAV, compared to marsh-edge and non-vegetated habitats in the Grand Bay National Estuarine Research Reserve (Hendon, 2013). Thus, SAV may also provide valuable habitat for late juvenile spotted seatrout. The utility of SAV as release habitat for hatchery-reared (HR) spotted seatrout has not been assessed, but HR fish can be used as a 'model' for determining habitat value for late juvenile spotted seatrout using an experimental approach.

In addition to traditional management and restoration practices, stock enhancement is often employed as a means to supplement exploited fish populations (Lorenzen, 2008). The ultimate goal of stock enhancement is to augment populations of intensively exploited species. In order to successfully achieve that goal, two outcomes must be realized: (1) acclimation and survival of HR fish in the wild, and (2) non-displacement of wild fish by stocked HR fish (Leber et al., 1995; Huntingford, 2004). The survival of HR fish involves three

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ecological requirements: (1) acclimation to natural conditions, (2) transition to novel wild prey, and (3) avoidance of predation. Differences in any of these prerequisites between HR and wild fish could result in the failure of stock enhancement efforts. Thus, ecological responses of newly released HR fish need to be examined through monitoring, field experiments, and modeling (Blankenship and Leber, 1995; Leber et al., 1995; Walters and Martell, 2004; Lorenzen, 2006; Hervas et al., 2010). Information gleaned can be used to maximize post-release survival of HR fish, as well as to determine and implement appropriate release strategies (Munroe and Bell, 1997; Mahnken et al., 2004). Resulting informed adaptive strategies reveal the best size at release (Leber, 1995), timing of release (Leber et al., 1997), conditioning of fish prior to release (Brennan et al., 2006; Brown et al., 2013), and suitability of habitats for release (Stunz and Minello, 2001; Andersen et al., 2005). The role of beneficial release habitat is a primary focus of the present study.

Early growth is a critical factor mediating fish survival (Sogard, 1997). Rapid early growth often equates to predator avoidance, tolerance of environmental stress, and a competitive advantage in feeding success (Houde, 1987; Sogard, 1992; Piet et al., 1998), each of which mitigates mortality (Sogard, 1997; Rooker et al., 1999). Likewise, high quality habitats promote faster growth through some combination of abundant food resources, available refuge from predators, and favorable physical conditions (Meng et al., 2000). Consequently, growth rate can be a good proxy indicator of habitat quality (Sogard, 1992; Meng et al., 2000; Necaise et al., 2005; Shervette and Gelwick, 2007).

Assessments of relative habitat value often employ caging fish in the field in order to restrict them to selected habitats from which they subsequently can be recovered (Mittelbach, 1988; Sogard, 1992; Jordan et al., 1996; Levin et al., 1997; Phelan et al., 2000; Shervette and Gelwick, 2007; Lanier and Scharf, 2007). This approach has also proved edifying for comparative studies of performance between wild and HR fishes under natural conditions (Stunz and Minello, 2001; Álvarez and Nicieza, 2003; Brennan et al., 2006). Advantages of caging generally involve manipulations of ecological conditions relative to the delineation of treatments in terms of habitat, density, predation, interspecific competition, etc. Restriction, however, also brings added risks of artifacts resulting from cage effects (Peterson and Black, 1994; Heath and Houde, 2001). Interpretation of caging studies is predicated on two general assumptions of parallel bias across treatments and the scalability of processes measured within the enclosed areas. Interactions between treatments and artifacts do occur though, and potential scaling issues exist whenever boundaries are imposed, as with the use of enclosures. Some unavoidable consequences of such restriction include specific effects on movement, behavioral interactions, and trophic interactions of subjects. As Peterson and Black (1994) point out, however, intervention using enclosures is necessary for answering certain questions. Thus, ecological insights compensate for cage effects, as long as one is aware of potential artifacts.

Considering the large gap in knowledge about the ecology of the late juvenile stage of spotted seatrout, as well as the need to evaluate current stock enhancement practices for this species, the objective of this study was to assess the growth, survival and diet of late juvenile HR spotted seatrout within three prospective nursery habitats in the shallow Point aux Chenes Bay system, which serves as an important regional source of recruitment (Comyns et al., 2008). Growth and survival of HR fish were assessed among SAV and two alternative habitat types, non-vegetated shoreline (NVS) and non-vegetated open water (NVO). Diets were also compared between HR and wild fish from designated habitats.

2. Materials and methods

2.1. Study area and cage design

A field caging experiment was conducted within Point aux Chenes Bay, Mississippi, USA (Fig. 1). Located on the north side of Mississippi Sound, this bay experiences a relatively high salinity regime and contains extensive SAV beds consisting of *Ruppia maritima* and *Halodule wrightii* (Moncreiff, 2007; Cho, 2007; Cho and May, 2008).

Circular cages (1.8 m diameter by 1.2 m height) were constructed of 1.9 cm square plastic mesh supported by 2.5 cm diameter PVC pipe and plastic tubing. Because a pilot 14 day growth experiment using cages without bottom panels yielded only 21 of the original 100 fish, bottom panels of the same mesh material as the cage sides were installed for the main experiment. Bottom panels allowed intermittent monitoring of mortality and replacement of missing individuals by "placeholder" HR fish throughout the duration of the experiment. All fish were uniquely identified using Passive Integrated Transponder (PIT) tags. Because bottom panels depressed the underlying natural seagrass, artificial seagrass fabricated of green polypropylene ribbon was fixed to the interior bottom panels of each SAV cage to mimic natural SAV habitat and to standardize the enclosed habitat structure. The height and surface area of the artificial seagrass simulated the extent of natural habitat structure, as determined from measurements of blade height and width obtained from random samples of SAV within the study area. Because artificial seagrass did not exactly match the spatial heterogeneity of naturally occurring SAV, the amount of artificial seagrass allocated to cages reflected total surface area (rather than natural density), thereby providing equivalent amounts of artificial SAV commensurate with natural SAV per unit area of bottom. Accordingly, the amount of artificial seagrass allocated to each cage equated to a mean blade height of 275.8 mm (range of natural SAV = 238–293 mm) and a mean blade width of 7.53 mm (range of natural SAV = 5.9–9.3 mm) per 6.4 cm^2 of bottom area.

To allow sufficient time for artificial seagrass to become conditioned and colonized by biofilm and macrofauna, SAV cages were initially randomly deployed within the SAV study area on 19 July 2012, 56 days prior to the addition of experimental fish. Initially, five cages were randomly placed fully within SAV habitat, and an additional five cages each were randomly sited along non-vegetated shoreline (NVS) and in non-vegetated open water (NVO) habitats. Due to dewatering during low tides, a fourth type of habitat within depositional marsh-edge was not a viable treatment option, but NVS cages were placed as close as possible to erosional marsh-edge while still maintaining continuous inundation. In Point aux Chenes Bay, two cages (one NVS and one NVO) were dislodged and lost due to Tropical Storm Isaac. Thus, the final design layout was five SAV, four NVS and four NVO cages within the Point aux Chenes Bay study area (Fig. 2). A duplicate experiment within adjacent Grand Bay was lost due to high wave energy from strong prevailing winds.

2.2. Experimental fish

Assessment of survival and growth of late juvenile HR spotted seatrout ensued within the selected habitats. Hatchery-reared fish ranging from 144 to 188 mm TL provided relatively uniform sizes of late juvenile fish for this field experiment. On 14 August 2012, 190 fish were anesthetized with MS-222 and injected with uniquely encoded Biomark© PIT tags (12 mm long, 134.2-kHz frequency) inserted into the abdominal cavity of each fish. The use of PIT tags enabled tracking of individual growth rather than relying on an aggregate measure of growth from each cage. Tagged fish were placed in a separate holding tank to monitor tag retention and fed on the same pelleted diet until release. Fish were acclimated by gradually adjusting water temperature and salinity over a three-day period to match field conditions prior to releasing them into cages.

One month after tagging (13 September 2012), HR fish were removed from the holding tank, anesthetized and scanned with a Biomark 601 hand-held reader to ensure tag retention and determine unique PIT tag codes. Each fish was weighed (wet weight) to the nearest 0.1 g, measured to the nearest mm standard length (SL), and randomly assigned to a numbered cage. Fish were placed into buckets lined with plastic fish-transport bags filled with tank water and labeled with the