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Inferred fish behavior its implications for hydroacoustic surveys in nearshore habitats

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ABSTRACT

Population availability and vessel avoidance effects on hydroacoustic abundance estimates may be scale dependent; therefore, it is important to evaluate these biases across systems. We performed an inter-ship comparison survey to determine the effect of vessel size, day-night period, depth, and environmental gradients on walleye (*Sander vitreus*) density estimates in Lake Erie, an intermediate-scaled system. Consistent near-bottom depth distributions coupled with horizontal fish movements relative to vessel paths indicated avoidance behavior contributed to higher walleye densities from smaller vessels in shallow water (i.e., < 15 m), although the difference decreased with increasing depth. Diel bank migrations in response to seasonally varying onshore-to-offshore environmental gradients likely contributed to day-night differences in densities between sampling locations and seasons. Spatial and unexplained variation accounted for a high proportion of total variation; however, increasing sampling intensity can mitigate effects on precision. Therefore, researchers should minimize systematic avoidance and availability related biases (i.e., vessel and day-night period) to improve population abundance estimates. Quantifying availability and avoidance behavior effects and partitioning sources of variation provides informed flexibility for designing future hydroacoustic surveys in shallow-water nearshore environments.

1. Introduction

Hydroacoustic surveys are a common tool for informing management of fish populations (Rudstam et al., 2009; Kubečka et al., 2009). A fish population is available to a hydroacoustic survey when a high proportion is within the survey area, and advantageously distributed within the water column (Simmonds et al., 1992; Simmonds and MacLennan, 2005). However, if population availability changes across the survey (Comeau and Boisclair, 1998; Lawson and Rose, 1999; Neilson et al., 2003; Gorman et al., 2012a), the utility of hydroacoustics as an assessment tool is limited. Fish availability and avoidance have been extensively studied in marine (e.g., De Robertis et al., 2008; Fréon et al., 1993; Olsen, 1990; Rose, 2003) and small freshwater systems (e.g., Draštík and Kubečka, 2005; Draštík et al.,2009; Muška et al., 2013; Wheeland and Rose, 2014). However, intermediate-scaled systems, such as coastal ocean areas and the Laurentian Great Lakes, which support important fishery production, have received less attention.

Diel migrations and system scale can affect population availability to hydroacoustic surveys, biasing abundance estimates. Many organisms undertake diurnal vertical migrations in response to changing abiotic and biotic conditions within the water column (Arhenstorff et al., 2011; Mehner, 2012). In particular, movements into and out of the near bottom “acoustic dead zone” can drastically reduce abundance estimates (Lawson and Rose, 1999; Neilson et al., 2003; Ona and Mitson, 1996). In nearshore areas, some fishes move horizontally between onshore and offshore habitats (i.e., diel bank migrations) to reduce predation pressure, or access optimal foraging, growth, and reproductive habitats (Fréon et al., 1993; Comeau and Boisclair, 1998,

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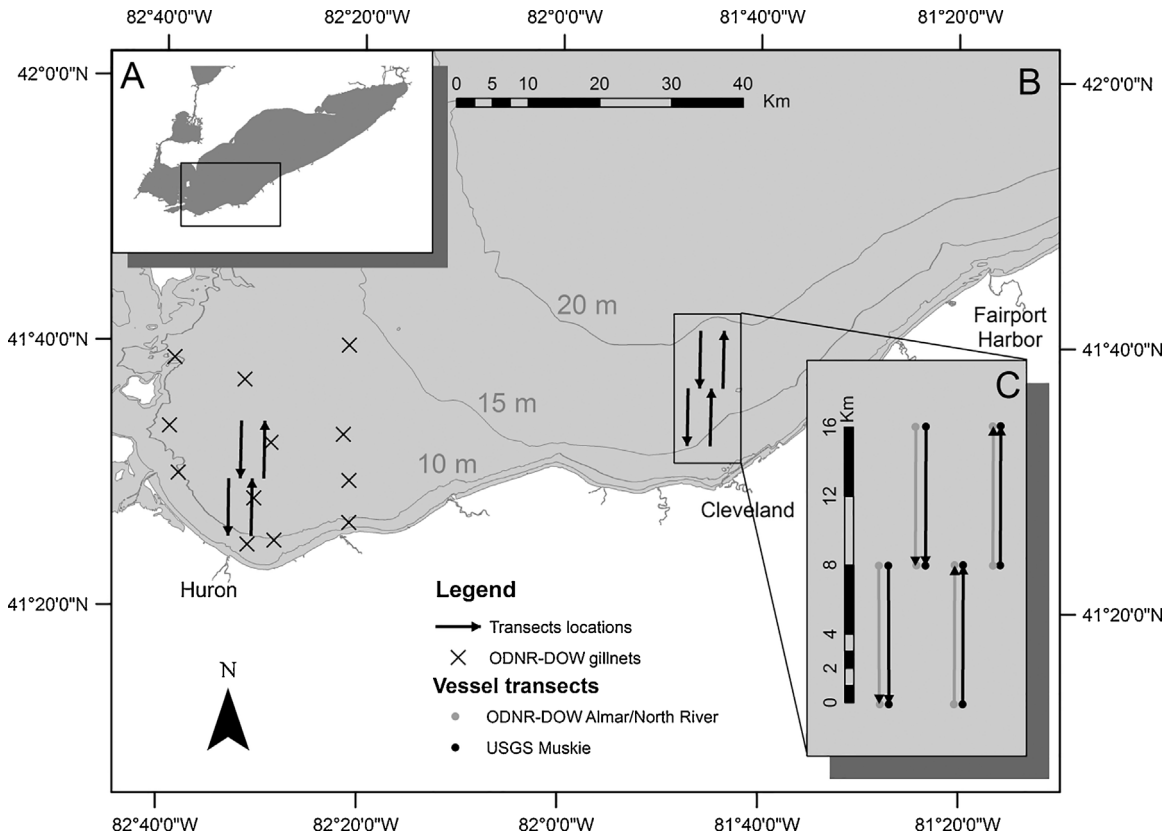

Fig. 1. Sampling extent in Lake Erie's Sandusky sub-basin and central basins (A) including hydroacoustic surveys near Huron and Cleveland, OH (B). Hydroacoustic survey paths denoted by offshore to onshore transects at each location (B; black arrows), each comprised of paired vessel specific transects (C; black and gray dots and arrows). Fishery independent gill net sampling locations are designated by x's (B) and fishery dependent creel survey coverage spanned District 2 from Huron to Fairport Harbor.

Gorman et al., 2012a; Cott et al., 2015). Seasonally and spatially dynamic nearshore areas, forming turbidity and temperature gradients (Schertzer et al., 1987; Binding et al., 2012), can influence fish movements. The juxtaposition of nearshore and offshore environments in intermediate-scaled systems may create mismatches between temporal-spatial scale of diel migrations and hydroacoustic surveys, negatively biasing abundance estimates.

Vessel avoidance can also contribute to biased abundance estimates across system scales. Fish avoid sampling vessels using auditory and visual cues (Mitson, 1995; Mitson and Knudsen 2003; Lévénez et al., 1990; Fréon et al., 1993). Therefore, proximity between vessels and fish in shallow water (e.g., small systems or nearshore areas; Draštík and Kubečka 2005; Wheeland and Rose, 2014) or due to near surface distributions (Neproshin, 1979; Olsen 1979, 1990; Soria et al., 1996) likely intensifies avoidance behavior. However, conditions indirectly related to vessel noise, light, and proximity, such as fish species and size, water temperatures (Neproshin, 1979), life stage (Misund, 1990), and time of day (Neproshin, 1979; Fréon et al., 1993) may modulate vessel avoidance behavior. The mechanisms (i.e., diel migration and avoidance) affecting availability are difficult to differentiate across scales but have similar effects, biased abundance estimates.

Hydroacoustic surveys in intermediate-scaled systems, such as the Laurentian Great Lakes, primarily focus on pelagic forage fishes in deep water (Rudstam et al., 2009), while large predatory fishes in shallow water are not generally targeted. Lake Erie walleye (*Sander vitreus*), a large predatory fish, are important to the Great Lakes region, supporting lucrative commercial and recreational fisheries (Locke et al., 2005, and Roseman et al., 2010). As a result, the population is monitored through a large-scale multi-jurisdictional gill net survey to provide relative abundance estimates used for making management decisions (e.g., quota allocation; Hatch et al., 1987; Vandergoot et al., 2010; Pandit et al., 2013). There is growing interest among fisheries managers in using hydroacoustics as a survey tool; however, habitat use and life history characteristics present a challenging scenario for hydroacoustic monitoring. For example, the walleye population migrates annually between shallow habitats in the western and central basins, and deeper habitats throughout Lake Erie and into Lake Huron (Wang et al., 2007; Pandit et al., 2013). The population is most available for survey when concentrated in the relatively shallow nearshore waters of the western and central basins during the fall, when environmental conditions are less dynamic (Schertzer et al., 1987; Binding et al., 2012). However, during this time, walleye may move vertically into the water column at night to forage (Kelso, 1978; Berger et al., 2012), and it is not clear how this behavior may affect vessel avoidance in shallow waters. Additionally, walleye may engage in diel bank migrations to forage in shallow nearshore areas (Kelso, 1978), which would make some portion of the population inaccessible to hydroacoustic surveys at night. Therefore, it is unclear how walleye behavior over day-night periods and in response to sampling vessels may affect availability to hydroacoustic surveys.

We were interested in how walleye availability and avoidance behavior may influence estimates of stock abundance. We used vessel comparison surveys in Lake Erie's western and central basins to, 1) quantify differences in walleye density estimates between two survey vessels and day-night sampling periods during summer and fall, and 2) detect relationships between environmental gradients, such as turbidity, temperature, forage fish abundance, and walleye distributions during summer and fall seasons to inform survey timing and extent. This research directly informs future hydroacoustic assessment of Lake Erie walleye, and generally informs avoidance and availability concerns of other fishes in the nearshore waters of intermediate-scaled systems.