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Assessing marine criteria for Ecologically and Biologically Significant Areas (EBSA): are the criteria interpretable and measureable in Lake Ontario?

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

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ABSTRACT

Ecological criteria that were developed for identifying Ecologically and Biologically Significant Areas (EBSA) in marine ecosystems of Canada were assessed and judged to be useful for identifying ecologically significant areas in a freshwater ecosystem of Lake Ontario. For assessing the criteria, metrics of habitat quality, productivity and fishes in the Bay of Quinte were compared to other areas of Lake Ontario, using available data and expert knowledge. All primary EBSA criteria, uniqueness, aggregation and fitness consequences, and the two qualifiers, naturalness and resilience, were examined and found to be relevant and interpretable. Example areas of the criteria in Lake Ontario could be supported by available scientific evidence. Each criterion was assessed in the context of ecological functions (e.g., spawning, growth and survival, refugia), or physical properties/structural features (e.g., thermal habitat, aquatic vegetation). Limitations, lessons learned and science gaps for assessing the criteria, evident from this Lake Ontario study, are discussed. For future application in the Great Lakes and elsewhere in freshwaters, additional science evaluation of the criteria is required for other habitat types and regions (e.g., fluvial habitat, northern ecosystems, areas where data are limited), and for other approaches to identify the appropriate spatial scale of ecologically significant areas (e.g., data-layering). Despite these limitations, the EBSA criteria and the underlying ecological concepts are an excellent starting point for identifying significant areas in freshwater ecosystems.

Évaluation des critères marins pour les zones d'importance écologique et biologique (ZIEB): Les critères sont-ils interprétables et mesurables dans le lac Ontario?

RÉSUMÉ

Les critères écologiques qui ont été élaborés pour désigner les zones d'importance écologique et biologique (ZIEB) dans les écosystèmes marins du Canada ont été évalués et jugés comme étant utiles pour la désignation des zones d'importance écologiques dans un écosystème d'eau douce du lac Ontario. Afin d'évaluer les critères, des mesures de la qualité de l'habitat, de la productivité et du nombre de poissons dans la baie de Quinte ont été comparées à d'autres secteurs du lac Ontario à l'aide des données et des connaissances d'experts que l'on possède. Tous les principaux critères des ZIEB, l'unicité, la concentration et les conséquences sur la valeur adaptative, ainsi que les deux qualificateurs, le caractère naturel et la résilience, ont été examinés et considérés comme étant pertinents et interprétables. Les secteurs utilisés comme exemples des critères dans le lac Ontario ont pu être appuyés par les preuves scientifiques disponibles. Chaque critère a été évalué dans le contexte des fonctions écologiques (p. ex., frai, croissance et survie, refuge) ou des propriétés physiques/caractéristiques structurelles (p. ex., habitat thermique, végétation aquatique). Il est question des limites, des leçons retenues et des lacunes scientifiques concernant l'évaluation des critères, évidentes d'après cette étude du lac Ontario. Pour toute application future dans les Grands Lacs et ailleurs en eau douce, d'autres évaluations scientifiques des critères seront nécessaires pour les autres types d'habitat et régions (p. ex., habitat fluvial, écosystèmes nordiques, secteurs où les données sont limitées), et pour d'autres approches visant à déterminer l'échelle spatiale appropriée des zones d'importance écologique (p. ex., couches de données). Malgré ces limites, les critères des ZIEB et les concepts écologiques qui les sous-tendent sont un excellent point de départ pour déterminer les zones importantes dans les écosystèmes d'eau douce.

INTRODUCTION

The identification and designation of ecologically significant areas, broadly defined as areas with relatively high productivity or biodiversity, is a useful tool for ecosystem-based resource management. Ecologically significant areas provide a spatial focus for the enhanced management of human activities, which can benefit the aquatic biota and their habitat (Rodwell et al. 2003; Roberts et al. 2005; Hedges et al. 2010).

Canada's Oceans Act (1997) authorized the Department of Fisheries and Oceans to lead the development of a national oceans management strategy, which was to be guided by the principles of sustainable development and integrated management. Subsequently, an Ocean Action Plan (OAP) was implemented (DFO 2005). Under the OAP, five Large Ocean Management Areas (LOMA) were identified; one in the Pacific (Pacific North Coast), one in the Arctic (Beaufort Sea), and three in the Atlantic (Eastern Scotian Shelf, Gulf of St. Lawrence and Placentia Bay/Grand Banks). Within each LOMA, four issues were investigated as candidate conservation priorities to be addressed:

1) Ecologically and Biologically Significant Areas (EBSA),
2) Ecologically Significant Species (ESS),
3) depleted or rare species and 4) degraded areas.

These conservation issues included both place-based (EBSAs and degraded areas) and species-based (ESS and rare species) valued ecosystem components. Criteria for each of the conservation priorities for identifying significant marine areas (DFO 2004) and species (DFO 2006) were applied to all LOMAs in Canada (e.g., for Beaufort Sea, see Paulic et al. 2009).

For marine EBSAs and ESS, 'significant' was interpreted as 'if the area or species were perturbed severely, the ecological consequences (in space, in time, or outward through the food-web) would be greater than an equal perturbation of most other areas or species' (DFO 2004). Therefore, the identification of significant areas or species is based on ecological criteria rather than on social, economic or jurisdictional factors.

The Ocean's framework and criteria were developed for marine ecosystems, but many of the concepts and criteria could apply in freshwater ecosystems (Randall et al. 2011). To further investigate this feasibility, the OAP's EBSA criteria are assessed in a coastal Lake Ontario context in this study. At a conceptual level, there are three main dimensions to the marine EBSA criteria for evaluating target areas from an ecological viewpoint: uniqueness of habitat, spatial aggregation of fishes, prey or nutrients and the fitness consequences to populations (DFO 2004). Each of these dimensions and the associated specific criteria are likely relevant to freshwater ecosystems as well.

The general objective of this paper is to assess if the key components of the EBSA criteria can be extrapolated and modified, if necessary, for potential use in coastal areas of the Great Lakes. Potential application of EBSA criteria in freshwater is thought to be feasible (DFO 2011a). A previous comparison of frameworks in marine and freshwater ecosystems to support integrated management (Randall et al. 2011) is advanced in this study by addressing three specific objectives:

1) determine if each of the Oceans criteria, and the conservation priorities they address are interpretable and relevant to Lake Ontario;
2) identify if appropriate science-based metrics exist for measuring the criteria; and
3) modify and add to the criteria in the context of Lake Ontario (and generally in the Great Lakes) if needed.

The utility of the criteria for use in freshwater ecosystems in Canada beyond Lake Ontario and the Great Lakes and the science needed if ecologically significant areas are to be identified as a conservation tool in future are also discussed.

The assessment of criteria for identifying ESS, a second OAP conservation issue, is dealt with in a second but complementary research document (Glass et al. 2014). The other two conservation priorities mentioned above (rare species and degraded areas) are also discussed in the two research documents.

METHODS

ASSESSMENT OF THE EBSA CRITERIA

EBSA criteria were interpreted and assessed in three chronological steps:

1) by obtaining definitions, narrative descriptions and examples of the criteria from marine ecosystems, particularly coastal areas if available;
2) by assessing if the marine criteria were relevant, measureable with quantitative metrics and able to be extrapolated for use in the Lake Ontario ecosystem; and finally
3) by assessing if any physical habitat features considered to be significant in Lake Ontario were absent from the marine criteria. Specifically, what were the 'lessons learned' regarding efficacy of the criteria for freshwater ecosystems?

For step 1, the EBSA criteria and marine examples were obtained from Canadian Science Advisory Secretariat published research documents, proceedings and science advisory reports. Narrative descriptions of three primary criteria, uniqueness, aggregation and fitness consequences, were included, along with definitions and descriptions of two additional qualifiers, resilience and naturalness. The three criteria and two qualifiers were described in the context of ecological functions (spawning, nursery, feeding, migration, and refugia) and structural features (oceanographic, structural habitat and biodiversity). For marine examples of each criterion, we initially focused on information from the Atlantic, as the Great Lakes are part of the Atlantic drainage basin. Examples from other LOMAs were also sometimes included.

For step 2, relevance of the criteria to the Great Lakes and feasibility of their extrapolation were assessed by identifying Lake Ontario examples of significant ecological functions, conservation objectives and metrics for each criterion. The Bay of Quinte (Lake Ontario), described below, was chosen as a pilot area for assessing the EBSA criteria. Bay of Quinte was chosen because this coastal region has received enhanced management for a numbers of years. Although eutrophication and other environmental concerns have negatively affected this ecosystem, it is known to have high productivity and biodiversity relative to other areas in Lake Ontario (Randall et al. 2011). The EBSA criteria were assessed by comparing quantitative metrics in Quinte with other coastal areas in Lake Ontario. Details of the function and structure of significant habitats were based on scientific evidence, either specific literature citations or from expert opinion.

The ecological functions in step 2 pertain to the habitat areas needed to complete key life history processes, i.e., spawning, nursery, rearing, feeding and migration. All of these functions are components of the definition of fish habitat in the *Fisheries Act*. Conservation objectives for the area (e.g., for restoration of degraded areas; IJC 1991) are discussed as part of this assessment to provide evidence of feasibility that the criteria can be measured and tracked with quantitative metrics (indicators) and reference points.

Finally, for step 3, the identification of gaps in the criteria from a Lake Ontario perspective and lessons learned were based on literature and the expert opinion of Great Lakes scientists.

EVALUATION PROCESS

As part of the Ocean's Action Plan, potential EBSAs were identified for each LOMA, prioritized and subsequently reduced to a reasonable number for further work. Identification of potential EBSAs was done collaboratively at workshops involving fishermen, regional resource experts and scientists, and was based on the interpretation and discussion of the EBSA criteria. The number and relative importance of criteria, cumulatively, that applied to each potential EBSA was used to inform prioritization and final EBSA selection. EBSAs were chosen by considering a subset of areas known to be ecologically significant within the LOMA, i.e., scaling down from the large geographic area to the much smaller EBSA scale. For example, 21 potential EBSAs were initially identified in the Beaufort Sea, but then were prioritized and reduced to a manageable number of 10 (DFO 2007a). The location of 10 EBSAs within the Gulf of St. Lawrence LOMA (DFO 2009) are shown in Figure 1. More recently, application of the EBSA criteria has been extended to marine areas outside LOMAs (DFO 2011b).

The objective of this study is to assess the criteria for use in freshwater (using Bay of Quinte as a pilot area), rather than to identify potential EBSAs in the Great Lakes *per se*. Similar to the marine areas, our process for evaluating the EBSA criteria in the Great Lakes was also done on a relative spatial scale, but the criteria are evaluated by scaling up from the Bay of Quinte to compare to other coastal areas in the Lake Ontario ecosystem. The constraints of the evaluation process and the spatial scale for this study are discussed later (General Discussion).

To examine the EBSA criteria from a freshwater perspective, a few examples of each criterion were selected from the Bay of Quinte to assess efficacy. The subset of examples chosen was not meant to be comprehensive.

BAY OF QUINTE AS A CASE STUDY

The Bay of Quinte is located along the northern shore of Lake Ontario (Figure 2). Prince Edward County and Amherst Island form a natural barrier separating Bay of Quinte from Lake Ontario proper. The Bay is 64 km and 254 km^2 in length and area, respectively, with a maximum width of 3.5 km (Sly 1986). The upper (35 km), middle (13 km) and lower (16 km) bays that constitute the Bay of Quinte watershed form a distinctive Z shape. The Bay of Quinte watershed totals 18,200 km^2 with 4 major rivers of varying drainages entering along the northern shore of the upper bay: Trent (12,600 km^2), Moira (2,700 km^2), and the Salmon and Napanee (together, 1,660 km^2) rivers (Johnson and Hurley 1986).

The upper bay consists of a series of connected bays which are approximately 4-8 m deep. The middle bay includes Long Reach, Picton Bay and Hay Bay; the middle bay depth increases from 6 to 17 m and 0.8 km to 5.6 km in width from north to south. The lower bay which includes Adolphus Reach and the North Channel, is about 3 km wide and ranges from 17 to 52 m in depth (Johnson and Hurley 1986). The lower bay is connected to Lake Ontario by two passages at opposite ends of Amherst Island; both passages are 2.4 km wide and have sill depths of approximately 24 m. The upper bay is connected westward to Lake Ontario (Presqu'ile Bay) by the Murray Canal, which was constructed for navigational purposes (Freeman and Prinsenberg 1986; Johnson and Hurley 1986).

The Bay of Quinte is contiguous with Lake Ontario: there is long term water mass exchange between Lake Ontario and the lower bay and subsequently between the lower and middle to upper bays. There is a prevailing clockwise circulation pattern around Amherst Island with flow occurring from Lake Ontario to the lower bay and from the lower bay to Lake Ontario (Freeman and Prinsenberg 1986). Although influenced by lake level changes, Bay of Quinte is also a semi-fluvial system which connects the four main rivers mentioned earlier to Lake Ontario.

RESULTS

1 - UNIQUENESS: CRITERIA DESCRIPTION AND MARINE EXAMPLES

Definition and interpretation

Uniqueness is one of the primary criteria used to identify a potential EBSA. On a relative scale, uniqueness is 'ranked from areas whose characteristics are unique, rare, distinct, and for which alternatives do not exist to areas whose characteristics are widespread with many areas which are similar in most important features'. Uniqueness can be considered in a "regional, national and global context with increased importance at each scale" (DFO 2004).

Uniqueness is ranked according to the functional properties of an area, which can include ecological functions (e.g., nursery/rearing habitat), physical features (e.g., tidal mixing zones, polynyas, or strong topography), structural habitat features (e.g., macrophyte beds or deep water corals) and biodiversity (e.g., endangered/threatened species or highly diverse/productive communities) (DFO 2004, Buzeta and Singh 2008). For example, an area containing the only nursery site used by a particular species would be highly unique and ranked higher than an area which contained one of multiple nursery sites available to the species. Areas containing strong topography such as canyons may rank high on the uniqueness dimension as such physical features generate locally significant circulation patterns and habitat conditions not observed in other areas. Additional descriptions of Uniqueness are given in Appendix 1.

Marine examples of uniqueness

Distinct physical processes combined with strong topography can often result in a unique environment. For example, the Passages EBSA in the Quoddy region of the Eastern Scotian Shelf LOMA is ranked high across all functional properties of the Uniqueness dimension. The Bay of Fundy EBSA contains an island archipelago with narrow passages between islands and strong benthic topography combined with rapidly shifting semidiurnal tides (Buzeta and Singh 2008). Flood tides force waters through these passages from the outer Bay of Fundy into Passamaquoddy Bay; currents then reverse with the ebb tide, resulting in abundant upwelling, convergence and rip zones. These passages provide migration corridors for multiple species. High current velocities and diverse substrates (e.g., cobble, boulder, ledge, and vertical cliffs) provide habitat for benthic organisms uniquely adapted to feeding in extreme conditions (Buzeta and Singh 2008). Rare and unique sponges (upright *Haliclona oculata* and the massive *Myxilla* sp.), found in the area are associated with the unique topography (Buzeta and Singh 2008). Also, rare saltwater ponds on islands in this Quoddy region EBSA form important feeding habitat for Stickleback, Mummichog, eagles, heron, and kingfishers. This area was combined with the neighbouring (continuous) Head Harbour/West Isles (HHWI) area in 2012 to create the Head Harbour, West Isles, and Passages EBSA (DFO 2012).

Areas with strong topography and distinct physical properties can also create unique habitat for threatened or endangered species. The proposed offshore Gully, Shortland and Haldimund Canyons EBSA in the Eastern Scotian Shelf LOMA is geologically unique and contains three submarine canyons (1000 to 1500 m depth). The Gully is the largest submarine canyon off of Eastern Canada and the United States, and extends well into the shelf with a broad basin at its head (Breeze 2004, DFO 2006). The area is highly productive with unique current patterns and high marine mammal diversity. This EBSA is a foraging habitat for various marine mammals including seals and the endangered blue and sperm whales. The canyons form critical habitat for the endangered bottlenose whales on the Scotian Shelf as they move between canyons along the 800-1200 m isobaths. Fish species diversity is high, and the deep canyons with hard substrate and strong currents also are critical habitat for cold water, deep sea corals which are rare elsewhere in Nova Scotia waters (Breeze 2004, DFO 2006).

Further examples of marine EBSAs identified under the Uniqueness criteria are provided in Table 1.

Marine assessment of the uniqueness criterion

Uniqueness is one of the most easily quantified criteria as it requires simple metrics to evaluate, such as frequency of occurrence of a species, feature, or process and is applicable to a regional, national, or international scale (Buzeta and Singh 2008). However, difficulties can arise with respect to the spatial scale of assessment and the level of knowledge (of habitats and associations with biota) when evaluating this criterion. In data deficient areas, such as large proportions of the Arctic, an entire area can appear to be unique, making it difficult to rank and identify potential EBSAs within the larger area (DFO 2011b). Coastal regions often have sufficient data available, however, difficulties arise when interpolating between relatively close data points when there is insufficient data to resolve a meaningful scale of patchiness (DFO 2011b). Uniqueness ranking relies on confidence of the available data sources. The current EBSA protocol lacks rigorous statistical analyses potentially biasing rankings towards well-studied, commercially important or endangered/threatened species. Standardization in scale, resolution and approaches are needed.

The definition of 'significance' for the EBSA process, with respect to uniqueness (and the other criteria as well), and its role in management requires further clarification. EBSA criteria do not explicitly include an assessment of threats or risk to an area; however, it is difficult to compare areas without including threats to some extent. Criteria for degraded areas in marine ecosystems have not yet been defined (DFO 2006).

2 - BAY OF QUINTE: UNIQUENESS

Uniqueness as a potential criterion of a significant area within Lake Ontario is examined using two examples from the Bay of Quinte:

i) the large extent of littoral areas with vegetation that provides structural habitat; and
ii) unique habitats that support biodiversity.

Extent of Bay of Quinte coastal wetlands and littoral habitat

In comparison to other coastal areas of Lake Ontario, the Bay of Quinte is unique because it is largely protected from the lake proper (low exposure) and cold upwelling. The average effective fetch in the Bay of Quinte is exceptionally low (1.4 km; Table 2) compared to other coastal areas. A combination of associated habitat cofactors characterize this protected coastal embayment: an extensive and complex coastline with littoral and sub-littoral habitats, high primary productivity, relatively warm seasonal water temperatures, and extensive areas with submerged aquatic vegetation (SAV) and wetland emergent vegetation that provide structural habitat for life history processes. On a relative scale, about 29% of the total near shore area (0-20 m depth) in the Bay of Quinte is covered with SAV, compared to < 5% in other coastal areas (model results; Table 2). Taken together, the habitat attributes in the Bay of Quinte are considered to be unique to Lake Ontario and the degradation or loss of this habitat would have a disproportionate effect on the fish productivity of the lake.

With over 75% of the original coastal wetlands in southern Ontario lost to agriculture or urban development since European settlement, remaining areas are considered to be rare and play a vital role in the ecosystem function in Lake Ontario (BQRAP 2001, EC 2007). In 2005, a pilot study of coastal wetlands was conducted by Environment Canada (Canadian Wildlife Service) and the Central Lake Ontario Conservation Association (CLOCA). The status (i.e., degree of disturbance) of wetlands was assessed by comparing areas within and outside the Bay of Quinte using Indices of Biotic Integrity (IBI) and a Water Quality Index (WQI; Chow-Fraser 2006)

(EC and CLOCA 2004, EC 2006, EC 2007, Macecek and Grabas 2011). Indices (IBI) were calculated for submerged aquatic vegetation (SAV), macro-invertebrates, wetland fishes and marsh breeding birds (Table 3). IBI metrics consisted of biological attributes with known and predictable responses to disturbance that were scored, standardized and combined to obtain a final score between 0 (highly disturbed) and 100 (undisturbed) using the algorithms of Minns et al. (1994) and Hughes et al. (1998).

Water quality in Bay of Quinte wetlands was on average higher than elsewhere in Lake Ontario wetlands, although water quality varied from degraded to good in all areas (Table 3). Similarly all Bay of Quinte IBI scores were higher than elsewhere in Lake Ontario, particularly the SAV IBI, which had an average score of about 23 at Lake Ontario sites and about 80 at Bay of Quinte sites. IBI values reflected habitat quality, with Bay of Quinte sites providing habitat with higher species richness and abundances of ecologically sensitive species than comparative sites (EC 2007). Although reference sites were not randomly selected, WQI and IBI scores indicated that Bay of Quinte coastal wetlands were considerably less degraded than similar coastal wetlands in Lake Ontario (Table 2). IBI and WQI wetland values consistently showed that this area is unique and (by inference) has significant fitness consequences for a range of biotic communities.

Habitat suitability indices for fishes in littoral areas adjacent to the wetlands in the Bay and Lake are discussed further in the section on the fitness consequences. Other aspects of uniqueness of fish habitat in the Bay of Quinte (e.g., physical features such as limestone spawning shoals and proximity to large watersheds) are discussed under the aggregation and fitness criteria.

Unique habitats that support biodiversity

Lake Sturgeon

Lake Sturgeon (*Acipenser fulvescens*) in Canada is currently managed as eight geographically and genetically distinct spawning populations (COSEWIC 2006; Welsh et al. 2008). The Great Lakes-Upper St. Lawrence (DU8) population was listed as threatened in 2006. Although some spawning populations in Ontario show signs of recovery, all populations are small (< 1000) compared to historic numbers (COSEWIC 2006).

Historically, shoal spawning by Lake Sturgeon was documented at Amherst Island, Bay of Quinte, and at numerous other sites in Lake Ontario (COSEWIC 2006). Shoal spawning is rare; most sturgeon spawn in fluvial habitat. Currently, spawning in Lake Ontario has been documented only in the Niagara and Trent Rivers and has been reported at the Salmon River (COSEWIC 2006, Golder Associates Ltd 2011). The status of the spawning population at the Amherst Island shoal is currently unknown; however, remnant sturgeon may still reside in the area, and the Bay of Quinte represents significant corridor habitat for the Trent and Salmon spawning populations (COSEWIC 2006, Golder Associates Ltd 2011). The Bay of Quinte is therefore unique as a source of critical habitat and genetic diversity for the threatened and depleted DU8 Lake Sturgeon population.

Walleye

Bay of Quinte Walleye (*Sander vitreus*) are abundant and are genetically distinct from the nearby population in West Lake (Wilson and Gatt 2001, Wilson and Mathers 2003). The large population in the Bay of Quinte appears to be the major contributor to Walleye captured elsewhere in the Eastern Outlet basin (e.g. Kingston Basin) and New York State waters of Lake Ontario (Wilson and Gatt 2001). The significance of spawning and rearing grounds for Walleye in the Bay of Quinte, Lake Ontario, was compared in importance to the highly significant Walleye nursery areas of the western basin in Lake Erie (Bowlby and Hoyle 2011).

Lake Whitefish

In Eastern Lake Ontario, there are two major spawning stocks of Lake Whitefish (*Coregonus clupeaformis*): the South Shore of Prince Edward County stock and the Bay of Quinte stock (Hoyle et al. 1999). The Bay of Quinte stock contains three geographically discrete whitefish spawning populations: the Trent River, Big Island near Belleville, and Hay Bay populations (Ihssen et al. 1981). Population and life history benefits of these spawning shoals are discussed in the Aggregation and Fitness Consequences sections.

Pugnose Shiner

In 2013, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated Pugnose Shiner (*Notropis anogenus*) as Threatened. While the historic and current abundance of Pugnose Shiner in the Great Lakes basin is unclear; its current distribution is restricted to four distinct areas including the eastern Lake Ontario drainage (Bouvier et al. 2010). In 2009, DFO captured Pugnose Shiner from East and West Lakes (Prince Edward County, eastern Lake Ontario). Based on expert opinion (N. Mandrak, DFO, personal communication) it is highly likely that Pugnose Shiner is also present in the Bay of Quinte, which is separated from West Lake by Prince Edward peninsula (Bouvier et al. 2010). West Lake and possibly the Bay of Quinte are likely critical habitat for this endangered species.

3 - AGGREGATION: CRITERIA DESCRIPTION AND MARINE EXAMPLES

Definition and interpretation

Aggregation is ranked from areas “where:

i) most individuals of a species are aggregated for some part of the year; or
ii) most individuals use the area for some important function in their life history; or
iii) some structural feature or ecological process occurs with exceptionally high density to areas where
iv) individuals of a species are widespread and even areas of comparatively high density do not contain a substantial portion of the total population; or
v) individuals may congregate to perform a life history function, but the area in which they perform the function varies substantially over time; or
vi) a structural property or ecological process occurs in many alternative areas” (DFO 2004).

As with Uniqueness, aggregation is ranked across multiple functional properties of an area, including ecological functions, physical features, structural habitat features and biodiversity (DFO 2004). For example, an area containing a spawning ground used by a high percentage of the total population of a species or a noteworthy percentage of multiple species would obtain a higher aggregation ranking than an area containing a spawning/breeding ground used by only a small portion of a population or multiple species (DFO 2004). Areas containing physical features such as convergence zones may rank high for the aggregation criterion as such features concentrate prey and nutrients for the production of fish larvae. See Appendix 1 for additional descriptions of Aggregation.

Marine examples of aggregation

Similar to examples mentioned in the Uniqueness criterion, strong topography coupled with distinct physical processes can result in areas of high aggregations; the proposed Georges Bank (Canadian waters) EBSA in the Eastern Scotian Shelf LOMA contains steep topography and strong tidal currents which form a tidal mixing front and upwelling zone. The Georges Bank tidal mixing front is estimated to be the largest in Canadian waters and globally. These distinct physical processes create a nutrient pump leading to extremely high aggregations; primary production and fish production are estimated to be 40% and 50% higher, respectively, in Georges Bank than in surrounding areas (Doherty and Horseman 2007). Georges Bank is a highly productive spawning and feeding area for a variety of fishes, invertebrates, birds and marine mammals including various commercially important species such as Scallop, lobster, Atlantic Cod, Pollock, Haddock, Herring, Yellowtail Flounder, Mackerel, Tuna, Swordfish, and shark species (DFO 1998). It is an important migratory corridor for a variety of species and provides seasonal refugia for species like lobster in summer. Marine mammals such as Minke whales, Pilot whales, Atlantic white-sided dolphins, and harbour porpoises are also present for feeding, nursery, seasonal refugia and migration throughout the year (Doherty and Horseman 2007).

Structural habitat features such as vegetation can have significant impacts on aggregations and resultant productivity. The Mahone Bay and Islands EBSA in the Eastern Scotian Shelf LOMA contains dense, extensive native kelp beds while Islands in the EBSA have extensive shallow eelgrass beds. These macrophyte beds and the shoals associated with multiple islands result in a highly productive system; macrophyte beds and shoals may be significant to the productivity and reproduction of small fish species. Mahone Bay and Islands also form significant nesting, feeding and rearing habitat for multiple bird species and are the only known breeding sites for some birds (Doherty and Horseman 2007).

Further examples of marine EBSA identified under the Aggregation criteria are provided in Table 1.

Marine assessment of the aggregation criterion

Aggregation is a quantifiable criterion. For inshore and offshore areas in the Quoddy region of the Eastern Scotian Shore LOMA, EBSA identification was often based on aggregation in combination with other criteria, and aggregation was the sole criterion for some of the identified EBSAs (DFO 2006). Aggregation metrics include relative density and area of occurrence of a species, feature, or process and data for metrics should be collected at various times throughout the year to reduce seasonal bias. Ideally, measures should be related to indices of reproductive state or feeding across the spatial range of the species, feature or process (DFO 2006). The overlap that exists among the primary criteria is a major difficulty in the current DFO EBSA assessment protocol. Aggregation and Fitness Consequences appear to be intrinsically linked, as any area containing high aggregations of a species, feature or process would likely have significant impacts on the fitness of species (DFO 2006, DFO 2011).

4 - BAY OF QUINTE: AGGREGATION

The aggregation criterion and examples from the Bay of Quinte are discussed in the context of:

i) physical properties that lead to aggregations of nutrients and prey species; and,
ii) habitat that aggregates fishes by providing biological functions.

Nutrients and productivity

The Bay of Quinte, based on its unique bathymetry and temperature regime, provides an important rearing and feeding area for both juvenile (warm- and cold-water) and adult warm-water species. Both larval Lake Herring *(Coregonus artedii)* and Lake Whitefish are resident for six to eight weeks in the bay before migrating to the open lake (Tim Johnson, OMNR, pers. comm.); the nutrients and secondary production available in the Bay of Quinte are greater than what is available in the open lake and gives larval stages of these species an advantage that they need for survival (Bowlby et al. 2011; Hoyle et al. 2011). Annual primary production in the Bay of Quinte is in the range of 320- 350 g C m^{-2} (Munawar et al. 2012) which is similar to other eutrophic environments in the Great Lakes such as Hamilton Harbour (Munawar et al. 2011) and western Lake Erie (Fitzpatrick et al. 2007). In contrast, in offshore areas, Stadelman et al. (1974) recorded annual primary production at about 170 g C m^{-2}. More recent information from Millard et al. (1999) showed seasonal estimates of primary production for the Bay of Quinte were almost twice the values for Lake Ontario (1987-1992) (Table 4). Recent observations confirm that primary productivity in the Bay of Quinte is much greater than offshore Lake Ontario (Mark Fitzpatrick, DFO, pers. comm.).

Consistent with the high primary production, the secondary production of zooplankton is higher in the Bay of Quinte than in Lake Ontario proper. For example, total seasonal zooplankton production in the Bay of Quinte has averaged 3243, 2344 and 612 mg m^{-3} at Belleville, Hay Bay and Conway over the 2001 to 2011 period (Johannsson and Bowen 2012). In comparison, data collected in 2009 from nearshore Lake Ontario indicated seasonal production values of only 477, 364 and 95 mg m^{-3} at Bronte, Waupoos and Cobourg, which was about an order of magnitude lower than Bay of Quinte values (K. Bowen, DFO, pers. comm.).

Although historically degraded (eutrophic), Bay of Quinte is a dynamic ecosystem that has undergone remediation over the past 30 years. Total phosphorus concentrations declined about 35% after point-source loadings were decreased (Minns et al. 1986).

Despite these improvements, measurements of water quality (e.g., total phosphorus; TP) and ecological indicators (e.g., trophic ladder; Munawar and Munawar 1982) indicate that eutrophication remains an impairment issue in the Bay of Quinte. Munawar et al. (2012) found that phytoplankton biomass (4-5 g m^{-3}) and chlorophyll a (12-15 µg L^{-1}) remain high. Phytoplankton biomass and species composition found during algal blooms were indicative of eutrophic conditions (Munawar et al. 2012). Also, zooplankton biomass has declined in the Bay of Quinte since the mid-1990s after the introduction of invasive dreissenid mussels and a predatory cladoceran, *Cercopagis pengoi* (Bowen and Johannsson 2011). Cyclopoid copepods and small-bodied cladocerans were the preferred prey of larval Lake Whitefish in the Bay of Quinte (Hoyle et al. 2011). An 89% decline in the two zooplankton groups appears to be causing decreased larval fish growth and survival of juvenile life stages of Lake Whitefish (Hoyle et al. 2011).

Aggregations of fishes

Walleye: Bay of Quinte is the principal spawning and rearing area for Walleye, supporting the majority (> 90%) of the population in eastern Lake Ontario (Payne 1963; Christie 1973, Bowlby and Hoyle 2011). Walleye is a valuable and abundant fish stock that is exploited annually in both the recreational and commercial catch. The open-water yield in 2012 was about 41,600 kg (recreational and commercial catch; OMNR 2013). Assessment gill net abundance indicates that the Walleye population has been stable for more than a decade and based on current recruitment levels will remain stable for at least the next five years (OMNR 2013). Walleye spawn in the main tributaries (Trent, Moira, Salmon and Napanee rivers) or along the shoreline on limestone shoals (Christie 1973; Bowlby and Hoyle 2011). Juveniles remain and use nursery habitat in the Bay for three to four years before beginning an annual summer migration into the Eastern Outlet basin of Lake Ontario (Bowlby and Hoyle 2011, OMNR 2013). There is little evidence of Walleye spawning in Lake Ontario proper as very few juveniles (< 4 years age) are found in eastern or western Lake Ontario waters despite optimal summer temperatures (Bowlby and Hoyle 2011). The dependence of juvenile Walleye on the productivity and climate in the Bay of Quinte and the summer feeding of adults in the open lake makes this species unique in the ecosystem (Christie 1973). Walleye that hatch in the Bay of Quinte have an additional month to develop and grow as the mean water temperatures in Lake Ontario lag about one month behind the bay. Small, coastal embayments in Lake Ontario, that are exposed and directly influenced by the open lake, do not offer warm-water fishes, like Walleye, the same advantage for growth based on water temperatures (Murphy et al. 2012).

Lake Herring**:** Historically, Lake Herring stocks were abundant in many nearshore areas and embayments of Lake Ontario and used the Bay of Quinte as a primary spawning and nursery ground. Lake Herring in this area traditionally spawned along gravel shoals (Hurley and Christie 1977). The Bay of Quinte Lake Herring stock collapsed in 1945; the stock was sustained by the remnant population spawning along the west and south shore of Prince Edward County (Christie et al. 1987). While the stock is still severely depleted from historic numbers, there has been a slight population growth in recent years. Currently, spawning adults and juveniles are most reliably caught in the Bay of Quinte, indicating that Lake Herring may have resumed using this area as a spawning and nursery ground. Bay of Quinte provides critical habitat and possibly, as noted earlier, a unique genetic population of Lake Herring in Ontario waters (OMNR 2013).

5 - FITNESS CONSEQUENCES: CRITERIA DESCRIPTION AND MARINE EXAMPLES

Definition and interpretation

Fitness Consequences (FC) is the third main criterion used to evaluate and identify Ecologically and Biologically Significant Areas (EBSA). Fitness Consequences are ‘ranked from areas where the life history activity(ies) undertaken make a major contribution to the fitness of the population or species present to areas where the life history activity(ies) undertaken make only marginal contributions to fitness’ and generally applies to ‘functional properties of areas, and in most cases reflects contributions to reproduction and/or survival of the species’ (DFO 2004). The functional properties of an area closely mirror the definition of fish habitat provided by the *Fisheries Act* as “spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes”. Further, Fitness Consequences are considered an ‘inclusive term, to include cases which may influence survival or reproduction indirectly as well as directly’ which are ranked on a regional, national or international scale (DFO 2004).

The functional properties of an area can include biological functions, physical features, structural habitat features and biodiversity (DFO 2004, Buzeta and Singh 2008). For example, an area containing a migration route which favoured population fitness would have a higher FC ranking than an area containing a migration route with no effect on fitness and no constraints on variable routes (DFO 2004). Similarly, an area which contains a physical feature, such as a tidal mixing zone, would have a high Fitness Consequences ranking as such features form key adult feeding areas for multiple species. Additional descriptions of Fitness Consequences are given in Appendix 1.

Marine examples of fitness consequences

An example area that favors population fitness is the Head Harbour/ West Isles (HHWI) EBSA in the Eastern Scotian Shelf (EESIM) LOMA. HHWI contains complex benthic topography, large tides and tidal streams surrounding an Island archipelago which result in a complex system of physical processes (currents, eddies, gyres, shear zones, upwellings and convergences). These distinct physical processes aggregate prey to form key feeding areas for multiple species; the area is a principal area of enhancement of Fundy waters which directly influences the metabolic function of the ESSIM LOMA (DFO 2004, Buzeta and Singh 2008). HHWI also contains key spawning habitat for adult fish (redfish, lumpfish and Atlantic Wolfish) and nursery/rearing habitat for juvenile fish such as Atlantic Cod and redfish (Scott and Scott 1988). Various marine mammals use HHWI as a feeding, breeding, refuge, nursery and rearing habitat including the endangered North Atlantic right whale. The area is a key migratory corridor, as well as reproductive and feeding site, for various seabird and shorebird species (Buzeta et al. 2003a, Buzeta and Singh 2008). The area is an important source of biodiversity for multiple species; for example, HHWI has hosted over 50% of the Canadian population of red-necked phalaropes in past years (Lotze and Milewski 2002) and is believed to be the only breeding site for this species in eastern Canada, Iceland and Greenland (Duncan 1996). Structural habitat features of the area include extensive sponge beds and stalked ascidians which enhance reproduction and survival of juvenile fish and shellfish by providing refugia (Hatfield et al. 1992, Conway 1999, Stocker and Pringle 2000).

An area necessary for the survival or reproduction of a Species at Risk represents an important source of biodiversity for that species, such as the Right Whale Conservation Area (i.e., Roseway Basin) EBSA in the Eastern Scotian Shelf LOMA. The endangered North Atlantic right whale has been depleted to a population of less than 350 individuals (DFO 2006). Due to the underlying bathymetry, physical features and year-round high levels of surface chlorophyll, which act to concentrate high aggregations of copepod prey species, Roseway Basin forms a key feeding ground for the endangered whales (Doherty and Horsman 2007). This EBSA occurs along the whale's migration route and does not lie directly within the main shipping lanes; alternative feeding grounds that occur in shipping areas result in decreased survival and fitness as ship strikes are a leading cause of mortality for this species. Feeding in the area occurs seasonally, and contributes significantly to annual growth, condition and maturation, and individual fitness. The Conservation Area was established as an EBSA as it has a direct impact on the reproduction rates and short and long-term survival of the species (DFO 2012).

Further examples of marine EBSAs identified under the Fitness Consequences criteria are provided in Table 1.

Marine assessment of the fitness consequences criterion

Fitness Consequences are the most difficult of the three criteria to quantify in marine areas due to significant knowledge gaps. During EBSA identification for the inshore and offshore Eastern Scotian Shelf LOMA, Fitness Consequences was the least likely primary criterion to be chosen to describe an EBSA, but it was listed with other primary criterion in over half of the inshore areas. No EBSAs were identified based solely on the Fitness Consequences, in contrast to Uniqueness and Aggregation (DFO 2006); Fitness Consequences were intrinsically linked to the other primary criteria. Interestingly, migration was a particularly significant life history function associated with Fitness Consequences (DFO 2011).

Information gaps associated with Fitness Consequences were evident because of a lack of quantitative area-specific data (e.g., indices of reproductive success, growth rate, survivorship and/or genetic diversity (DFO 2006).

The criteria used by the international Convention on Biological Diversity (CBD 2009) for identifying significant areas were modified and reduced in number by DFO (DFO 2004). Utilizing the original CDB criteria may reduce overlap among the criteria.

6 - BAY OF QUINTE: FITNESS CONSEQUENCES

The examples for the Fitness Consequences criterion from the Bay of Quinte are discussed under:

i) physical features (water exchange and temperature regime);
ii) structural features (vegetation including macrophtyes and habitat suitability); and,
iii) biodiversity features (richness and composition of the fish community).

Physical features

A two-layered seasonal exchange flow process occurs between the mid and lower bays of the Bay of Quinte through the Glenora Gap. From May to July, there is substantial discharge from the Trent River which causes a prevailing southward surface (~4.5 m) flow from Long Reach to Adolphus Reach, with a substantial northward return flow evident at 10 and 17 m. From August to September, river discharge decreases by an order of magnitude causing a significant flow reversal in the two-layer circulation (Freeman and Prinsenberg 1986). The prevailing surface (~10 m) flow occurs from Adolphus Reach into Long Reach, with a return flow occurring at 17 m. The seasonal thermocline in the Adolphus Reach/North Channel basin is below the sill depth at the Glenora Gap and slopes downward during this period, reversing density-driven flows between upper and lower layers. From September to October, cooling surface waters cause the water column to become increasingly homogeneous and flow to become uniform from surface to bottom (Freeman and Prinsenberg 1986). During summer months, the shallow, upper bay remains well-mixed with no thermal stratification (Sly 1986; Minns et al. 2011).

Seiche events occur in the Bay of Quinte watershed with cold, bottom water seiche events having been recorded as far as the upper limits of the middle bay during the summer months. During stratified periods, vertically and horizontally entrained flows occur and can cause corresponding changes in local water quality independent of overall bay water quality (Sly 1986) because of upwelling from the main lake.

Current speeds in the mid and lower bays are generally <10 cm/s except at the Lower Gap where speeds >10 cm/s predominate; current speeds >10 cm/s can occur through the Glenora Gap during high river discharge periods (Freeman and Prinsenberg 1986). Bay flushing occurs two to three times annually. Spring flushing is influenced by the peak discharge of the Moira River while summer flushing is dominated by the Trent River discharge.

Seasonal water flow and exchange between Bay of Quinte and Lake Ontario, seiche events, and thermal stratification are all physical features which have positive (but sometimes negative) consequences to the fitness of fishes (enhanced survival; refugia and migration). The distribution and movement of Walleye between the Bay of Quinte and Lake Ontario, for example, is correlated with seasonal changes in water temperature and prey availability (Bowlby and Hoyle 2011). Lake Ontario warms more slowly in spring and cools more slowly in autumn than the Bay of Quinte. Seasonal movements of adult Walleye track these changes in temperature, likely in response to their preferred temperature for growth (Bowlby and Hoyle 2011). As discussed under the aggregation criterion, Walleye spawning and rearing habitat in the Bay of Quinte is abundant. Because of earlier spring warming, eggs and fry have an additional month to develop than in the lake. Growth and survival (fitness) of Walleye at different life history states are tied to the seasonal thermal structure and dynamics of the Bay and the interface with Lake Ontario.

Structural habitat

A fish habitat classification model was developed for the upper and middle sections of the Bay of Quinte by Minns et al. (2006). Fish habitat suitability was based on inventories of shoreline, bathymetry, substrate and vegetation, and documented species-specific fish habitat preferences. SAV and habitat covariates provide structural habitat for a large number of fish species in the Great Lakes. For habitat classification, nine fish groups were determined from the list of species present (63) in the Bay of Quinte, grouped by their thermal and vegetation preferences, and size and age at maturity. For each fish group, habitat suitabilities for three life stages, spawning, YOY and adult fishes, were predicted using the 'Defensible Method's software (Minns et al. 2001). In addition to fish habitat suitability, information on spatially rare habitats and local expertise (recreational fishers) of important habitat were incorporated into the classification model.

Structural habitat (SAV and associated substrate and bathymetry) was a primary driver in the habitat classification model. The resulting habitat maps and the analyses of area by habitat class indicated that there was abundant highly suitable fish habitat in the upper and middle Bay areas of the Bay of Quinte. There was good overall agreement between maps of habitat suitability and maps of fishing success. The study confirmed that the Bay of Quinte contains extensive areas of high quality structural habitat associated with the littoral macrophyte cover and emergent wetlands.

Recently, the relative quality and quantity of structural habitat in Bay of Quinte was compared to other coastal areas of Lake Ontario (Fig. 2; Table 1). Building on updated habitat suitability algorithms (Minns et al. 2001), temperature suitability was added as a metric, and multiplied by habitat suitability to give an overall suitability index for each habitat area (Gertzen et al. 2012). Weighted Suitable Area (WSA) in km^2 was calculated as the product of the suitability index and the wetted area. Average WSA values for the Bay of Quinte are compared to five other coastal habitat zones in Lake Ontario in Table 1. Using WSA as the metric, spawning, YOY and adult fish habitat ranked higher than all other adjacent or distant coastal areas in Lake Ontario. These model results confirmed that structural fish habitat is exceptionally abundant in the Bay of Quinte.

High habitat suitability indices infer that there are positive fitness consequences to the fishes that inhabit the Bay of Quinte. Near shore electrofishing and trap net surveys confirm that warm-water and cool water species of fishes are abundant and thrive in the bay (Brousseau et al. 2011, Hoyle et al. 2012). Randall et al. (2012) found that biomass and production indices of sunfish and Yellow Perch (*Perca flavescens*) were higher in areas with SAV than in areas with sparse or no SAV. The biomass component of fish production was related to macrophyte cover, but the growth component and P/B (determined by allometry with body size) was not. In terms of fitness consequences, the strong effect of fish abundance (biomass) on production was consistent with the successful recruitment of fishes in the Bay of Quinte (Randall et al. 2012).

Bay of Quinte Lake Whitefish spawn preferentially on shallow, restricted shoals and outcroppings of flattened limestone such as the Hog’s Back shoal in Big Bay, Sherman Fall Unit and Telegraph narrows (Hart 1931, Sly 1986). Similar preferences for shallow, limestone shoals have been observed in Lake Whitefish spawning populations in the Detroit River (Roseman et al. 2007). While similar spawning habitat is available on the south shore of Prince Edward County, the limestone shoals in Bay of Quinte are particularly significant as they have a direct impact on the reproduction and survival of the 3 distinct spawning populations which constitute the Bay of Quinte stock. In 2005, Lake Whitefish abundance in Eastern Lake Ontario reached its lowest level since 1981; therefore this area forms critical habitat and has direct fitness consequences for a depleted stock (Hoyle et al. 2008).

Biodiversity features

Bay of Quinte supports both high fish biodiversity and high productivity. The Bay provides habitat to a wide variety of freshwater fishes at different life stages; both warm- and cold-water species reside in the bay both annually and seasonally. Warm-water species that prefer aquatic vegetation (phytophilic) are abundant (e.g., Centrarchidae) and are protected in the upper bay from cold water intrusions from Lake Ontario. Cool-water species like Northern Pike (*Esox lucius*), Yellow Perch, Walleye and a wide variety of suckers (Catostomidae) are also abundant. As noted previously, the largest proportion of the eastern Lake Ontario population of Walleye is spawned and reared in the Bay of Quinte. Cold-water species, like Lake Herring and Lake Whitefish, use the bay for spawning and feeding. Non-resident warm-water species like

Muskellunge (*Esox masquinongy*), from the St. Lawrence River, make foraging excursions into the bay in the fall (OMNR). The complexity of the bay, between large tributaries and shallow, warm productive areas, offers important habitats for a large portion of the global population of the panmictic American Eel for this region (eastern Lake Ontario –Bay of Quinte, upper St. Lawrence). The American Eel is designated as Threatened, and River Redhorse and Grass Pickerel are designated as Species of Special Concern by COSEWIC. Also, as noted earlier, Pugnose Shiner, a species listed as Endangered under the federal *Species at Risk Act*, is thought to reside in the bay (Nick Mandrak, DFO, pers. comm.).

Fishes and other biota in the Bay of Quinte have been studied for over 40 years. Both long (OMNR) and short-term (DFO, Environment Canada) monitoring and assessment programs have been in place to monitor valued aquatic resources from either a fishery (commercial, recreational and Aboriginal) or an ecosystem health perspective. Although the Bay of Quinte was identified as an Area of Concern (AOC) in 1987 by the International Joint Commission, it supported a large Walleye fishery (OMNR 1990). Prior to phosphorus (P) control, fish reproduction was considered to be impaired due to hyper-eutrophic conditions (Hurley 1986), but P management and a large die-off of the invasive White Perch in the late 1970s led to a partial recovery of the fish community. Since then, the fish community in the Bay of Quinte has continued to improve and change with the return of submerged aquatic vegetation (SAV) in the bay (Hoyle et al. 2012, Leisti et al. 2012). Currently, the fish assemblages measured in both the near shore and offshore monitoring programs are considered healthy and diverse despite the current impaired status (Brousseau et al. 2011, Hoyle et al. 2012). Bay of Quinte is scheduled to be upgraded in ecosystem status (delisted as an AOC) by the IJC, likely by 2015.

Measures of biodiversity which have been applied to Bay of Quinte fishes include the electrofishing-based Index of Biotic Integrity (IBI; Minns et al. 1994, Brousseau et al. 2011) and the proportion of piscivore biomass (PPB) as measured using standardized fish surveys (trap and gill nets) in the nearshore and offshore fish community (Hoyle et al. 2012). The IBI was designed to assess nearshore fish assemblages based on water quality, physical habitat, non-native species and piscivore abundance. An integrated IBI greater than 60 indicates a 'good' and an IBI >80 indicates an 'excellent' fish community score. The IBI and fish species diversity are strongly correlated (Randall and Minns 2002). The PPB was selected as a biodiversity measure of fish community health because Hurley (1986) and current studies indicate that the fish community depreciates when the PPB falls below 0.2 (Hoyle et al. 2012).

Brousseau et al. (2011) found that nearshore fish assemblages in the upper and middle Bay of Quinte had IBI scores in the good to excellent range and were similar or often higher than scores from reference locations. A total of 42 species of fish were captured during boat electrofishing surveys conducted between 1990 and 2011. Five non-native species were captured but comprised less than 10% of the total catch (Brousseau et al. 2011). Hoyle et al. (2012) found that the PPB in both nearshore (trap net) and offshore (gillnet) surveys was greater than 0.2 between 2006 and 2011 and comparable to PPB values from reference locations (Hoyle 2013). The OMNR fish surveys captured 38 species during the 1969-2011 survey period, of which seven were non-native (Hoyle et al. 2012).

Currently, Walleye and Largemouth Bass (*Micropterus salmoides*) are the top predators in the Bay of Quinte (Brousseau et al. 2011, Hoyle et al. 2012). Walleye are the most sought after species in the Bay of Quinte and the Province of Ontario places a high recreational value on this species. In 2012, creel surveys indicated that 36,240 Walleye were captured in the Bay of Quinte and over 27,000 were harvested (OMNR 2013). The Bay of Quinte also hosts an important commercial fishery, of the 181,896 kilograms of fish that were harvested from Lake Ontario in 2012, just over half of that harvest came from the Bay of Quinte (OMNR 2013).

Some of the species that were harvested commercially included species of Centrarchidae, Yellow Perch, Northern Pike, Lake Whitefish and Lake Herring (OMNR 2013).

7 - RESILIENCE AND NATURALNESS FROM A MARINE PERSPECTIVE

Once potential EBSA sites have been identified, there are two additional qualifier dimensions which can be used to evaluate these sites: Resilience and Naturalness. Resilience is “ranked from areas where the habitat or species are highly sensitive, easily perturbed, and slow to recover to areas where habitat structures are robust, resistant to perturbation, or readily return to the pre-perturbation state” (DFO 2004). This dimension is mainly applicable to the structural properties of an area but can also be applied to functional properties. For example, a potential EBSA which featured a migration pathway that would be permanently lost if the area was disrupted (such as cases where juveniles learn migration routes from adults) would rank higher than an area where the migration route could be re-established readily if disrupted (such as when migration is cued by magnetic field or sun position).

Naturalness is ranked from “areas which are pristine and characterized by native species to areas which are highly perturbed by anthropogenic activities and/or with high abundances of introduced or cultured species” (DFO 2004). For example, a potential EBSA which acted as a feeding ground where introduced or cultured species were not major components of the food web and/or food resources were not dependent on man-made structures or processes initiated or sustained by anthropogenic activities would rank higher than an area where major energy flow through the food web is channeled through an exotic species and/or where human activities have altered the food web by stimulating the production of alternate prey or artificially sustaining the production of top consumers.

Efficacy of the resilience and naturalness criteria for freshwater ecosystems (using Bay of Quinte as a case study) are considered in the general discussion.

GENERAL DISCUSSION

The primary space-based ecological criteria of uniqueness, aggregation and fitness consequences that are used for identifying significant areas in marine ecosystems of Canada can be usefully applied to freshwater habitat and ecosystems as well. Assessment of criteria in freshwater habitats of Lake Ontario, using Bay of Quinte as a case study, showed that each criterion could be interpreted, measured with available metrics and data, and supported by science literature or by regional expertise. However, certain limitations or qualifications from this assessment were evident, and further science evaluation in other areas would be helpful. Successes, limitations and qualifications for using the criteria in freshwaters are discussed in anticipation of the use of ecologically significant areas as a potential management tool in future.

Overall, the three primary EBSA criteria were relevant, and could easily be interpreted and applied to the Bay of Quinte, when using the whole of Lake Ontario for comparison and spatial context. Experiences with the criteria from the marine environment applied equally to Lake Ontario: specifically the criteria were sometimes redundant (i.e., the same habitat type applied to more than one criterion), and information on fitness consequences was the most challenging of the three criteria to quantify. For example, the ecological value of extensive littoral habitat with abundant SAV was discussed under all three criteria: unique in terms of extent, aggregation in terms of nutrients and prey, and fitness in terms of growth and survival (habitat suitability). For this study however, redundancy among criteria was viewed as being positive as it confirmed the importance and consistency of all three criteria in the Bay of Quinte. The results of this study confirm that the EBSA criteria are generally applicable to freshwater and coastal habitats (DFO 2011a).

Certain limitations and qualifications apply to this criteria assessment. Bay of Quinte was selected to assess the EBSA criteria because of the availability of long-term (> 30 years) data sets for all trophic levels and environmental conditions. However, the fact that Bay of Quinte was a degraded area undergoing remediation was sometimes a confounding factor for interpreting the EBSA criteria. Nevertheless, the extrapolation and application of the criteria would be more challenging in freshwater areas where fewer data are available, particularly in northern areas. Also, assessment of the criteria must still be done for fluvial freshwater fish habitat (watersheds).

The spatial scale of the approach used in this study, that is, Bay of Quinte versus the whole of Lake Ontario, was informative for evaluating the EBSA criteria. On the one hand, the significance of ecological functions and structural habitat features in the Bay of Quinte could be effectively judged by comparison to other areas in Lake Ontario. On the other hand, however, the spatial scale of the EBSA for this case study was predetermined by our approach (all of Bay of Quinte). EBSAs in marine areas are often larger than the Bay of Quinte. However, during criteria assessment, it was apparent that some key ecological functions and structural features sometimes applied to more localized (smaller) habitat areas. Also the conservation objectives would be relevant for identifying the appropriate scale; conserving critical habitat for species-at-risk would focus on a smaller spatial scale than conserving fisheries (populations). This study was not designed to assess and determine the appropriate spatial scale of EBSAs. Other approaches for identifying potential EBSAs such as data-layering (DFO 2007b) may be more useful for detecting the spatial boundaries and extent of ecologically significant areas.

Resilience, the capacity of ecosystems or habitats to resist change, is linked to biodiversity. More diverse ecosystems recover more quickly than less diverse ecosystems. The ecological significance of resilient habitat applies equally as a criterion to marine and freshwater ecosystems, but there are differences. Resilience of specific habitats to physical disturbance may be more relevant to marine habitats (e.g., impacts of benthic trawling) than to freshwater habitats. Resilience of the Bay of Quinte at an ecosystem scale is evidenced by its recovery over the past years from earlier ecosystem degradation, although this is a habitat degradation issue as well as a resilience issue. Restoration in the Bay of Quinte was aided by targeted management actions. For comparing the resilience criterion between marine and freshwater systems, the distinction between natural resilience (ability of an organism to recover) and anthropogenic resilience is important. In addition, freshwater ecosystems are affected by more human-related stressors than marine habitats.

The naturalness criterion applies to both species and to habitat. The presence of native aquatic plants and fish species was important for assessing all EBSA criteria in the Bay of Quinte and Lake Ontario; metrics of native versus non-native species were readily available from the science literature that was generated to support fisheries, species at risk and habitat management. Although strictly speaking there are no pristine areas remaining in Lake Ontario, the assessment of the EBSA criteria was a reminder of the importance of the naturalness criterion for two reasons:

1) regardless of the state of the ecosystem, the health and value of habitat varies spatially and can be ranked from low to high value on a relative scale; and
2) the ecological significance of habitat areas can only be judged in the context of reference areas, whether these areas are pristine or not.

For freshwater areas in Canada, naturalness will be an increasingly important criterion for identifying significant freshwater habitat in northern and arctic latitudes.

Assessment of each EBSA criteria revealed a few ‘lessons learned’ to consider for future applications (relevant to ecological function) in freshwater:

- The influence and importance of riparian areas to freshwater aquatic habitat could be added as an ecological function affecting fitness;
- Also, the extent of the land-water interface (transition zone) and degree of exposure are important physical properties in freshwater lakes;
- Freshwater habitat diversity is important, as there is a strong correlation between habitat diversity and fish species diversity in freshwater regions;
- Thermal habitat as a factor affecting regional patterns in productivity, and resilience to fluctuations in climate are important in freshwater ecosystems;
- Identification of significant areas of high biodiversity (fishes and other biota) is a priority in the Great Lakes and elsewhere in freshwaters. Although biodiversity is clearly recognized in the marine EBSA criteria, latitudinal and regional variation in biodiversity is a primary driver and a focus for managers in freshwater ecosystems;
- Connectivity of habitat is a key factor in freshwaters;
- Threats to rare or low abundance species in freshwater are often habitat-related rather than fishing-related, as is often the case for marine species. The identification and conservation of essential habitat for all life stages, even for small spatial scales, is important for freshwater species.

To further assess and advance potential use of the criteria in freshwater ecosystems, a list of science gaps to be addressed are:

- Science assessment of the efficacy of the EBSA criteria in;
    - 1) watersheds;
    - 2) northern regions of Canada; and
    - 3) data-deficient areas;
- Knowledge of regional differences in productivity, thermal conditions and projected future change;
- Integration of knowledge and criteria of significant areas from other conservation programs, such as biodiversity strategies and species at risk;
- Advancement of studies of spatial and individual-based models that functionally link habitat to fish populations, to better understand area-dependent survival (fitness consequences)
- Investigate and further develop science-based methods to best define the boundaries and the appropriate spatial scale of ecologically significant areas (e.g., GIS based data-layering).

The identification of ecologically significant areas in the Great Lakes and elsewhere in freshwaters, as a potential tool for managers, is a future task that will require further and rigorous assessment of the criteria. However, extrapolation of the current EBSA criteria from marine to freshwater habitat is feasible and provides a strong initial framework.

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TABLES

Table 1. Examples of marine EBSAs identified for the three primary criteria: Uniqueness, Aggregation and Fitness Consequences.

EBSA (LOMA)	Ecological Functions	Physical Features	Structural Habitat Features	Biodiversity	References
			Criterion: Uniqueness		
Husky Lakes (Beaufort Sea)	Significant spawning habitat for Lake Trout and Pacific Herring, nursery /feeding habitat for Lake Trout, migratory corridor/seasonal refugia for birds, feeding habitat for marine mammals	Estuarine and lacustrine habitat, strong tidal flows		Contains 10% of Canadian Brant population	Paulic et al 2009
West Northumber-land Strait (Gulf of St. Lawrence or GOSLIM)	High abundance of groundfish with limited ranges (White Hake and Windowpane Flounder), high diversity/abundance of meroplankton, significant habitat for marine mammals	Shallow (>20m), tidal mixing zone, retention potential, highest annual temperatures in GOSLIM	High abundance of Giant Scallop beds	Isolated population of endemic subspecies of calico crab, >50% of total population of endangered winter skate in summer/fall	DFO 2007b
Brooks Peninsula (Pacific North Coast, PNC)	Seasonal habitat for endangered Green Sturgeon possible staging area for migratory sturgeon), high diversity of migratory/breeding birds and threatened sea otters			Only identified habitat of endangered Green Sturgeon in PNC, only known spawning habitat for Lingcod in PNC	Clarke and Jamieson 2006
			Criterion: Aggregation		
Lower Estuary (Gulf of St. Lawrence)	High aggregations of phytoplankton and zooplankton year-round, seasonally highest abundance of juvenile Greenland Halibut, Witch Flounder and Thorny Skate in GOSLIM, high aggregations of benthic invertebrates,	Estuarine habitat, with tidal mixing, deep water resurgence and vertical water movement, contains part of Laurentian channel (depth=300m),acts as a nutrient pump		Significant habitat for population of threatened Beluga Whale, 1 of only 3 known habitats of deep water mysid *Boreomysis arctica* in GOSLIM	DFO 2007b

EBSA (LOMA)	Ecological Functions	Physical Features	Structural Habitat Features	Biodiversity	References
	feeding/refugia habitat for marine mammals				
Hershel Island/Yukon North Slope (Beaufort Sea)	Spawning habitat for Arctic Cod, breeding habitat for Black Guillemots and shorebirds, feeding/breeding/seasonal refuge and migratory corridor for marine mammals, migratory corridor and seasonal refuge for anadromous fish, marine fish and birds	Corridor with steep bathymetry extending to a trough along the coast of Hershel Island			Paulic et al 2009
Criterion: Fitness Consequences					
Western Cape Breton (Gulf of St. Lawrence)	Migration corridor for groundfish (Atlantic Cod and White Hake), Feeding habitat for groundfish and pelagic fish, reproductive site for marine mammals and Atlantic Herring, overwintering refuge for juvenile herring	Cape Breton Channel		Highest biodiversity of meroplankton in GOSLIM	DFO 2007b
Beluga Bay (Beaufort Sea)	Significant nursery/rearing /feeding habitat for marine mammals (Beluga, Ringed Seal, and Polar Bears), significant spawning/nursery habitat for Pacific Herring, migration corridor for birds	Freshwater and saltwater mixing zone, gravel shoals, landfast ice			Paulic et al 2009

Table 2. Spatial extent of average area (0-20 m depth), coastal wetlands, average effective fetch, littoral areas with submerged aquatic vegetation (SAV), seasonal average water temperatures, and Weighted Suitable Areas (WSA) of the near shore of Lake Ontario (shoreline locations are shown in Fig. 2). Standard deviations (SD) of area are based on varying water levels, 1990 to 2000. Calculations of WSA are discussed in text. Model results are from S. Doka and E. Gertzen (unpubl. data).

Shoreline Location	Average Area (0-20m; km^2)	Wetland Polygon Area (km^2)[1]	Average effective fetch (km^2)	SAV Area (0-5 m; outside of wetlands; km^2)	Average temperature (^{o}C; May to Sep)	Average Spawning Relative WSA	Average YOY Relative WSA	Average Adult Relative WSA
East	1132.23 (±2.25)	46.20	16.49 (±16.06)	34.17 (±1.14)	15.21 (±1.01)	0.30 (±0.12)	0.71 (±0.08)	0.57 (±0.08)
North	433.12 (±1.70)	10.16	25.24 (±18.66)	14.53 (±0.20)	14.48 (±1.03)	0.19 (±0.09)	0.67 (±0.08)	0.53 (±0.08)
West	320.17 (±0.54)	3.42	13.72 (±14.19)	11.62 (±0.24)	15.07 (±1.02)	0.20 (±0.09)	0.66 (±0.07)	0.56 (±0.07)
South Central	450.73 (±0.29)	16.95	29.66 (±20.17)	7.15 (±0.19)	15.58 (±0.99)	0.29 (±0.10)	0.73 (±0.08)	0.60 (±0.08)
South East	348.56 (±1.40)	50.13	18.79 (±19.12	10.75 (±0.59)	16.04 (±0.97)	0.51 (±0.15)	0.84 (±0.09)	0.69 (±0.09)
Bay of Quinte	225.76 (±1.89)	60.92	1.40 (±0.88)	66.15 (±1.31)	19.03 (±0.69)	1.00 (±0.27)	1.00 (±0.08)	1.00 (±0.09)

[1] IJC Wetlands Working Group

Table 3. Water Quality Index (WQI) and Index of Biotic Integrity (IBI) average scores and ranges from 2006 to 2009 for Bay of Quinte and Lake Ontario.From Macecek and Grabas (2011).

Metric	Bay of Quinte	Lake Ontario
Water Quality Index[1]	0.18 (-0.80 to 1.24)	-1.25 (-2.74 to 0.74)
SAV IBI[2]	79.88 (57.6 to 98.2)	22.96 (0 to 87.2)
Aquatic Macro-Invertebrate IBI[3]	64.57 (33.2 to 91.9)	41.64 (5.1 to 87.9)
Fish IBI[4]	80.20 (55.4 to 90.9)	38.43 (6.3 to 73.3)
Breeding Bird IBI[5]	65.79 (28.2 to 100)	45.84 (2.2 to 96.4)

[1]The WQI used Equation 7 of the Chow-Fraser WQI (2006), with parameters such as temperature, pH, conductivity and turbidity, to rank sites into six categories on a scale of -3 (highly degraded) to 3 (excellent).
[2]SAV IBI metrics included number of turbidity-intolerant species, Relative % cover of turbidity-intolerant species, Floristic Quality Index, total coverage and total number of native species.
[3]Macroinvertebrate IBI metrics included number of Crustacea and Mollusca genera, number of Ephemeroptera and Trichoptera genera, number of Odonata genera, total number of families, % Amphipoda, % Crustacea and Mollusca, % Ephemeroptera, % Diptera, % Isopoda, % Trichoptera and % Crustacea.
[4]Fish community IBI metrics included number of native species, number for centrarchid species, % piscivore biomass, number of native individuals, % non-indigenous biomass and biomass of yellow perch.
[5]Marsh breeding bird IBI metrics included marsh area-sensitive species richness, % marsh-nesting obligates, % marsh-users and % marsh area-sensitive.

Table 4. Seasonal (May 1-Oct 31) estimates of area primary production (PP) in g C m-2 [reproduced from Millard et al. (1999)]

Lake	Years	Areal PP (g C m^{-2} ±SD)
Lake Ontario		
Mid-lake	1987-92	134.4 ± 23.9
East basin	1987-92	140.0 ± 19.6
Bay of Quinte		
Upper	1989-94	236.0 ± 47.8
Middle	1989-94	260.5 ± 54.8
Lower	1989-94	171.1 ± 30.7

Table 5. Summary of EBSA criteria and examples from the Bay of Quinte, Lake Ontario. The selected examples include both the biological function and structural features of habitat depending on the example. Acronyms: SAV - submerged aquatic vegetation; IBI-Index of Biotic Integrity; WQI – Water Quality Index; TP – total phosphorus; CPUE – catch per unit effort; AOC – Area of Concern; WSA – weighted suitable area; PPB – proportion piscivore biomass.

Criteria	Examples	Metrics	Data available	Notes
Uniqueness: habitat that is rare elsewhere, or habitat that supports rare fishes	Extent of coastal wetland and littoral habitat (with SAV)	Area in ha; IBI and WQI	Well documented in science literature	Requires habitat and species inventory for whole lake
	Sturgeon, Walleye, Pugnose Shiner	Present/absent Abundance	Long term fish population monitoring of Walleye; literature, local expertise	Genetic studies are few
Aggregation: concentration species, prey or nutrients	Nutrients and productivity	TP µg L^{-1} g C m^{-2}	Abundant data; science literature	Difficult to assess because of confounding influence of eutrophication and natural productivity
	Spawning and rearing of Walleye Spawning and rearing of coregonids	Trap net and gill net data (CPUE); long term monitoring	Science literature and local expertise	
Fitness consequences: reproduction, survival or growth related to habitat	Physical : seasonal water movement, thermal conditions	Limnological measurements	Much data available because of AOC work	
	Structural habitat; high habitat suitability; spawning shoals	WSA Habitat Suitability Indices (HSI)	Long standing research for AOC and water levels	Inference from HSI of enhanced growth and survival
	Biodiversity	CPUE IBI PPB	Trap net, gill net, and electrofishing surveys	Good consistency among gears
Resilience	Area of Concern restoration success		Long term science-based monitoring	Much literature on restoration of macrophyte beds in freshwater
Naturalness	Habitat conditions range from perturbed to relatively healthy	Percent native fishes and plants	Long term science-based monitoring	No areas of Lake Ontario are pristine

FIGURES

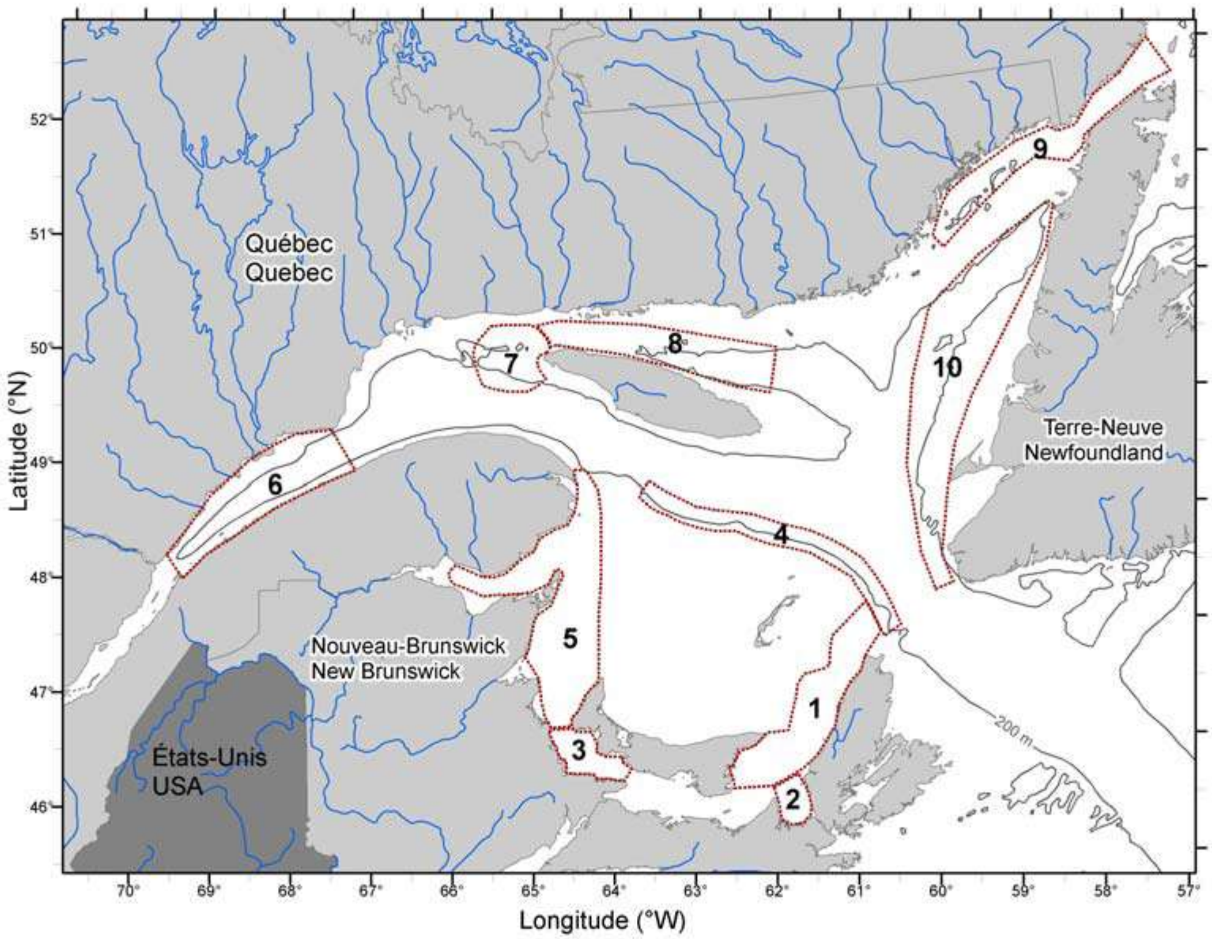

Figure 1. EBSA distribution in the Estuary and Gulf of St. Lawrence: EBSA (1) Western Cape Breton, (2) St. George's Bay, (3) Northumberland Strait, (4) the southern fringe of the Laurentian Channel, (5) the south-western coast of the Gulf, (6) the lower estuary, (7) western Anticosti Island, (8) northern Anticosti Island, (9) the Strait of Belle Isle, (10) the west coast of Newfoundland. Figure and caption reproduced from DFO (2009).

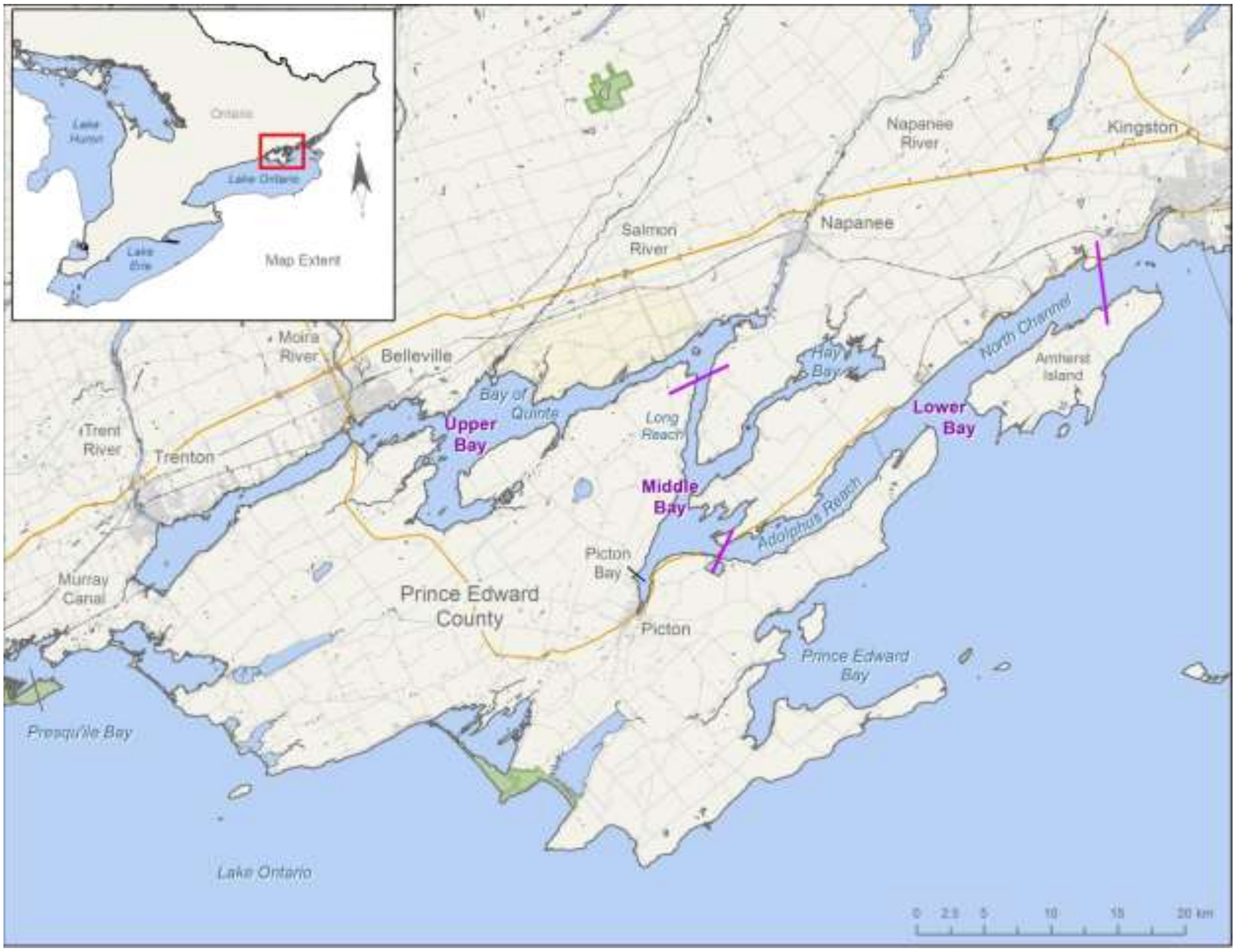

Figure 2. Map of the Bay of Quinte, Lake Ontario.

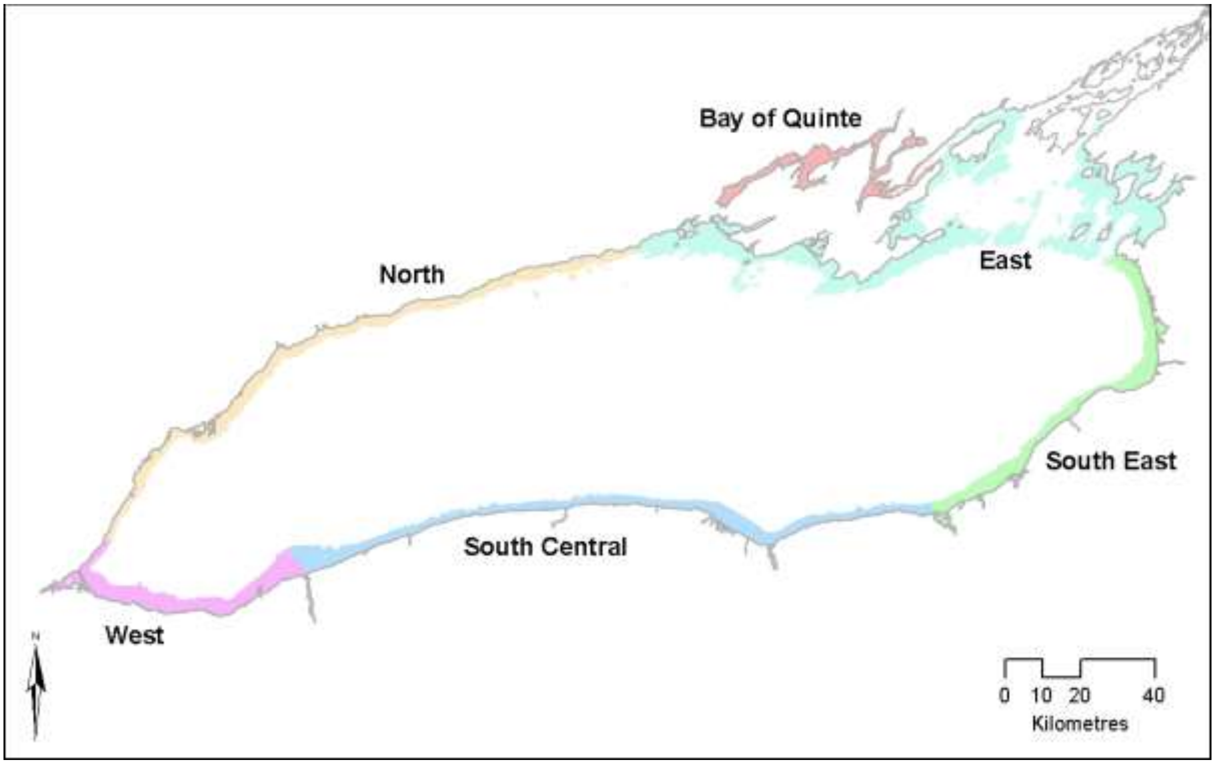

Figure 3. Location of coastal zones of Lake Ontario which were used to compare the physical characteristics and extent of near shore habitat in Bay of Quinte with other coastal areas (see Table 1 for source). The 0-20 m depth area is shown.

APPENDIX 1

Appendix 1a. Description and examples of the three primary (uniqueness, aggregation, and fitness) and two qualifier (resilience and naturalness) EBSA criteria in marine ecosystems (unshaded) and in the Bay of Quinte (shaded rows).The criteria are identified for a number of ecological funtions: spawning,nursery, feeding, migration and refugia. Examples from the Bay of Quinte are described in more detail in the text.

		Uniqueness	**Aggregation**	**Fitness Consequences**	**Resilience**	**Naturalness**
Spawning /Breeding	**High**	Only one suitable spawning site known to exist for a species; Site used for spawning by many species	High percentage of total population use the area; Noteworthy percentage of many species use the area	Semelparous, so loss of one spawning event poses risk of loss of lineage; or a single site's quality or quantity of breeding habitat greatly affects the productivity of the population.		
	Low	Suitable spawning sites are widespread over a large number of at least partially disjunct areas	Only a small portion of the population(s) is present at any given time.	Continuous reproduction throughout the year, over many years. Reproduction occurs at many sites. A single site's quality or quantity of breeding habitat has little effect on the productivity of the population		
	Bay of Quinte	Extensive coastal wetlands used by many phytophilic species; historically, shoal-spawning of Lake Sturgeon at Amherst Island- identified by commercial fisherman in the past[2] and OMNR employee[1]; remnant Lake Herring population[1]	Walleye spawing in rivers, shoals[1;]	Walleye in Bay of Quinte contribute disproportionately to the population in Lake Ontario[1]; Lake Whitefish and Lake Herring spawning shoals		Extensive coastal wetlands, with predominantly native species of plants [1]

		Uniqueness	Aggregation	Fitness Consequences	Resilience	Naturalness
Nursery/ Rearing	**High**	Only a single nursery/ rearing area exists for the species	Larvae/juveniles are found in high concentrations in an area or a number of species use the area as nursery grounds/rearing	Larvae/juveniles have increased survivorship/fitness compared to other areas, especially if for reasons which can be tied to characteristics of the site.		
	Low	Multiple nursery/rearing sites for the species	Larvae/juveniles widespread or found evenly over a large area or single species uses area for nursery/rearing purposes	Larvae/juveniles fitness is comparable to adjacent habitats		
	Bay of Quinte		Larval Whitefish and Lake Herring are resident for 6 -8 weeks in the bay; high productivity and food supply. Nursery habitat for Walleye [1,2]			
Feeding	**High**	Favors the production of a key food source that isn't found in other areas and can't be easily substituted/ Provides a major food item not found elsewhere to a highly specialized consumer/ No alternate area being used by this population or segment of a population	High concentration of prey, both a large biomass and a high productivity/ An intense feeding area for a wide variety of species or for a large proportion of an important population/ For sessile animals, a feeding area where a species occurs at higher densities	Feeding takes place in periods or in a manner that is more critical to an organism's fitness, productivity and/or short-term and long-term population sustainability/ Consumers are known to use the area consistently/ Contribution to annual growth, condition and maturation is great	Production of prey organisms depends on large-scale dynamic mechanisms unlikely to be affected by local events/ Consumers have a varied diet and are attracted to an area to feed on a variety of prey in a complex food web	Introduced or cultured species are not major components of the food web/ Production of food does not depend on man-made structures or processes initiated or sustained by anthropogenic activities.

		Uniqueness	Aggregation	Fitness Consequences	Resilience	Naturalness
	Low	Prey have a wide distribution/ Major consumers known to feed in other areas as well/ Consumers are omnivorous	Prey have a low standing biomass with very low productivity/ Few species use the area/ Species using the area are known to forage in many other locations or very wide areas/ Sessile animals are not abundant	Presence of prey is sporadic and use of the area for feeding is occasional/ Feeding in the area has marginal impacts on growth, condition and maturation	Production of preys dependent on very local irregular small scale processes/ Consumers are highly specialized and the food web is very simple	Energy flow through the food web is channeled through an exotic species/ Human activities have altered the food web by stimulating the production of alternate prey or artificially sustaining the production of top to adjacent habitats
	Bay of Quinte		Important feeding area for St. Lawrence River Muskellunge that follow Lake Whitefish and other prey fishes into the Bay of Quinte in the fall (OMNR)[2]	Seasonal timing of high primary and secondary productivity that makes the Bay of Quinte a prime area for feeding (warms faster and cools later than the lake proper). See also notes for rearing.		Bay of Quinte is a perturbed system, but has high productivity and biodiversity relative to other areas in Lake Ontario.
Migration	**High**	The route is an obligatory passage (e.g. narrow strait, estuary) for a single species, population or life stage. OR The route is travelled by many species or populations.	Most individuals in the population travel along the route. OR Noteworthy percentages of several species use the route	The route itself or its endpoints favour population fitness (reproduction and survival).	Alternate routes represent a much greater cost or risk to migrants.	A disruption to the migration pathway would result in an irrevocable loss of the route. Example: cases where juveniles learn migration routes from adults.

		Uniqueness	Aggregation	Fitness Consequences	Resilience	Naturalness
	Low	The migration is carried out using several routes, which are chosen indiscriminately.	Only a small fraction of a population uses the route.	The migration has no effect on fitness, or the route taken is variable and not constrained by any known factors.	If temporally disrupted, the route could be re-established readily. Example: when navigation is controlled by large-scale processes (sun position, magnetic field).	The migration is carried out by an introduced species and is cued by anthropogenic activities.
	Bay of Quinte		Walleye, Lake Whitefish, Lake Herring, American Eel[1]			
Seasonal Refugia	High	Refuge utilized by a rare, endemic or unusual species or population; refuge utilized by many different populations or species; refuge utilized for an unusual purpose or under unusual conditions.	Refuge contains a high proportion of a single population or species during adverse conditions (e.g. low or high temp); refuge demonstrates greater than average biomass under adverse conditions.	Refuge necessary for survival of the species, population, or individuals (listed in order of significance) using it; survival of individuals within a refuge important for survival of a dependent species or population (e.g. survival of overwintering *Calanus* important for other species); use of refuge coincides with other important life-history events, such as spawning or breeding. Note: more than one refuge may be necessary.	Conditions inside the refuge demonstrate a high level of stability compared to conditions outside the refuge (e.g. limited seasonal or inter-annual variability).	Refuge exists independent of human intervention; refuge not influenced by human activities

		Uniqueness	Aggregation	Fitness Consequences	Resilience	Naturalness
	Low	Refuge utilized by commonly occurring species or populations; evidence of many similarly utilized sites with no evidence of site preference.	Only utilized by a small proportion of a population or species.	Alternate refugia are available, suitably distributed and easily accessible; conditions outside the refugia are not sufficiently adverse to cause mortality.	Conditions inside refuge demonstrate the same level of stability as conditions outside refuge; refuge demonstrates characteristics that increase its susceptibility to human disturbance, e.g. greater sound transmission during winter.	Refuge created or maintained by humans.
	Bay of Quinte		The lower bay may offer thermal refugia in the winter for White Perch, Gizzard Shad and other species [2]			Provincially significant wetlands[1]

Source: 1 - science literature; 2 - expert opinion (OMNR, DFO and others)

Appendix 1b. Description and examples of the three primary (uniqueness, aggregation, and fitness) and two qualifier (resilience and naturalness) EBSA criteria in marine ecosystems (unshaded) and in the Bay of Quinte (shaded).Criteria are described for a number of structural features.

Feature	Uniqueness	Aggregation	Fitness Consequences	Resilience	Naturalness
Tidal mixing zones	Benthic and water column productivity and dynamics important to many species or populations.	Both convergence and divergence, vertically and horizontally. Could define the role of tides in defining biological population distributions.	Productivity can be very locally determined. Key areas for adult feeding.	Degree of temporal stability. The dynamics of the stability could be directly determined.	Dams, runoff, and tidal power facilities can have significant influences
Bay of Quinte	Not applicable				
Convergence zones (e.g. banks on continental shelves)	Convergence zones, and water properties, provide key conditions for limited species	Aggregation of prey and nutrients for production, and minimal dispersal of larvae	Reproductive success related directly to physical dynamics. Key areas for larval growth.	Dynamical system with changing characteristics	
Bay of Quinte	Protected embayment with extensive shallow bathymetry and warm water; provides unique connectivity between the rivers, embayment and Lake Ontario[2]	Aggregation of prey for larval fishes[1,2]	Enhanced survival, growth and reproduction for warm and cool water fishes because of the high productivity[2]	Highly diverse fish community[1]	
Polynyas (open waters zones in sea–ice)	Heat exchange and circulation create unique physical conditions that have direct biological consequences	Planktonic organisms concentrate leading to food chain convergence.	Availability of prey lead to local and variable fitness consequence issues.	Persistence and variability vary. Timing ofappearance and duration would be important characteristics.	Some such features (e.g. hot water from a power plant would look dynamically similar)
Bay of Quinte	Not applicable				
Upwelling zones	Generate locally well-defined oceanographic properties	Can lead to both convergence and divergences. Spatial scale would determine the ecological importance	Has both direct (metabolic) and indirect impacts on ecosystem function. Coupled with uniqueness and aggregation to determine importance.	Highly dynamic, spatially and temporally and hence has potential to be crucial to fitness but unpredictable	Driven primarily by wind-forcing coupled with topography and coastline where human influences can occur.

Feature	Uniqueness	Aggregation	Fitness Consequences	Resilience	Naturalness
Bay of Quinte	Seiche events from Lake Ontario to the lower bay Hay Bay almost daily in the summer (OMNR and anglers[2]); linked to seasonal movements of species such as Lake Whitefish, Herring, Walleye and Lake Trout; unique mixing zone [1]				
Strong topography (e.g. canyons on the continental shelves, fjords)	Canyons can generate locally important circulation that generates habitat conditions unique on the continental shelf	Can lead to both convergence in some zones and divergence in others	Can have both direct and indirect impacts on ecosystem function	Relatively stable (much more so for example than upwelling features)	Benthic habitat can be disrupted by deep sea trawling or oil exploration
Bay of Quinte	Uniqueness related to the Z-shaped bay, and the combination of fluvial and seiche-related water movements[1,2]				
Structural Habitat Features					
Sponge reefs	Extent to which the feature is globally unique	density and size of biotherms	older/larger individuals provide greater population fecundity and community structure	long-lived habitat-forming species, exposed to very little disturbance and therefore unlikely to have resilience	Relatively undisturbed and extremely old. Most reefs are pristine; limited impact from trawling
Bay of Quinte	Limestone shoals for whitefish spawning[1];				
Deep water corals	Geographic scale and species composition of the coral assemblage	density and variety of species	older/larger individuals provide greater population fecundity and community structure	slow growth, deep water habitat and therefore little exposure to disturbance, therefore unlikely to be resilient to disturbance'	undisturbed by virtue of deep location, some areas subject to increased disturbance from trawl fishing
Bay of Quinte	Not applicable				

Feature	Uniqueness	Aggregation	Fitness Consequences	Resilience	Naturalness
Macrophyte beds	Geographic scale and species composition of macrophytes	density and variety of species	older/larger individuals provide greater population fecundity and community structure	annual or perennial species; temporal or spatial stability	presence of exotic species;
Bay of Quinte	Extensive coastal macrophyte beds (emergent and submerged vegetation); hight SAV IBI; high Water Quality Index; low effective fetch[1].		Habitat Suitability; WSA[1]		
Biodiversity					
Presence of endangered or threatened species	Number of rare or endangered species present.	Proportion of the total population present in the area	Degree to which area is important for survival or reproduction of species	Score depends on biology of the species	
Bay of Quinte	Habitat that supports unique populations of Walleye, Lake Sturgeon, Lake Whitefish and Pugnose Shiner [1,2]		Disproportionately important for Walleye, Lake Whitefish and Lake Herring[1]		
Presence of highly diverse or productive communities	Extent to which species or communities are not common elsewhere	Percentage of total populations of species present	Degree to which area is important to the survival or reproduction of many species	temporal occurrence of most species	Number of exotic species present, and proportion of community comprised of exotic species.
Bay of Quinte	Relatively high primary and secondary productivity[1]		Fish community and wetland data (IBI, PPB)[1] confirm high habitat suitability and inferred high fitness consequences	AOC Delisting is evidence of ecosystem resilience[1]	

Source: 1 - science literature; 2 - expert opinion (OMNR, DFO and others)