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Size-specific growth and mortality of juvenile yellow perch in southwestern Lake Michigan

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ABSTRACT

Yellow perch have experienced widespread recruitment failure within Lake Michigan since the early 1990s. Efforts to explain annual recruitment variability have primarily focused on the first year of growth, while the juvenile life stage has largely been neglected. Juvenile yellow perch, age-0 through age-2, were collected annually from 2006–2010 in Illinois waters of Lake Michigan to assess temporal variability of size-at-age and size-selective mortality. Age-0 and age-2 total length at capture differed significantly between years with a maximum difference of 4.4 mm and 11.2 mm, respectively. First winter size-selective mortality was not observed for any year-class, however size-specific growth, with larger individuals growing faster than smaller counterparts, occurred during the first winter for all year-classes but 2006. Size-selective mortality was documented between age-1 and age-2 of the 2006 year-class with yellow perch less than 70 mm at age-1 not surviving through age-2. Though population level effects remain unknown, size-specific growth and mortality during the juvenile life stage may influence the size structure and year-class strength of yellow perch in southwestern Lake Michigan. Identification of size-selective mortality occurring beyond the first growing season highlights the significance of rapid growth during early life and the importance of investigating whole life stages to identify factors influencing year-class strength.

Introduction

Recruitment strength of fishes is often determined early in life though the exact life stage is highly variable. In freshwater environments, mortality during the juvenile stage often limits year-class strength; while in marine systems, the prolonged, pelagic, larval life stage serves as a bottleneck influencing recruitment strength (Houde, 1994, 2008). Size is one of the most important factors influencing survival through these critical life stages as larger fishes have fewer predators, lower mass-specific metabolic rates, wider range of prey items, larger energy reserves, and greater swimming capabilities compared to smaller counterparts (Hjort, 1926; Schultz and Conover, 1999; Werner and Gilliam, 1984). Within meso-oceanic systems such as Lake Michigan (52,000 km^2, mean depth 89 m) a suite of biotic and abiotic factors influence the growth rate of fishes; thus it is not uncommon for recruitment strength to fluctuate widely at both temporal and spatial scales (Dettmers et al., 2005; Marsden and Robillard, 2004). Examining the interplay between growth and survival dynamics of pre-recruit fishes can increase our understanding of recruitment fluctuations common to many species.

Yellow perch, *Perca flavescens*, have historically been one of the most sought after native species by both commercial and recreational anglers within Lake Michigan (Clapp and Dettmers, 2004). However, prolonged periods of poor recruitment since the early 1990s led to a closure of commercial fishing, stricter harvest regulations for recreational anglers, and formation of a lake-wide task group to identify factors contributing to recruitment variability (Clapp and Dettmers, 2004; Makauskas and Clapp, 2008; Marsden and Robillard, 2004). Because early life history dynamics often influence recruitment and early indicators of year-class strength are of the most use to management agencies, investigations of the early life stages of yellow perch have been the focus of much research (Makauskas and Clapp, 2008).

Within Lake Michigan, large-scale counter clockwise currents advect larval yellow perch offshore for an extended pelagic life stage that can last greater than 60 days (Dettmers et al., 2005; Weber et al., 2011). Once swimming capabilities are sufficient or favorable currents are present (Beletsky et al., 2007), age-0 yellow perch return to the benthic nearshore area as juveniles until sexual maturity occurs, typically around age-2 for males and age-3 for females (Headley and Lauer, 2008). Due to the large scale hydrological dynamics of Lake Michigan and the prolonged, pelagic, larval life stage, investigations of yellow perch recruitment variability have largely followed in the footsteps of marine research, focusing on the larval and early juvenile life stages that occur prior to the end of the first growing season (Fitzgerald et al., 2004; Houde, 1994; Makauskas and Clapp, 2008). As a result,

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age-0 catch per unit effort (CPUE) in the fall is often used as a proxy of future recruitment at sexual maturity (Marsden and Robillard, 2004; Redman et al., 2011).

Although understanding the recruitment dynamic of yellow perch has been the focus of much research, investigations of size variability and mortality during the juvenile life stage have been limited to the first winter or based on back-calculated lengths from adult otoliths (Fitzgerald et al., 2004; Horns, 2001). Difficulties associated with sample collection and preparation at least partly contribute to the lack of investigation into the juvenile life stage. Gill and fyke nets commonly used to sample adult yellow perch rarely capture individuals younger than age-3 while bottom trawls specifically designed to capture age-0 yellow perch, are not effective for sampling age-1 and age-2 individuals that have sufficient vision and swimming capabilities to evade capture (Robillard and Dettmers, 1998). Additionally, aging juvenile yellow perch is often a difficult and time consuming task as sagittal otoliths are too small for rapid and widely used preparation methods (i.e. crack and burn) and scales have repeatedly been shown to be less accurate than otoliths (Maceina and Sammons, 2006; Pawson, 1990; Robillard and Marsden, 1996). Direct investigations using gear designed to capture yellow perch beyond the first growing season and prior to sexual maturity are required to fully assess growth and survival dynamics of juvenile yellow perch in southwestern Lake Michigan.

Size-selective-mortality during the juvenile life stage of freshwater fishes is often non-random and largely attributed to over-winter mortality and predation (Houde, 1994; Post and Evans, 1989; Sogard, 1997). Requirements for size-selective mortality include size variability within a population, differential selection pressures based on size, and relatively high mortality of individuals selected against (Sogard, 1997); all of these conditions may be met during the juvenile life stage of yellow perch. Age-0 yellow perch return to benthic nearshore areas in the fall from 30 to 100 days old with total lengths ranging from 28 mm to 98 mm (Weber et al., 2011). Large size variability within a year-class influences selection pressures and can result in varying rates of survival dependent on size. Additionally, schooling behavior concentrates juveniles in benthic nearshore areas where they may be vulnerable to size-dependent predation and high levels of competition (Irwin et al., 2009). Size-selective mortality may influence year-class strength and size-structure of the adult population if size-variability and differing selection pressures persist throughout the juvenile life stage of yellow perch (Fitzgerald et al., 2004; Post and Evans, 1989).

Without thoroughly exploring the juvenile life stage of yellow perch, predictions of future year-class strength and conclusions as to when year-class strength is set may be limited. Our objectives were to 1) assess temporal variability of juvenile yellow perch length at capture and 2) determine if size-selective mortality occurs either over the first winter, between ages-1 and ages-2, or cumulatively between age-0 and age-2 for juvenile yellow perch in southwestern Lake Michigan.

Methods

Sample collection

Juvenile yellow perch were collected weekly during August and September from 2006 to 2010 in northern Illinois waters of Lake Michigan (Fig. 1). Three sites differing in substrate composition were selected to target juvenile yellow perch while concentrated in benthic nearshore areas during fall months (Creque and Czesny, 2012). Two locations north of Waukegan, IL consisted of mostly fine sand and pebble substrate while the remaining location, south of Waukegan, IL, was primarily heterogeneous gravel and cobble (Creque et al., 2010; Fig. 1). Due to the close proximity of sampling locations, yellow perch collected at each site were combined in an effort to increase sample sizes. Small mesh monofilament gill nets, 40.3 m long, with stretched mesh lengths of 12.5, 16.0, 20.0, and 25.0 mm, designed to sample juvenile yellow perch, were set at depths of 3, 5, 7.5, and 10 m at each location every

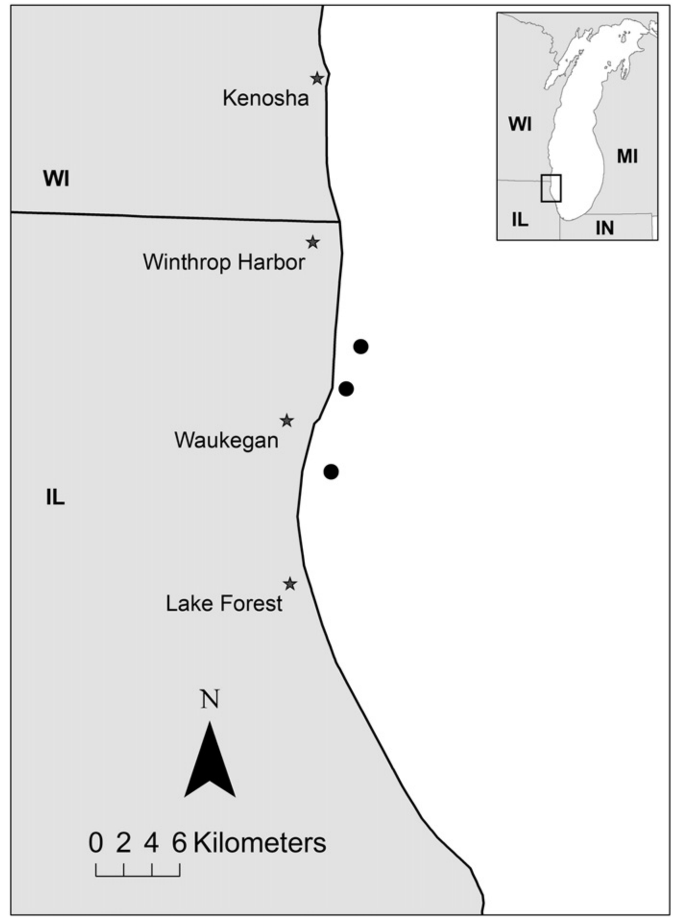

Fig. 1. Map of sampling locations within Illinois waters of Lake Michigan. Circles represent sampling locations while stars represent cities.

year. Nets were set for approximately 3 h, after which yellow perch were removed, sorted by mesh size, euthanized, and stored in ethanol. Total length was recorded to the nearest 0.01 mm and sagittal otoliths (hereafter otoliths) were removed upon returning to the laboratory. Otoliths have been shown to accurately estimate age and growth of yellow perch and were used to assign ages, back-calculate size-at-age, and assess size-selective mortality (Maceina et al., 2007; Vandergoot et al., 2008). Otoliths were processed following a modified version from Secor et al. (1991) then photographed using a digital camera attached to a compound microscope and radius was measured to the nearest 0.001 mm. All juvenile yellow perch otoliths were aged by an experienced reader while a subset of 200 otoliths was aged by two additional readers to assess age reproducibility and percent agreement (Campana et al., 1995).

Size-at-age

Otoliths are present prior to hatch in yellow perch and proportionality between somatic and otolith growth occurs during early life (Craig, 2000; Fitzgerald et al., 2004; Maceina et al., 2007). As a result, we observed a strong linear relationship between total length (L) and otolith radius (R) at capture (regression equation: $L = -2.2 + 97.9R$; $p < 0.001$, $R^2 = 0.93$), and utilized the Dahl–Lea method ($L_i = (R_i / R_c) L_c$, where L_i = total length at previous age, R_i = otolith radius at previous age, R_c = otolith radius at capture, and L_c = total length at capture) to back-calculate size-at-age. The Dahl–Lea method has been shown to provide accurate back-calculations of total length for yellow perch and was selected over other methods (i.e. Frasier-lee or Biological intercept) that include an intercept to represent the point where somatic and body