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Edge effects on abiotic conditions, zooplankton, macroinvertebrates, and larval fishes in Great Lakes fringing marshes

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ABSTRACT

Fragmentation and edge creation is common in many freshwater coastal wetlands, though relatively little is known about edge effects on abiotic conditions and faunal communities within these habitats. We investigated edge effects associated with anthropogenic fragmentation in 16 fringing coastal marshes of Lake Michigan and Lake Huron. Environmental data, zooplankton, macroinvertebrates, and larval fish were collected along transects extending into each marsh from reference (i.e., where the wetland naturally interfaced with open water) and anthropogenic edges (i.e., where the wetland interfaced with open water habitats created by vegetation removal). Physical and chemical gradients were apparent from marsh edges toward marsh interiors regardless of edge type. Faunal communities appeared to respond to these gradients. Zooplankton biomass, macroinvertebrate richness and macroinvertebrate Shannon diversity were depressed at edges and increased toward marsh interiors. Larval fish catch per unit effort, taxon richness, and Shannon diversity increased from reference edges toward marsh interiors. Larvae of individual fish species displayed varying patterns across edges. Our results suggest that because of edge effects, fragmentation of coastal marshes causes impacts that exceed the area of marsh habitat that is actually lost. For example, as a marsh's protected inner core area is reduced, the marsh fragment may cease to function as a viable refuge from hydrologic energy and open water predators. Therefore, fragmentation should be viewed as a significant impact to freshwater coastal marsh ecosystems similar to how it is regarded in terrestrial ecosystem management.
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Introduction

Edge effects result from the interaction between differing habitat patch types and are often conceptualized as ecological gradients from the outer margin of a habitat toward its interior (Reis et al., 2004). Studies of terrestrial ecosystems have shown that when an edge is created during habitat fragmentation, exposure to the matrix environment can alter the physical structure of the habitat patch along a transition zone from its edge toward its inner core (Matlack, 1993; Young and Mitchell, 1994). This can result in physical, chemical, and biotic gradients extending into the habitat patch from the edge (Chen et al., 1995; Didham and Lawton, 1999; Matlack, 1993). Edge effects have been described for many terrestrial ecosystems including tropical forests, temperate old-growth forests, temperate second-growth forests, and prairies (Chen et al., 1992; Dale et al., 2000; Manolis et al., 2002; McKone et al., 2000). While edge effects have been occasionally examined in wetlands (Baldi, 1999; Hooftman et al., 2003; Lienert and Fischer, 2003), there remains little understanding of how fragmentation and resulting edge effects alter physical and chemical conditions and biotic communities within freshwater coastal wetlands. Similar to terrestrial ecosystems, anthropogenic fragmentation and the creation of artificial edges in vegetated coastal ecosystems may profoundly alter both the abiotic and biotic conditions in these habitats well beyond the areas that are directly manipulated. The current study focused on ecological impacts of artificial edges associated with boat channels in fringing coastal marshes of the Laurentian Great Lakes.

In the Great Lakes, fringing coastal marshes generally occur in embayments where shoreline geomorphology or bathymetric features (e.g., sand bars) reduce wave energy to a point in which rooted plants can persist (Albert et al., 2005; Jude et al., 2005). Coastal marshes are critical components of the Great Lakes nearshore ecosystem and provide habitat for many species of fish (Jude and Pappas, 1992; Uzarski et al., 2005), amphibians (Hecnar, 2004), reptiles (Bishop and Gendron, 2004), birds (Prince et al., 1992; Riffell et al., 2003), and macroinvertebrates (Gathman et al., 1999; King and Brazner, 1999). Despite the ecological importance of Great Lakes coastal marshes, anthropogenic fragmentation has commonly occurred in these habitats. Throughout the Great Lakes region, large areas of coastal marsh have been

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drained for agriculture and urbanization while boat launches and navigational channels cut through many remaining marshes (Jude et al., 2005; Uzarski et al., 2009). Navigation of both small recreational watercraft and larger commercial vessels through channels bisecting marsh patches disrupts sediment and prevents vegetation from growing (Asplund and Cook, 1997; Eriksson et al., 2004). Additionally, larger boat channels are often dredged to maintain safe passage for vessels. Consequently, boat channel formation and maintenance has caused widespread fragmentation of marshes throughout the Great Lakes. To the best of our knowledge, data on the number of boat channels bisecting Great Lakes coastal marshes have not been collected, even at regional scales. However, such channels are very common in marshes that fringe populated shorelines (Fig. 1a). While other types of anthropogenic degradation, such as eutrophication, sediment contamination, and non-indigenous species invasions, have received considerable attention in Great Lakes coastal ecosystems, edge effects resulting from habitat fragmentation remain largely overlooked.

To explore the ecological impacts of edge effects caused by boat channels in Great Lakes fringing marshes, we focused on zooplankton, macroinvertebrates, and larval fish assemblages. We included macroinvertebrates and zooplankton because these organisms are critical in aquatic food webs due to their high abundances and diverse feeding ecologies (Batzer and Wissinger, 1996). Accordingly, invertebrates often form linkages between algal and detrital resources and higher trophic levels such as fish (Vadeboncoeur et al., 2002). We chose to examine edge effects on larval fish assemblages because the majority of Great Lake fish species utilize coastal wetlands at some point in their life (Jude and Pappas, 1992), either as spawning and nursery habitat (Gregory and Powles, 1985; Höök et al., 2001) or for habitat as adults (Jude and Pappas, 1992; Uzarski et al., 2005). Furthermore, the larval stage is critical for fish recruitment and larval fish are highly vulnerable to abiotic stress, predation, and food scarcity (Breitburg et al., 1999; Rose, 2000).

We predicted that edge effects would be evident in the structure of faunal communities inhabiting coastal marshes incised by boat channels and that these faunal edge effects could be explained by associated edge effects on macrophyte community structure and abiotic conditions. Numerous studies have reported strong associations between macrophyte community structure (e.g., dominant plant species or morphology, stem density, plant biomass) and faunal community structure in Great Lakes coastal marshes (Brazner and Beals, 1997; Cardinale et al., 1998; Uzarski et al., 2005). In addition, relationships between abiotic conditions (e.g., dissolved nutrients, water temperature, turbidity) and faunal communities have been reported (Brazner et al., 2005; Cooper et al., 2007a; Seilheimer and Chow-Fraser, 2006). Therefore, since we predict that artificial edge creation impacts both abiotic conditions and plant communities in fragmented coastal marsh patches, there is a strong likelihood that resident fauna would also exhibit edge effects. Our objectives were to determine how edge effects impact zooplankton, macroinvertebrate, and larval fish communities in fringing marshes and to identify potential proximal drivers of these faunal edge effects by exploring gradients in abiotic conditions and vegetation structure that correlated with faunal edge effects.

Materials and methods

Study locations and time frame

Coastal fringing marshes of Lakes Michigan and Huron occur in both open and protected embayments, the majority of which are distributed among rock till/island complexes or along open shorelines with gently sloping bathymetry (Albert, 2003; Albert et al., 2005). The coastal fringing wetlands that we sampled had a direct surface water connection to nearshore waters and had substrates consisting of sand, silt, clay, and some gravel, with relatively little organic sediment (Albert et al., 2005).

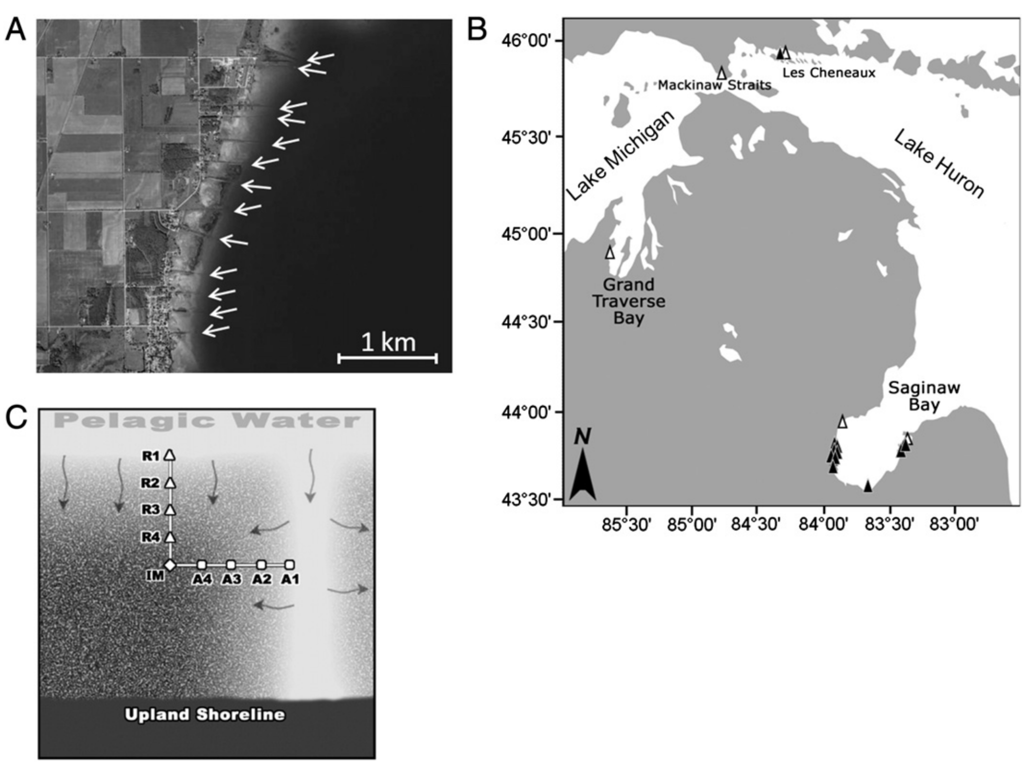

Fig. 1. A: Aerial image of western Saginaw Bay, Lake Huron, showing a high density of small boat channels incising fringing coastal wetland habitat (highlighted by the arrows). Image courtesy of U.S. Department of Agriculture Farm Service Agency. B: Coastal marsh sampling sites on Lake Michigan and Lake Huron where macroinvertebrate, larval fish, and chemical/physical samples were collected. Open triangles indicate locations where zooplankton were also collected. C: Sampling transects within a marsh fragment. Sampling points were located 10 m apart along transects. Reference transects extended from the reference edge (R1) toward the inner marsh (IM). Anthropogenic transects extended from the anthropogenic edge (A1) toward the inner marsh (IM). Each pair of transects shared a corner sampling point (IM).

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