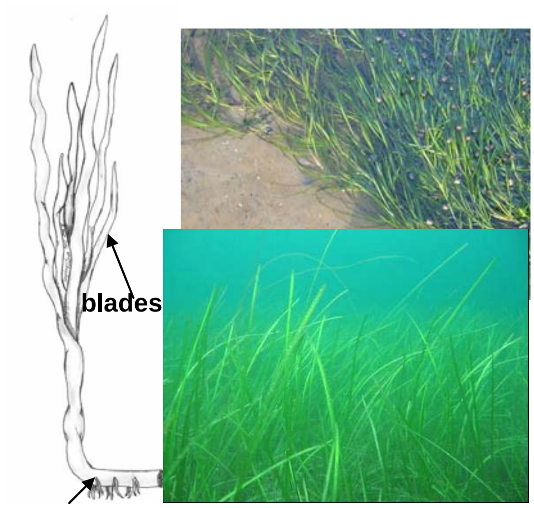
DOES EELGRASS (*Zostera marina*) MEET THE CRITERIA AS AN ECOLOGICALLY SIGNIFICANT SPECIES?



Line drawing by Stephanie Cooper; Photos: Allison Schmidt, Jeff Barrell

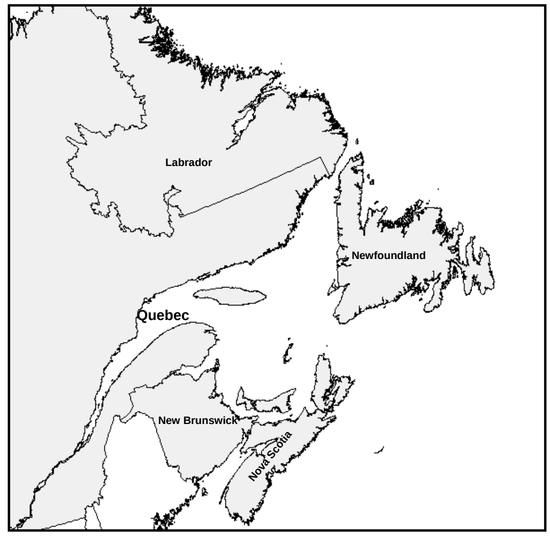


Figure 1: Map of eastern Canada for which eelgrass distribution and abundance was considered.

Context :

Canada's Oceans Act promotes an Ecosystem Approach to the integrated management of human activities. Integrated management plans must include objectives intended to protect the ecosystem. As such, enhanced protection should be provided to species and community properties that are particularly significant to maintaining ecosystem structure and function. The identification of Ecologically Significant Species (ESS) is a tool for calling attention to a species or community property that has particularly high ecological significance. DFO held a workshop in September 2006 to review and develop criteria to differentiate species or properties which are "particularly important" or "significant" with regards to specific ecosystem structure and function.

Eelgrass (Zostera marina L.) is an important primary producer and provides three dimensional structure considered important to biodiversity and productivity. DFO Oceans requested advice on whether eelgrass meets the criteria as an Ecologically Significant Species. A science review of the advisory request was conducted during March 4-5, 2009. The objectives of the meeting were to review the functional role of eelgrass within the estuarine and coastal ecosystem. The review included an assessment of the quantity of the species present, the temporal variation in distribution and abundance, the quality of the structural habitat being provided, and the significance of the structural habitat to the overall ecosystem structure and function. The output from the science review was a science advisory report that drew conclusions on whether eelgrass met the criteria as an ESS. Participants at the review included DFO Science and Oceans, Environment Canada, aboriginal peoples, provincial governments, academia and external experts from the US.

SUMMARY

- Eelgrass (*Zostera marina*) occurs commonly in eastern Canada.
- Under pristine conditions, eelgrass is a persistent and constant habitat feature.
- Loss of eelgrass and other seagrass populations is a worldwide phenomenon largely associated with anthropogenic stresses. Eelgrass populations have been lost in virtually all areas of intense human settlement.
- Eelgrass plays an important role in the physical structuring of the nearshore marine environments by filtering the water column, stabilizing sediment, and buffering shorelines.
- Eelgrass meadows have extremely high levels of primary production, ranking among the most productive ecosystems on the planet.
- Eelgrass adds spatial complexity above and below the substrate creating a three-dimensional habitat that contributes to higher densities and different species compositions than in unstructured habitats, particularly mud/sand flats.
- Numerous species across several phyla (seaweed, invertebrates, fish) utilize the support structures of eelgrass and / or benefit from lower predation rates in vegetated habitat compared to unvegetated areas.
- There are no substitute structuring organisms with the same function as eelgrass that can grow on the sand/mud flats of intertidal and subtidal areas within the salinity ranges occupied by eelgrass. In the absence of eelgrass, these areas would consist of sand/mud flats.
- By being sufficiently abundant and widely distributed, eelgrass often constitutes a dominant habitat feature and has a measurable influence on the overall ecology of adjacent terrestrial and marine ecosystems.
- Eelgrass (*Zostera marina*) in eastern Canada has characteristics which meet the criteria of an Ecologically Significant Species. If the species were to be perturbed severely, the ecological consequences would be substantially greater than an equal perturbation of most other species associated with this community.

INTRODUCTION

The identification of Ecologically Significant Species (ESS) is a tool for calling attention to a species or community property that has particularly high ecological significance in order to facilitate provision of a greater-than-usual degree of risk aversion in management of human activities that may affect such species or community properties.

DFO held a workshop in September 2006 to review and develop criteria to differentiate species or properties which are “particularly important” or “significant” with regards to specific ecosystem structure and function (DFO 2006 a, b). Significance was defined by DFO (2006a) as:

> “Significance refers to the role of a species, community property, area, etc. in the ecosystem, and is used in a relative sense. To identify a species or community property as “significant” is to conclude that if the species or community property

were perturbed severely, the ecological consequences (in space, in time, and/or outward through the food web) would be substantially greater than an equal perturbation of most other species or community properties… The concept of ecologically significant species and community properties applies to the high end of the continuum, where current knowledge indicates that the species or community property has controlling influence over key aspects of ecosystem structure and function."

Species which provide three-dimensional structure important to biodiversity and productivity were considered potential candidates as ESS (DFO 2006a). By definition, structural species create habitat that is used preferentially by other species. This function can result directly from the physical support for other biota or protection for the associated community.

Eelgrass (*Zostera marina* L.) is a common highly productive perennial aquatic plant that can form extensive intertidal and subtidal beds in estuaries and coastal areas. Its function as a habitat structure includes providing cover from predation, reducing local current regimes, and increasing secondary productivity by adding to local habitat complexity and surface area.

In order to consider eelgrass as an Ecologically Significant Species, the following conditions must be met:

a. By its structure, it creates habitat that is used preferentially by other species,
b. It physically support(s) other biota, and provides either settlement substrate or protection for this associated community, and
c. It is abundant enough and sufficiently widely distributed to influence the overall ecology of that habitat.

In addition to the functional role of eelgrass in structuring habitat, it also has an important primary production role in the ecosystem which may qualify it as an ESS under the trophodynamic criteria of DFO (2006b).

ASSESSMENT

The following sections review the evidence for the functional role of eelgrass within the estuarine and coastal ecosystem. The information is drawn from studies in eastern Canada, the eastern US, and throughout the global range of eelgrass.

Biology and environmental requirements of eelgrass

Seagrasses are underwater plants that are usually perennial, with an extensive network of underground roots and rhizomes. The seagrass shoots are characterized by both vegetative foliage leaves and sexually reproductive stems. The flowering shoots can be dislodged by wave action, and distributed by currents over 100 km distant. Seagrasses occur worldwide but only one species is widespread in Atlantic Canada, *Zostera marina* Linnaeus.
Zostera marina Linnaeus, also known as eelgrass, is the dominant seagrass found in coastal and estuarine areas of the western North Atlantic, from the Atlantic coast of Labrador at about 60° N to North Carolina (US) at 35° N. It can form extensive beds over the full range of low intertidal to subtidal (down to 12 m depth in some areas) habitat and from sheltered areas to exposed coasts. Eelgrass occurs predominantly in a mono-culture throughout most of its

distribution but can overlap with widgeon grass (*Ruppia maritima*) in the upper low salinity portions of estuaries in Atlantic Canada.

Zostera marina has a relatively narrow niche as defined by its tolerance for various chemical, biological and physical factors. Eelgrass has an optimal salinity range of 20 to 26 ppt for photosynthesis but it is tolerant of salinity levels of 5 to 35 ppt and freshwater for short periods of time. It grows well over a wide range of temperatures (10 - 25º C) and survives in temperatures from freezing to 35º C. Elevated temperatures can weaken eelgrass and make it more susceptible to disease. It is intolerant of anoxic (<63 µM O_2 plus ≥ 100 µM H_2S) and eutrophic conditions (> 5 to 10 µM NO_3 d^{-1}). Nutrient loading of 30 kg N ha^{-1} yr^{-1} has been associated with losses of 80% to 96% of eelgrass bed area. Eelgrass thrives best in clear water and has a high minimum light requirement for survival (growing season average of 275 - 300 microeinsteins m^{-2} s^{-1} as photosynthetically active radiation). The maximum depth of water colonized by eelgrass is determined by the amount of light reaching the bottom.

Eelgrass grows on unconsolidated (mud to cobble or mixed) bottoms that can be scoured out by currents. It prefers water currents equal to or greater than 16 cm s^{-1}. At sustained high current velocities, eelgrass is unlikely to occur as contiguous beds and at near maximal current conditions for eelgrass (120 to 180 cm s^{-1}), the beds in shallow water areas will often turn into small, raised elliptical patches.

The upper limit of eelgrass on shore may be determined by wave exposure, ice scour and desiccation. Shallow beds exposed to wave action will exhibit variable shape and position over time. Eelgrass beds can be damaged by excessive sediment deposition and erosion. The deeper limit is set primarily by light limitations but can be influenced by sediment movement and / or bioturbation (organisms that disturb the substrate).

“Wasting disease” in the 1930s reduced eelgrass populations along the Atlantic Coast of North America and in Europe by 90% and they did not recover until the 1960s. Wasting disease symptoms are caused by the infection of a marine slime mould-like protist, *Labyrinthula zosterae*. The mechanism of mortality resulting from *L. zosterae* infection appears to be reduced photosynthetic activity. Wasting disease continues to affect eelgrass meadows in North America and Europe with variable degrees of loss, though none to date as catastrophic as the epidemic of the 1930’s.

Spatial distribution of eelgrass in eastern Canada

Eelgrass occurs commonly in eastern Canada where there are suitable conditions. Eelgrass will generally be absent along rocky, high energy coastlines or areas of high turbidity. Individual meadows may be patchy if there is localized erosion and or deposition of sediments, otherwise the beds can be continuous.

The information on eelgrass distribution is based on interpretation of airphotos and satellite images, by aerial surveys and boat surveys, and from local knowledge. In some cases, the information is several decades old. Detectability of eelgrass is affected by tide state, water clarity and season. It was concluded that the distribution and abundance of eelgrass based on these surveys are underestimated.

An estimate of the areal extent of eelgrass in Quebec was derived mainly from an over-flight survey in 1995, augmented by surveys in specific areas in more recent years. Eelgrass beds are geographically distributed throughout the St. Lawrence estuary and the Gulf of St. Lawrence in the Province of Québec. The westernmost eelgrass beds lie in the upper estuary off Les

Prairies near Baie-Saint-Paul. Towards the east, eelgrass beds are scattered all along the Upper, Middle and Lower North Shores, and are present at the tip of the Gaspé Peninsula, in Chaleur Bay and in the waters off the Magdalen Islands. The minimum total estimated areal extent of eelgrass is over 10,000 ha.

The Maritime Wetland Inventory (Canadian Wildlife Service, Environment Canada) provides an estimate of the areal extent of salt marshes and wetlands in the Maritime Provinces. The information is based on interpretation of colour air photos acquired in 1974-1978 for Nova Scotia, 1974 for Prince Edward Island, and 1980-1985 for New Brunswick. These air photos were not taken to maximize their suitability for identifying intertidal and subtidal habitat and hence there are limitations with these data for mapping eelgrass. The distribution of eelgrass in estuaries and lagoons in New Brunswick is primarily along the Gulf of St. Lawrence. In Nova Scotia the distribution is along both the Gulf of St. Lawrence coastline and the Atlantic coastline. Eelgrass is distributed along the entire coastline of Prince Edward Island. The distribution of eelgrass in the Bay of Fundy is very limited and restricted to the outer portion of the bay. It was estimated that there were about 20,000 ha of eelgrass in each of New Brunswick and Nova Scotia, and over 30,000 ha in Prince Edward Island at the time of photo acquisition.

In Newfoundland, eelgrass is distributed around the entire island with the greatest abundance on the southwest coast which has more suitable habitat for eelgrass. Most of the surveys are only sufficient for delimiting presence but not for estimating abundance. It has been identified as far north as Nain (Labrador) and is extensively distributed in Lake Melville. Distribution of eelgrass in Newfoundland is constrained by coastal features and the extent of ice scour. There are no estimates of areal coverage in Newfoundland, except in a small number of individual embayments (e.g. Newman Sound). There are several large beds on the west coast of the island.

Temporal variation in abundance

Under pristine conditions, eelgrass is a persistent and constant habitat feature. Well documented studies demonstrate that eelgrass meadows will persist for decades and even millennia. In higher energy environments, position, shape and cover may vary over time, but the beds will persist on a baywide scale.

Loss of seagrass populations has been a worldwide phenomenon largely associated with anthropogenic stresses. Eelgrass populations have been lost in virtually all areas of intense human settlement. On the east coast of the U.S., loss of eelgrass as of 2003 is estimated to be in the order of 20% north of Cape Cod, Massachusetts, while as much as 65% of eelgrass has been lost south of Cape Cod where the coast is more heavily populated and industrialized.

In the estuary and the northwestern part of the Gulf of St. Lawrence, eelgrass beds seem to have remained stable or expanded over the last 20 years. In the southwestern sector of the Manicouagan peninsula (Quebec) eelgrass beds have expanded; in 1986, eelgrass occupied 384 ha compared to the 1,456 ha in 2004.

Eelgrass declines in the recent decade have been reported in the southern Gulf of St. Lawrence and on the Atlantic coast of Nova Scotia. There is limited information on coastwide trends but in some locations of the Maritime Provinces inter-annual (2 – 20+ years) declines of 30% to 95% were reported. Possible reasons for these declines in eelgrass distribution include eutrophication, disturbance by invasive green crab (*Carcinus maenas*), human activities, and environmental changes. Throughout Prince Edward Island, eutrophication and nutrient enrichment of bays and estuaries is contributing to reductions in eelgrass distribution and threatening its persistence.

In Newfoundland, there appears to be a general increase in eelgrass abundance in the last decade based on local knowledge. The increases in some locations may be due to improved conditions for eelgrass (milder temperatures, more favorable sea ice conditions).

Preferential use and function of eelgrass habitat by other aquatic organisms

The information on species diversity and dynamics within eelgrass habitat are mostly based on observations from intertidal and shallow subtidal eelgrass environments because deep water eelgrass communities are more difficult to study.

There are more than 20 obligate species of seaweed adapted to eelgrass in Atlantic Canada, including six macroscopic species. These seaweeds require eelgrass to complete their life cycle, using the blades of the plant as support structures. A large number of other non-obligate seaweed species are most abundant when found in association with eelgrass, using the leaves for supporting structure or becoming entwined with the plant.

The settlement of macroscopic epiphytic algae on the blades of eelgrass creates another level of habitat complexity. The most common macroscopic algae found on eelgrass leaves in Atlantic Canada are the filamentous algae (e.g. *Ulothrix* spp., *Pilayella littoralis, Ecotocarpus* spp., and *Polysiphonia* spp.) which grow in dense or highly branched clumps providing refuge and food to small and highly mobile herbivores such as amphipods.

Invertebrates

There are several invertebrate species which are / were strongly dependent on eelgrass. The spat of bay scallop (*Argopecten irradiants)* in the eastern US settle exclusively on blades of eelgrass. The eelgrass limpet (*Lottia alveus*) was apparently restricted to and ate only eelgrass. It is considered extinct as it has not been reported since the eelgrass crash of the 1930s; the last specimen collected was in 1929 from Bar Harbor (Maine, USA).

The invertebrate communities associated with eelgrass are routinely more abundant and of different composition compared to those in unstructured bottom types (sand, mud flats) and in some instances to those in habitats with structure. Specific examples of this are found in studies from Manicouagan (Quebec) and numerous estuaries in NS and NB.

A diverse community of invertebrate species is closely associated with eelgrass. The species types include attached epifauna (for ex. hydrozoans, tube-dwelling polychaetes), mobile epifauna associated with eelgrass leaves (for ex. snails, amphipods), organisms living in the sediments around the plants (benthic infauna, for ex. polychaetes, amphipods), fauna which are free moving on top of substrate (epibenthic fauna, for ex. gastropods, crabs), and pelagic species located in the water column within the eelgrass fronds (for ex. many zooplankton species). The invertebrate community associated with eelgrass differs from that found on other substrate types. The differences are greatest between eelgrass and mud/sand habitats. The mobile epifauna community also differs between eelgrass and mud flats but the differences are less important between eelgrass and other structured habitat. Epifaunal invertebrates that live on eelgrass blades are thought to feed primarily on the epiphytes growing on the blades, as well as detrital and living eelgrass tissue.

Preferential use of eelgrass habitat has been inferred from the observations of higher densities, biomass, and differing species composition of invertebrates in eelgrass compared to other unstructured and structured habitats. Eelgrass habitat has been shown to reduce mortality from predation and as a result, the higher densities observed may also be explained by differential survival in the different habitat types of the settling or colonizing organisms.

Fish

There are no known eelgrass obligate fish species although the northern pipefish (*Syngnathus fuscus* Storer) is commonly associated with eelgrass habitat in the Maritime Provinces during some phases of its life cycle.

Eelgrass habitat has been shown to support higher densities and greater diversity of fishes in comparison to unvegetated sand or mud bottoms. Specific examples of this are from studies in the Magdalen Islands, Newfoundland, Nova Scotia and in Kouchibouguac (NB). Several mechanisms may explain the high abundance of fish in seagrass habitats. Among these, refuge from predation, enhanced food resources and habitat structural complexity are generally considered most important.

Eelgrass can serve as important spawning and nursery habitat. Some species of fish (e.g. Atlantic cod in northeast Newfoundland) preferentially settle in eelgrass beds while others actively migrate into the habitat post-settlement. Predation rates have been shown to be lower in eelgrass beds than unvegetated substrates due to reduced predator foraging effectiveness in vegetated areas. Predation risk on age-0 cod is higher in fragmented eelgrass habitats than in larger continuous eelgrass habitats, likely due to increased predator foraging efficiency along fragmented edges. Although eelgrass itself is rarely consumed by fishes, the rich fauna associated with eelgrass habitats are potential prey for many fish species. In several temperate fish species (Atlantic cod, cunner, tautog) higher juvenile growth rates have been reported in eelgrass habitat.

Role of eelgrass in the overall ecology of the aquatic habitat

In the salinity range occupied by eelgrass, there are no alternative organisms that provide habitat structure by growing on the sand/mud flats of intertidal and subtidal areas. In the absence of eelgrass, the habitat would consist of sand/mud flats.

Eelgrass plays an important role in the physical structuring of the nearshore marine environment by filtering the water column, stabilizing sediment, and buffering shorelines. Eelgrass beds attenuate wave energy and change the level of turbulence in the water, the effect being more pronounced with increasing density of eelgrass beds. As currents are slowed, sediment particles fall out of suspension resulting in sediment filtration, trapping and stabilization. These same hydrodynamic properties also enable planktonic larvae to settle in eelgrass. Eelgrass beds are known for their ability to stabilize coastal sediments, particularly in low or moderate current regimes. On a larger scale, this action may serve to buffer entire shorelines from erosion. By promoting the deposition of suspended sediments, light availability in the water column can be enhanced.

Eelgrass has extremely high levels of primary production, which is an important trophodynamic (food web) feature. Eelgrass habitats rank among the most productive ecosystems on earth. The high primary productivity is due both to the rapid turnover of eelgrass leaves themselves and epiphytic algae on leaf surfaces. The primary productivity releases oxygen into the water column as well as in the sediments which counters the high oxygen consumption in this ecosystem.

Eelgrass forms the basis of coastal foodwebs and contributes to the broad scale nutrient cycle. Epiphytes on eelgrass serve as a primary food source for a variety of invertebrate species and contribute to the high invertebrate densities in eelgrass beds. Eelgrass provides nutrients directly to a small number of invertebrate species which feed on living eelgrass blades. Eelgrass tissue is most commonly consumed via detrital pathways. Eelgrass fragments and particles (green, senescent or dead) are rapidly utilized by a host of bacteria, fungi and protozoans. Eelgrass-derived detritus is also transported considerable distances by waves and currents, where it provides a critical source of organic matter in extremely food-limited environments. Thus eelgrass detritus provides habitat structure and trophic subsidy to unvegetated nearshore and offshore ecosystems. Much excess organic carbon produced in eelgrass beds is buried in the sediments, thus contributing to carbon sequestration.

The organisms which live on eelgrass blades and among the root-rhizome system are important in the diets of other organisms of higher trophic levels.

CONCLUSIONS

In order to consider eelgrass as an Ecologically Significant Species, the following conditions must be met:

a) <u>By its structure, it creates habitat that is used preferentially by other species.</u>

There are no substitute structuring organisms with the same function as eelgrass that can grow on the sand/mud flats of intertidal and sudtidal areas within the salinity ranges occupied by eelgrass. There are a large number of obligate species of seaweed adapted to eelgrass, using the blades of the plant as support structures. The settlement of macroscopic epiphytic algae on the blades of eelgrass creates another level of habitat complexity. Eelgrass adds spatial complexity above and below the substrate creating a three-dimensional habitat that contributes to higher densities and different species compositions of invertebrate and fish communities than in adjacent unstructured habitat, particularly mud/sand flats. Higher densities of organisms in eelgrass habitat relative to adjacent habitat types, particularly for mobile organisms, can be inferred as the result of directed preference for eelgrass habitat.

b) <u>It physically support(s) other biota, and provides either settlement substrate or protection for this associated community, and</u>

Numerous species across several phyla (seaweed, invertebrates, fish) utilize the support structures of eelgrass. Numerous organisms with drifting planktonic stages, including mollusks and crustaceans, use eelgrass as a settlement substrate. Lower predation rates due to reduced predator foraging effectiveness in vegetated habitat compared to unvegetated areas has been shown for fish and invertebrate species.

c) <u>It is abundant enough and sufficiently widely distributed to influence the overall ecology of that habitat.</u>

Eelgrass occurs commonly in eastern Canada where there are suitable conditions. Eelgrass will generally be absent along rocky, high energy coastlines or areas of high turbidity. Individual meadows may be patchy if there is localized erosion and or deposition of sediments, otherwise the beds are continuous. Eelgrass beds in eastern Canada have been measured to be as large as 50 km^2. Distances among eelgrass beds in adjacent bays can vary from a few km to several hundred km. In certain bays, eelgrass beds may represent a majority of the area, covering over 90% of the bottom. At the spatial scale of a bay, eelgrass is often the dominant habitat feature which influences the overall ecology of the bay, as evidenced from the descriptions above. In eastern Canada, eelgrass is sufficiently abundant and widely distributed to have a measurable influence on the overall ecology of the estuaries, bays and adjacent ecosystems. When significant eelgrass areas are lost, and particularly if the loss is due to anthropogenic factors, they can be extremely difficult to reestablish, even with interventions (transplants, seeding).

Based on these considerations, it is concluded that eelgrass (*Zostera marina*) in eastern Canada has characteristics which meet the criteria of an Ecologically Significant Species. As such, if the species were to be perturbed severely, the ecological consequences would be substantially greater than an equal perturbation of most other species associated with this community. Based on current knowledge, eelgrass, where it presently exists, can have controlling influence over key aspects of the nearshore marine ecosystem structure and function.

OTHER CONSIDERATIONS

Migratory aquatic birds

Eelgrass is an important component of the diet of several species of migratory aquatic birds. It is particularly important to Atlantic Brant (*Branta bernicla hrota*) in eastern North America which is known to feed, where possible, almost exclusively on eelgrass. The wintering and staging areas reflect the distribution of eelgrass which contributes largely to over-winter survival and serves as fuel for their long migrations. The importance of eelgrass to other waterfowl including Canada Goose, American Black Duck, Common Goldeneye and Barrow's Goldeneye has long been recognized. Historical evidence suggests that if eelgrass declines were to become widespread there would be major impacts on waterfowl feeding behaviour, migration patterns and over-winter survival.

Uncertainties

The information on eelgrass distribution is based on interpretation of airphotos and satellite images, by aerial surveys, boat surveys and from local knowledge. In some cases, this information is several decades old. As well, the accuracy of some of these methods has rarely been quantified. Detectability of eelgrass is affected by tidal state, water clarity and season. It was concluded that the distribution and abundance of eelgrass based on these surveys are underestimated.

Due to the uncertainties of eelgrass distribution, there is little information on spatial continuity of eelgrass as a habitat feature. The interpretation of the fragmented distribution of eelgrass along scales ranging from coastlines (100s km) down to bays (10 km or less) may be exaggerated by the incomplete information. If eelgrass has a more contiguous distribution, its importance as a habitat feature may be more substantive than would otherwise be interpreted. The spatial scale of ecological processes in eelgrass communities is not well known.

There is limited information on temporal variation in eelgrass distribution and abundance, on time scales of months, years, and decades in eastern Canada. Persistence of eelgrass beds over decades and centuries has been demonstrated elsewhere in the species range and under appropriate conditions the same persistence feature could be expected in eastern Canada.

Most of the factors contributing to eelgrass declines worldwide are anthropogenic and seemingly well understood. But the variability in eelgrass bed structure and size associated with natural events (such as climate variation) and anthropogenic factors in eastern Canada is not well studied. In addition, cumulative impacts and interactions of multiple stressors are poorly understood. Incorporating eelgrass as an ESS in integrated management plans still requires the definition of specific operational conservation objectives and reference points for the species.

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