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Assessment of nearshore features in the Northern Shelf Bioregion against criteria for determining Ecologically and Biologically Significant Areas (EBSAs)

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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.

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ABSTRACT

Canada is committed to maintaining biological diversity and productivity in the marine environment under the *Oceans Act* (Government of Canada 1997). Identifying Ecologically and Biologically Significant Areas (EBSAs) is a key component of this commitment. Fisheries and Oceans (DFO) and the Convention on Biological Diversity (CBD) have developed guidelines and eight combined criteria to identify EBSAs. In 2006, EBSAs were identified in the Northern Shelf Bioregion (NSB) using a two-phase expert-driven approach. In response to a science advice request from Oceans Sector and to address a nearshore geographical gap in the previous process, we assess five nearshore features (canopy-forming kelp forests, eelgrass meadows, estuaries, surfgrass meadows, and high current tidal passages) against the CBD and DFO EBSA criteria. We also summarize the available spatial datasets for each feature, outline feature condition and trends, and note species of particular ecological importance that inhabit the features. Upon assessment of the eight combined DFO and CBD EBSA criteria, there is scientific support to designate canopy-forming kelp forests, eelgrass meadows, and estuaries as nearshore EBSAs. There was insufficient evidence to designate surfgrass meadows as nearshore EBSAs at this time. Similarly, there is not enough spatial or biological information to designate all high tidal current passages in the NSB as nearshore EBSAs. However, three specific high tidal current areas with associated biological information do have strong support for EBSA designation: Hoeya Head Sill, Nakwakto Rapids, and the waters around Stubbs Island. The five features considered here are an initial assessment of nearshore features and are not the only potential nearshore EBSAs in the NSB. Future work in nearshore EBSA identification should consider other nearshore biogenic or physical features against the EBSA criteria such as clam beds, mussel beds, and rocky reefs.

1. INTRODUCTION

1.1. CONTEXT

The identification of Ecologically and Biologically Significant Areas (EBSAs) is a step towards meeting Canada's commitments under the Oceans Act (Government of Canada 1997), which provides the legislative framework for an integrated ecosystem approach to management in Canada's oceans. EBSA identification is also a commitment by Canada as a signatory on the Convention of Biological Diversity (CBD). Canada was one of the first CBD signatory countries to develop criteria and guidance for identifying EBSAs (DFO 2004, 2011a), and has also endorsed the scientific criteria used by the CBD for identifying EBSAs[1] (CBD 2008). DFO's science advice recommends identifying EBSAs as a first step to planning networks of marine protected areas (DFO 2010), in accordance with the CBD (2008). This approach was re-emphasized in Canada's National Framework for Canada's Network of Marine Protected Areas (MPAs) (Government of Canada 2011). EBSA identification is an important input into the ongoing MPA network planning process in the Northern Shelf Bioregion (NSB) following guidance outlined in the Canada-British Columbia (BC) MPA Network Strategy (2014). The integration of EBSAs into the network is a key strategy and this work will provide the Marine Protected Area Network Technical Team (MPATT[2]) guidance for the ongoing MPA network planning process in the NSB.

1.2. BACKGROUND

1.2.1. Defining an EBSA

An EBSA is defined as an area of especially high ecological or biological significance where greater risk aversion is required in the management of activities (DFO 2004). Within the EBSA boundary, perturbations are also expected to cause greater ecological consequences than in surrounding areas exposed to comparable perturbations. Similar to the DFO definition, CBD (2008) defines an EBSA as an area that is important for the healthy functioning of our oceans and the services they provide.

1.2.2. EBSA Identification Criteria

Scientific criteria to identify EBSAs have been established at the national (DFO 2004) and international (CBD 2008) levels (Box 1 & 2 respectively). The DFO and CBD criteria overlap (Table 1), and it is generally accepted that similar areas will be identified by following either set of criteria (DFO 2012; Gregr et al. 2012; Westhead et al. 2013). The approach in Ban et al. (2016), which incorporates both the DFO and the CBD criteria, is used here to identify nearshore habitat features that qualify as EBSAs. DFO science advice (DFO 2004) states that features or areas that rank High for one or more of uniqueness, fitness consequences, or aggregation can be designated as an EBSA. A feature or area that ranks above average (Medium or High) across multiple criteria also meets the EBSA criteria (DFO 2004).

[1] The Convention on Biological Diversity defines EBSAs as Ecologically or Biologically Significant Marine Areas but we will refer to them as Ecologically and Biologically Significant Areas to keep consistent with DFO language.

[2] MPATT is the technical team responsible for the design and implementation of the MPA network planning process in the NSB, with representatives from the federal government, the province of British Columbia and 16 partner First Nations.

EBSAs can be identified based on single features (e.g., spawning areas for a single species, or aggregations of species), or multiple features (e.g., areas of high diversity, productivity, or overlap of single-feature EBSAs). In the Pacific Region, single-feature or taxon-specific EBSAs have been referred to as “Important Areas” (IAs) (Clarke and Jamieson 2006a; Levesque and Jamieson 2015).

Box 1. Summary of the DFO (2004) EBSA criteria, reproduced from Hastings et al. (2014)

1. Uniqueness

- The area contains unique, rare, or distinct features.

2. Aggregation

- Significant numbers of a species are found in the area during some period of the year.
- Significant numbers of a species use the area for a life history function.
- A structural feature or ecological process is observed in high density in the area.

3. Fitness Consequences

- The life history activities of a species or population in the area strongly affect its fitness.

4. Resilience

- The habitat structures or species present in the area are highly sensitive, easily perturbed, and/or slow to recover.

5. Naturalness

- The area is relatively pristine, with little to no evidence of human influence.

Box 2. Summary of the CBD (2008) criteria, reproduced from Hastings et al. (2014)

1. Uniqueness or rarity
   - A unique, rare, or endemic species, population, or community is present.
   - A unique, rare, or distinct habitat or ecosystem is present.
   - A unique or unusual geomorphological or oceanographic feature is present.
2. Special importance for life-history stages of species
   - The area is required for a population to survive and thrive (e.g., breeding or nursery grounds, spawning areas, migratory species habitat).
3. Importance for threatened, endangered or declining species and/or habitats
   - The area contains habitat that is critical for the survival and recovery of endangered, threatened, or declining species.
   - Significant assemblages of endangered, threatened, or declining species are found in the area.
4. Vulnerability, fragility, sensitivity, or slow recovery
   - The area contains a high proportion of sensitive habitats, biotopes, or species that are especially susceptible to degradation or depletion, and/or are slow to recover.
5. Biological productivity
   - The area contains species, populations, or communities with comparatively higher natural biological productivity.
6. Biological diversity
   - The area contains comparatively higher diversity of ecosystems, habitats, communities, or species.
   - Comparatively higher genetic diversity is observed in the area.
7. Naturalness
   - Exhibits a comparatively higher degree of naturalness resulting from little to no anthropogenic pressure.

Table 1. Overlap between DFO and CBD criteria as indicated in Westhead et al. (2013), Hastings et al. (2014) and Ban et al. (2016). Shading indicates overlap between two criteria.

CBD (2008)	DFO (2004)				
	Uniqueness	Aggregation	Fitness Consequences	Resilience	Naturalness
Uniqueness or Rarity	X				
Special Importance for life history stages of species		X	X		
Importance for threatened, endangered or declining species and/or habitats		X	X		
Vulnerability, fragility, sensitivity, or slow recovery				X	
Biological productivity		X			
Biological diversity					
Naturalness					X

1.2.3. EBSA management

Areas identified as EBSAs do not automatically trigger new management measures. However, EBSAs are considered special natural areas and are afforded an increased measure of risk aversion in marine spatial management of human activities (DFO 2004, 2011a). The need for management, and the type of management action required to conserve or protect an EBSA, is determined by the ecological characteristics of the EBSA, including the reason it was designated as an EBSA, the type and extent of human activities occurring in or adjacent to it, and how the ecological components and the stressors associated with the human activity interact. A first step in EBSA process is to identify features or areas that meet the EBSA criteria, followed by compiling spatial information to delineate the EBSAs.

1.2.4. Previous EBSA processes in the Northern Shelf Bioregion

EBSAs in the NSB (Figure 1) were identified in 2006 (Clarke and Jamieson 2006a, 2006b) and reviewed in a Canadian Science Advisory Secretariat (CSAS) Regional Peer Review Process in February 2012 (DFO 2013). However, this process did not include a comprehensive analysis of nearshore areas (defined as 0.25 km from shore, DFO 2013). Consequently, DFO Oceans Sector of the Ecosystems Management Branch requested that DFO Science provide advice regarding nearshore areas in the NSB that meet the EBSA criteria.

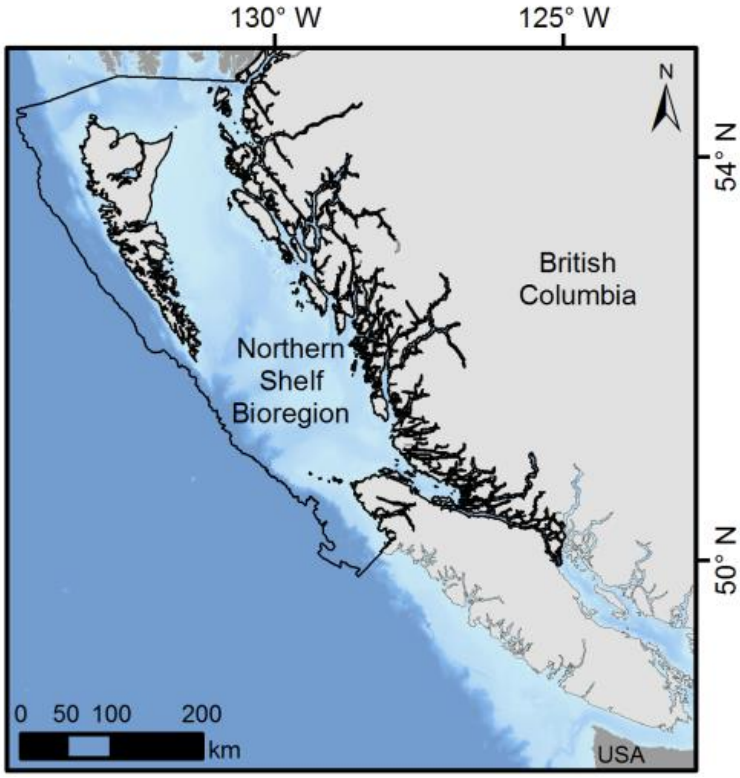

Figure 1. Extent of the Northern Shelf Bioregion (NSB) in British Columbia.

Gregr et al. (2012) defined nearshore as shelf areas shallower than 50 m. However, a depth-based measure includes shallow banks far from shore, and omits deep regions close to shore (e.g., in fjords). For this analysis, we generally follow the nearshore definition described in Rubidge et al. (2018) as areas shallower than 20 m and less than 2 km from shore, plus all semi-enclosed waters (bays, inlets and fjords).

This project assesses five nearshore features (canopy forming kelp forests, eelgrass meadows, estuaries, surfgrass meadows, and high current tidal passages) against the established EBSA criteria. These five features were selected as a preliminary set of potential nearshore EBSAs because they have recognized ecological importance but have not been formally assessed against the EBSA criteria in Pacific Region. Marine plants, including eelgrass meadows and kelp beds, were identified as EBSAs in Maritimes Region (Kenchington 2014); eelgrass was identified as an Ecologically Significant Species (ESS[3]) in Gulf Region (DFO 2009); and kelp, eelgrass, and surfgrass were identified as conservation priorities in the NSB MPA network process (DFO 2017). In addition, River Mouths and Estuaries were identified as EBSAs in the original EBSA process in the NSB (Clarke and Jamieson 2006b) but were not formally assessed against the CBD criteria and were not mapped.

The methods used here for assessing EBSAs follow Ban et al. (2016), where the DFO and EBSA criteria were merged into 8 criteria based on conceptual overlap (see Table 1, Box 1 & 2 for definitions and a summary of the overlap). The Ban et al. (2016) approach was reviewed and

[3] Species that have particularly high ecological importance and warrant special management measures, such as keystone and other highly influential predators, key forage species, nutrient importing and exporting species, and habitat-forming species (Rice 2006, DFO 2007a).

approved through a CSAS Regional Peer Review process in February 2015 (DFO 2016) as a defensible approach for identifying EBSAs. ESSs and conservation priorities identified for the MPA network in the NSB (DFO 2017; Gale et al. 2019; ESSs are considered as those receiving a "strong fit" score for criterion 1.2 in Gale et al. 2019) are also incorporated into this EBSA assessment via known habitat linkages with the five nearshore features assessed. These linkages identify the importance of these habitats to ecologically important species.

The combined EBSA criteria are:

- Uniqueness;
- Special importance for life history stages of species;
- Importance for threatened, endangered or declining species;
- Vulnerability;
- Productivity;
- Biodiversity;
- Naturalness;
- Aggregation

The specific objectives of this report are to:

1. Describe the spatial distribution and associated species[4] of each assessed nearshore feature and include maps, where possible.
2. Provide the rationale and supporting evidence to determine if the assessed nearshore features meet the DFO/CBD EBSA criteria.

By providing a general, coastwide assessment of the ecological and biological significance of the five nearshore features considered here, this report covers the first step in the EBSA process by identifying preliminary nearshore areas that meet the EBSA criteria.

It is important to note that the five features considered here are just an initial assessment of nearshore features and these are not the only potential nearshore EBSAs. Multiple other nearshore biogenic or physical features can be assessed in the future (e.g., clam beds, mussel beds, rocky reefs).

2. METHODS

Following Ban et al. (2016), each feature was assessed against the combined EBSA criteria (refer to Box 1 & 2 for criteria definitions). All criteria for EBSA designation are relative to the surrounding area, which includes the seabed and water column around the feature being assessed. "Feature" refers to the biological structures created by species (e.g., canopy-forming kelp forest) or those created by the physical characteristics of the area (e.g., rocky reef, estuary, high tidal current passage). The EBSA criteria were applied to each feature as follows:

Uniqueness or rarity: This criterion was applied to the feature itself, not to the species that occupy it.

[4] Only species identified as MPA network conservation priorities (which includes ESSs; DFO 2017, Gale et al. 2019) were included in the habitat association tables.

Special importance for life-history stages of species: This criterion is focused on the species that use the feature for specific life history stages.

Importance for threatened, endangered or declining species and/or habitats: This criterion was applied to both the features themselves and the species that inhabit them.

Vulnerability, fragility, sensitivity, or slow recovery: This criterion was applied to the biological components of the feature.

Biological productivity: This criterion was assessed by examining the relative productivity in the vicinity of the feature.

Biological diversity: This criterion was assessed by examining the relative biodiversity within the feature (e.g., the number of species that use the feature as habitat)

Naturalness: This criterion was applied based on the state of the feature being assessed. In all cases, the features in this assessment are found throughout the study area and therefore experience a range of human impacts. An analysis specifically examining the distribution of human impacts across the NSB is needed to identify areas with higher naturalness.

Aggregation: This criterion is related to life history stage and biological productivity, and was applied to both the feature itself, and the species that occupy it.

2.1. CANOPY FORMING KELPS

Figure 2. Nereocystis luetkeana *on Louise Island, Haida Gwaii. (photo credit: Sharon Jeffery)*

2.1.1. Introduction

Two species of canopy-forming kelp predominate along the eastern North Pacific coast: the perennial *Macrocystis pyrifera* (Giant Kelp), and the annual *Nereocystis luetkeana* (Bull Kelp). Large patches of Giant and/or Bull Kelp visible at the surface are often called “kelp forests”, and are the focus of this assessment. However, there are many other genera of kelp (e.g., *Laminaria*, *Alaria*, *Pterygophora*) that create mid-water canopies with potentially similar ecological importance. Mid-water kelps should therefore be a priority in future assessments of this feature. Distributed on rocky and mixed substrates in neritic waters (typically to 20 m), kelp forests rank among the most productive ecosystems in the world (Mann 1973; DFO 2009). These forests provide a variety of important ecosystem services, including the creation of coastal habitat (Markel 2011; Markel and Shurin 2015), carbon sequestration (Wilmers et al. 2012), and shoreline protection (Tallis et al. 2012). Both species have been identified as ESSs and as conservation priorities for the MPA network in the NSB (DFO 2017).

2.1.2. Distribution

Bull Kelp and Giant Kelp are found from Alaska to Mexico (Druehl 2001) and are broadly distributed in BC. Bull Kelp tends to prefer moderate to higher energy waters, while Giant Kelp prefers waters of moderate to low energy. Mixed stands are not uncommon in BC, with Bull Kelp often observed forming a fringe in the higher energy zone around Giant Kelp beds closer to shore (E. Gregr, J. Lessard, and S. Jeffery, pers. obs.[5]). Kelp forests are also often observed on suitable substrate in shallow areas further from shore.

In the Pacific Northwest, the distribution of canopy kelps is influenced by bottom type, sunlight, temperature, water motion, salinity, sedimentation, and nutrient levels (Druehl 1978, 2001; Dayton 1985; Springer et al. 2007). These factors have also been shown to influence kelp distributions in other parts of the world (Bekkby et al. 2009; Gorman et al. 2013; Méléder et al. 2010). Required habitat features include hard, stable substrate to provide a strong attachment point, adequate sunlight at all life history stages (Dayton 1985), and water motion.

Water motion, particularly through wave action, plays an important role in the observed distribution of canopy kelps because of its ability to dislodge kelp from its substrate (Springer et al. 2007). High wave energy is thus regularly identified as a significant factor in restricting kelp distribution (e.g., Bekkby et al. 2009; Cavanaugh et al. 2010; Pedersen et al. 2012; Gorman et al. 2013; Gregr et al. 2018). Lessard et al. (2007) described an empirically derived optimal exposure for kelp using fetch as a proxy. Additionally, although excessive wave action may be responsible for dislodging plants, less disruptive water movement likely improves habitat quality by circulating nutrient-rich waters (Gregr et al. 2018).

In California, spring growth of Giant Kelp has been negatively correlated with sea surface temperature (SST) (e.g., Krumhansl et al. 2016). Sea surface temperature has been interpreted as a proxy for nutrient availability (Cavanaugh et al. 2010) as cold, upwelled waters are also typically nutrient rich. However, temperature may also be physiologically limiting for canopy kelp. Springer et al. (2007) reported an upper thermal limit for Bull Kelp, and Buschmann et al. (2004) reported improved early growth of Giant Kelp at lower temperatures.

Although not well studied, salinity also affects kelp distribution, as few kelp species can tolerate low salinities (Dayton 1985). Gregr et al. (2017) found salinity to be an important predictor of kelp habitat distribution in sounds with significant freshwater input, and identified likely interactions between salinity and exposure. There is also evidence of a positive correlation between salinity and Giant Kelp spore production (Buschmann et al. 2004).

Kelp distributions are also strongly influenced by grazing predators, particularly sea urchins that are able to transform a kelp forest into an urchin barren when they occur at high abundance (Watson and Estes 2011; Lee et al. 2016). Because of this well-documented trophic interaction (e.g., Estes and Palmisano 1974), the potential for kelp to be dislodged in storms, and their annual (Bull Kelp) and perennial (Giant Kelp) life histories, the distinction between potential habitat (where kelp could be) and realised habitat (where they are currently observed) is important when mapping distributions for spatial planning. The distribution of canopy-forming kelp, particularly in terms of depth and canopy extent, is strongly influenced by the presence of Sea Otters (Estes and Palmisano 1974; Watson and Estes 2011). In the absence of Sea Otters, the distribution of canopy-forming kelps is reduced by sea urchin grazing to higher energy, shallow water refugia, which are inhospitable to urchins (Duggins 1980; Steneck et al. 2002).

[5] Fisheries and Oceans Canada, Victoria/Nanaimo, BC, 2019.

When Sea Otters are present, and reduce urchin populations through predation, large canopy and high biomass forests can be formed.

Spatial datasets

To create the EBSA Kelp layer, five datasets from the British Columbia Marine Conservation Analysis (BCMCA) were combined: 1) Bull Kelp bed polygons, 2) Giant Kelp bed polygons, 3) General kelp polygons, 4) Bull Kelp biobands, and 5) Giant Kelp biobands (Figure 3).

The BCMCA Bull Kelp and Giant Kelp polygon layers include species-specific data from the Province of BC Land Use Coordination Office, Living Oceans Society, Parks Canada, and the Capital Region District. The BCMCA General Kelp layer represents areas of canopy-forming kelp from those same sources, but where species information was not recorded. These polygons were used without modification in the EBSA Kelp layer.

The ShoreZone shoreline classification (Howes et al. 1994) includes “biobands” that classify sections of shoreline according to biological assemblages. The Bull Kelp and Giant Kelp biobands were extracted from the BCMCA into individual layers.

These spatial datasets are limited in several ways. In addition to being outdated in many areas, the data only represent areas that have been surveyed for kelp and may thus include false absences. Kelp distribution is also highly dynamic (see Distribution, above), so its occurrence is not constant through time. A concurrent project is underway using remote sensing techniques to delineate kelp canopy extent, distinguish between the two canopy-forming kelp species, and perform a 30-year temporal analysis to identify kelp hotspots (Nijland et al. 2019). When combined with ecological understanding represented in species distribution models, this work has the potential to greatly improve canopy kelp distribution maps on the coast of BC, and provide a cost-effective way to regularly map kelp forests to inform our understanding of kelp dynamics. For EBSA identification, this method will aid in prioritizing specific kelp forests based on size (i.e., canopy extent), and persistence (i.e., areas where kelp forests consistently re-occupy over the 30 years).

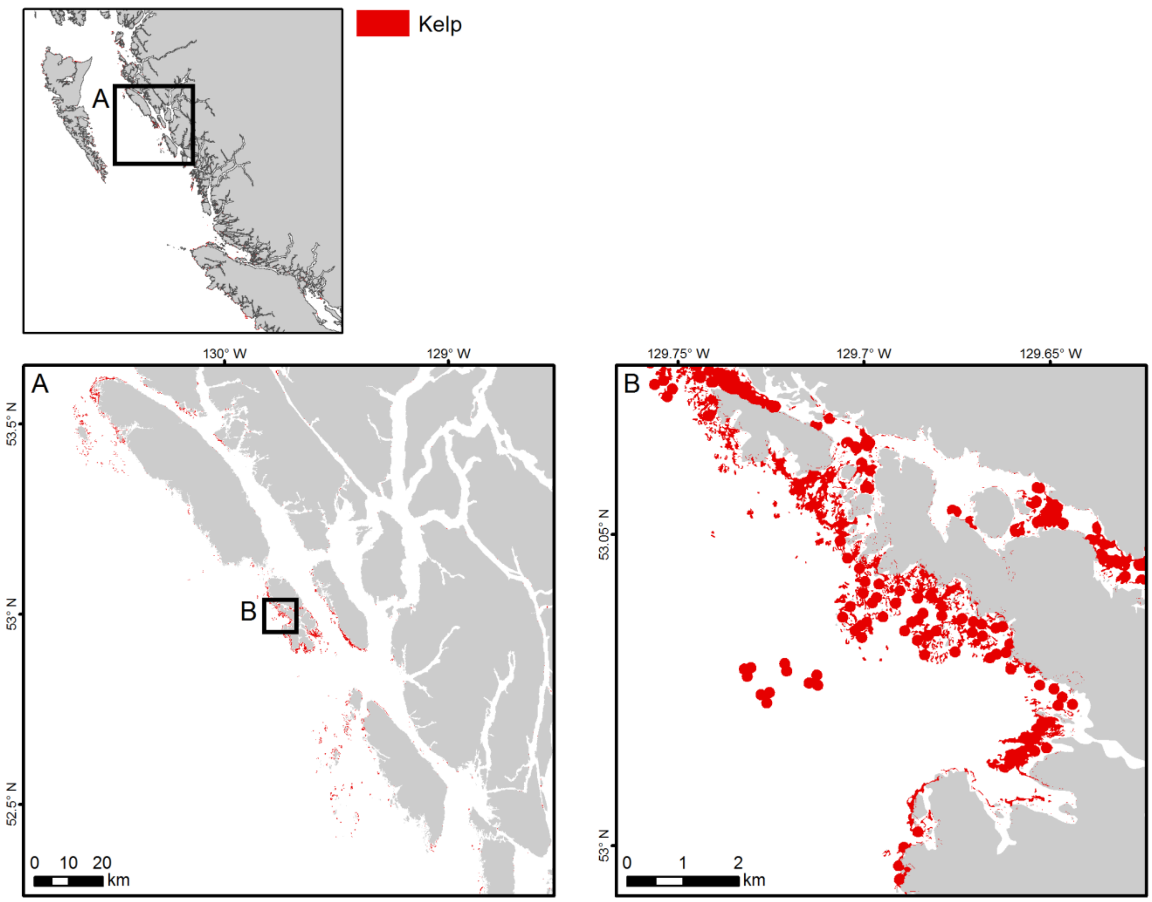

Figure 3. An example of the kelp layer in the central portion of the Northern Shelf Bioregion.

2.1.3. Feature description

Bull Kelp is primarily an annual species, although some individuals may overwinter (Springer et al. 2007). Individual plants can grow to lengths exceeding 40 m, and at a rate of up to 15 cm/day (Druehl 1978), with each adult sporophyte producing 30–60 blades (Springer et al. 2007) up to 4 m in length (Druehl 1978). Giant Kelp is a long-lived perennial, and is both the most widely distributed kelp taxon, and the world's tallest benthic organism (Steneck et al. 2002), reaching 55 m in length under suitable conditions (Druehl 1978). Sporophyte fronds survive about 1 year, but are regularly re-grown from the holdfast. Individual sporophytes may live until they are dislodged (Graham et al. 2007).

In general, kelp forest ecosystems support coastal species through two distinct ecological processes (Markel 2011). First, by creating and enhancing habitat (e.g., Trebilco et al. 2015), and second through the provision of primary production (Duggins 1988; Steneck et al. 2002; Markel 2011). Within a kelp forest, the spatially complex three-dimensional structure increases the abundance and diversity of coastal organisms (Duggins 1988; Steneck et al. 2002), with the vertical component known to be used by mid-water reef fishes (Hallacher and Roberts 1985; Ebeling and Laur 1988; Markel and Shurin 2015), and juvenile Coho and Chinook Salmon (Daly et al. 2009). The benthic and edge habitats, and the plants themselves, provide habitats for other species (Duggins 1988). For example, kelps serve as substrate for a diversity of small planktivorous and detritivorous invertebrates (Graham et al. 2008). This high habitat complexity leads to high species diversity (Graham et al. 2007) and trophic complexity (Graham et al.

2008), in part through the provision of refugia from predators (Lee et al. 2016). Increased retention of particulate matter (Graham 2003) may also enhance nursery and rearing habitat, while at broader extents, the size and configuration of kelp forests modifies nearshore hydrodynamics (Eckman et al. 1989; Graham 2003; Wu et al. 2017), potentially affecting recruitment of fishes and invertebrates with a nearshore larval phase (Eckman et al. 1989; Graham 2003; Markel 2011). Many of the species that use and depend on kelp forests for critical stages in their life history have been identified as conservation priorities for NSB MPA network planning (Table 2).

Kelp forests provide as much as 30% more biomass than the same rocky reef feature dominated by grazing invertebrates, contributing significantly to the overall productivity of the coastal eastern North Pacific (Gregr 2016). This biomass enhances secondary production by feeding a range of detritivores and grazers (Steneck et al. 2002). Kelp-derived primary production can also supplement filter feeders at places (e.g., Duggins et al. 1989; Salomon et al. 2008) or times (Ramshaw 2012) when planktonic primary productivity is reduced. However, the magnitude of this effect is mediated by complex biological and physical interactions, and has likely been over-estimated in some studies (Miller and Page 2012). The result is an enhanced, complex food web where senescent or detached kelp enters as detritus and is consumed by small grazers and detritivores (Markel 2011), which then nourish higher trophic levels (Koenigs et al. 2015). Kelp detritus is regularly transported beyond the footprint of individual kelp forests to ‘recipient’ habitats and ecosystems both at sea and on land (Polis and Hurd 1996; Steneck et al. 2002; Kaehler et al. 2006; Dugan et al. 2011; Krumhansl and Scheibling 2012). In addition to their importance as a nutrient importer, kelp forests have been identified with other macroalgae and marine plants for their important role in reducing atmospheric carbon and carbon sequestration (see Krause-Jensen and Duarte 2016; Wilmers et al. 2012).

Table 2. Known uses of canopy-forming kelp forests by species identified as conservation priorities, including ecologically significant species, for the MPA network in the NSB.

Species Conservation Priority	Habitat Use Type	Reference
Lingcod	Feeding	Cass et al. 1990; Paddack and Estes 2000
Herring	Spawning, Rearing	Haegele and Schweigert 1985;
Rockfishes (Black, Bocaccio, Canary, China, Copper, Quillback, Silvergray, Vermilion, Widow, Yellowtail)	Rearing/Nursery; Feeding	Carr 1991; Paddack and Estes 2000; Love et al. 2002; Markel and Shurin 2015; Trebilco et al. 2015
Chinook Salmon	Rearing/Nursery; Migrating; Feeding	Shaffer 2004; Daly et al. 2009
Coho Salmon	Rearing/Nursery; Migrating; Feeding	Shaffer 2004; Daly et al. 2009
Crustacean zooplankton	Rearing/Nursery	Graham 2004
Northern Abalone	Feeding	Lee et al. 2016
Filter feeding molluscs (e.g., Purple-hinged Rock Scallop)	Feeding	Graham 2004
Giant Pacific Octopus	Resting/hiding	Scheel and Bisson 2012
Echinoderms (Sunflower Sea Star, Green Urchin, Red Urchin)	Feeding	Lee et al. 2016
Orca (transient)	Feeding	Ford et al. 2000
Orca (resident)	Feeding; Aggregation (other - socializing)	Ford et al. 2000
Sea Otter	Breeding; Feeding; Rearing/Nursery	Kenyon 1969; Riedman and Estes 1990; Lee et al. 2016

2.1.4. Feature conditions and trends

Beyond the annual loss of Bull Kelp to senescence, and the irregular loss of Giant Kelp to winter storm events, kelp abundance is also influenced by changes in water temperature (Krumhansl et al. 2016) and invertebrate grazing (e.g., Watson and Estes 2011, and references therein). Climate change may lead to shifts in kelp distribution in response to increased temperatures (Schiel et al. 2004; Krumhansl et al. 2016), modified ocean currents, or lowered salinity. Other anthropogenic threats include sedimentation and changes in nutrient balance (Vandermeulen 2005). Biological threats include grazing, pathogens, and introduced species (Ambrose et al. 1982; Springer et al. 2006; Krumhansl et al. 2011; Schiel and Foster 2015). Given what has been observed for other species (e.g., sea stars) subject to pathogen effects (e.g., wasting disease, Bates et al. 2009), it is reasonable to expect non-linear, and perhaps even threshold-type responses to interactions between oceanographic factors (e.g., temperature) and pathogens. This has been dramatically illustrated recently in California where purple urchins, released from predation pressure by sea star wasting, have decimated kelp forests in recent years (e.g., Bonaviri et al. 2017). Physical factors may also shift ecological relationships with invasive species.

With growth rates of 10's of cm/day during peak growing periods, canopy-forming kelp forests are best seen as semi-permanent features, whose areal extent can be variable between seasons and years. However, it is clear that predator control of grazers (urchins in particular) is an essential component of kelp distribution. In the presence of Sea Otters, red sea urchin densities are drastically reduced, leading to an increase in kelp stipe density and depth distribution (Watson and Estes 2011; Lee et al. 2016). The resulting trophic cascade (Estes and Palmisano 1974) leads to the increased abundance and diversity of invertebrate and finfish species (Markel and Shurin 2015; Gregr 2016). Kelp distributions in the NSB are currently responding to the recovery of Sea Otters following their extirpation in the 18th and 19th centuries as part of the maritime fur trade (Nichol et al. 2009), but may be at risk from Purple Sea Urchins if sea star wasting persists.

2.1.5. Assessment against EBSA criteria

Characteristics of kelp forests were assessed against the EBSA criteria to evaluate whether they should be included as nearshore EBSAs (Table 3).

Table 3. Assessment of kelp forests against the eight EBSA criteria (Boxes 1 and 2). Insuffic. Info.: insufficient information.

EBSA Criteria	**Ranking of criterion relevance**			
	Insuffic. Info.	**Low**	**Medium**	**High**
Uniqueness or rarity			X	
Rationale: Kelp forests are a unique, biogenic habitat feature supporting a diversity of coastal species through habitat provisioning and enhanced primary production (Steneck et al. 2002; Markel 2011; Lee et al. 2016). Habitat is enhanced by the complex three-dimensional structure (Duggins 1988; Steneck et al. 2002) and increases species abundance, diversity, and trophic complexity (Graham et al. 2007, 2008). Increased retention of particulate matter (Graham 2003) may also enhance nursery and rearing habitat. Regionally, the size and configuration of kelp forests modifies nearshore hydrodynamics (Eckman et al. 1989; Graham 2003, Wu et al. 2017), potentially improving the recruitment of fishes and invertebrates with a nearshore larval phase (Eckman et al. 1989; Graham 2003; Markel 2011). Despite the unique ability of kelp to build canopy-forming, complex three dimensional structure for multiple species, the criterion is scored as Medium because the feature is widely distributed in BC.				
Special importance for life-history stages of species			X	
Rationale: Kelp forests provide habitat for a variety of fish species including juvenile and adult life stages of rockfish (Hallacher and Roberts 1985; Ebeling and Laur 1988; Markel and Shurin 2015), salmon (Shaffer 2004; Daly et al. 2009), and invertebrates (Krumhansl and Scheibling 2012; Lee et al. 2016). They also serve as substrate for small invertebrates (Graham et al. 2008). Despite this habitat provisioning for a range of species during critical early life history stages, a ranking of Medium is assigned because most species persist in the absence of canopy kelp (though see Graham 2004), perhaps due to a similar contribution by understory kelp in deeper waters.				

<table>
<tr><th rowspan="2">EBSA Criteria</th><th colspan="4">Ranking of criterion relevance</th></tr>
<tr><th>Insuffic. Info.</th><th>Low</th><th>Medium</th><th>High</th></tr>
<tr><td>Importance for threatened, endangered or declining species and/or habitats</td><td></td><td></td><td>X</td><td></td></tr>
<tr><td colspan="5">Rationale: Kelp forests create important habitat for a diversity of species, some of which may be declining or listed as species at risk (e.g., endangered Northern Abalone; DFO 2007b; Lee et al. 2016). The importance of kelp forests to many commercial finfish may be quite high, particularly in their early life history stages (e.g., Daly et al. 2009; Markel and Shurin 2015). The nutritional supplement to higher trophic levels from the considerable primary production may also contribute significant nutritional support for declining species and species at risk such as some rockfish species. Despite its likely importance to threatening and declining species, most of these species can occur in alternative habitats in the absence of kelp, so it was scored Medium.</td></tr>
<tr><td>Vulnerability, fragility, sensitivity, or slow recovery</td><td></td><td>X</td><td></td><td></td></tr>
<tr><td colspan="5">Rationale: Kelp forests are comprised of fast-growing species that are functionally robust and appear fairly resilient. The most direct threats include rising water temperatures and associated changes in trophic dynamics leading to increased herbivory, and invasive species (Schiel and Foster 2015; Krumhansl et al. 2017), which can lead to permanent loss of kelp forests.</td></tr>
<tr><td>Biological productivity</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td colspan="5">Rationale: Kelp forests are one of the most productive ecosystems on the planet (Mann 1973; Krumhansl et al. 2016). They are significant contributors to the overall productivity of the coastal eastern North Pacific (Gregr 2016), enhance secondary production via grazers (Steneck et al 2002) and filter feeders (e.g., Duggins et al. 1989; Salomon et al. 2008). They also play an important role in carbon sequestration and reducing atmospheric carbon (see Krause-Jensen and Duarte 2016; Wilmers et al. 2012).</td></tr>
<tr><td>Biological diversity</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td colspan="5">Rationale: The habitat provisioning service provided by kelp forests leads to higher species diversity, unique communities, and higher density of some species and life stages (Steneck et al. 2002; Graham 2004; Koenigs et al. 2015; Gregr 2016).</td></tr>
<tr><td>Naturalness</td><td>Variable</td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Rationale: The distribution of canopy-forming kelps, particularly in terms of depth and canopy extent, is strongly influenced by the presence of Sea Otters (Estes and Palmisano 1974; Watson and Estes 2011). In the absence of Sea Otters, the distribution of canopy-forming kelps is reduced by sea urchin grazing to higher energy, shallow waters (Duggins 1980; Steneck et al. 2002). The consumption of herbivores by Sea Otters, when present, can lead to kelp recovery and the formation of large canopy and high biomass kelp forests form, which can be considered their more natural state (Estes and Palmisano 1974; Watson and Estes 2011). Sea Otter populations have not fully recovered from the maritime fur trade, but where they are abundant (e.g., Kyuquot Sound, Central Coast near Bella Bella), kelp forests are often larger, denser, and deeper (Watson and Estes 2011; Lee et al. 2016). The patchiness of kelp forests occupied by Sea Otters results in a patchy distribution of naturalness for canopy-forming kelp in the NSB; therefore, this criterion was scored as Variable.</td></tr>
</table>

EBSA Criteria	Ranking of criterion relevance			
	Insuffic. Info.	Low	Medium	High
Aggregation				X
Rationale: The habitat provisioning service provided by kelp forests leads to higher diversity and higher density of some species and life stages, making it a significant aggregation feature relative to surrounding areas (Duggins 1988; Graham et al. 2007).				

2.1.6. Summary

Kelp forests scored High for 3/8 criteria and Medium for 3/8 criteria, demonstrating this feature is suitable for EBSA designation. Kelp scored High for Productivity, Biological Diversity, and Aggregation; Medium for Uniqueness, Special Importance to Life History Stages, and Importance to Threatened/Declining Species; Low for Vulnerability and Variable for Naturalness. A more thorough analysis of canopy-extent and biomass, linking ground-truthed remote sensing analysis currently being adapted to the BC coast (e.g., Nijland et al. 2019) with species distribution modelling will aid in identifying rocky reef features likely to support large, canopy-forming kelp forest EBSAs.

2.2. EELGRASS MEADOWS

Figure 4. Copper Rockfish (Sebastes caurinus) in an eelgrass meadow, Gwaii Haanas, Haida Gwaii. (photo credit: Sharon Jeffery).

2.2.1. Introduction

The native eelgrass, *Zostera marina*, is a perennial plant belonging to a group of plants known as seagrasses[6] that form meadow habitats along the coast of BC. A non-native eelgrass species is also present in BC (*Zostera japonica*), and may form mixed-species meadows with the native species in the NSB. Nearshore areas that support eelgrass meadows (also referred

[6] The term “seagrass” is used to describe vascular plants that grow submerged or partially submerged in marine or estuarine waters, and that have the unique ability to complete sexual reproduction while immersed in a saline environment (Scagel 1971).

to as eelgrass beds) have not been previously assessed against the EBSA criteria in the NSB. Eelgrass has been identified as an ESS in eastern Canada (DFO 2009), and as an ecological conservation priority for the NSB (DFO 2017), based on its role in providing an important biogenic habitat for numerous species. Eelgrasses are also very important primary producers, ranking among the most productive ecosystems in the world (DFO 2009), and are recognized as important ecosystem service providers (e.g., carbon sequestration, shoreline stability, erosion prevention, water clarity improvement, reduction in pathogens, and fish habitat provisioning) (Orth et al. 1984; Hughes 2002; DFO 2009; Vandermeulen 2009; Barbier et al. 2011; Plummer et al. 2012; Duarte et al. 2013; Lamb et al. 2017).

2.2.2. Distribution

Eelgrass is the dominant seagrass species in BC (BC MSRM 2002), where it forms extensive meadows in shallow subtidal and intertidal areas, especially in estuaries. Eelgrass meadows are most commonly found in wave protected areas, especially covering large areas of embayments, and the shallow estuarine heads of inlets (Pojar and MacKinnon 1994). They are also widely distributed as patchy, fringing beds throughout coastal areas in the NSB. One of the largest eelgrass meadows in the region is located on Flora Bank, in the Skeena River estuary. Flora Bank supports 50–60% of the total eelgrass found in Skeena estuary, and is considered a vital fish rearing area (Hoos 1975; Moore et al. 2015).

Spatial dataset

To create the EBSA Eelgrass layer, spatial data on eelgrass were merged in ArcMap into a single layer. Two datasets from the BCMCA were combined: 1) Eelgrass polygons, and 2) Eelgrass Biobands.

The Eelgrass polygons layer was created by BCMCA by combining layers provided by the Province of BC Land Use Coordination Office, DFO, Parks Canada, Shorezone, and the Community Mapping Network (Figure 5).

BCMCA extracted the Eelgrass Biobands into an individual layer. While the biobands represent the best available intertidal habitat classification, the data are outdated in many areas and, as lines along the shore, do not indicate the depths or extent inhabited by the species.

Work is underway to convert the eelgrass biobands to eelgrass polygons. While those maps have not yet been finalized, completion is expected in the near future. Reshitnyk et al. (2016) used ShoreZone-derived eelgrass biobands, the average maximum depth of eelgrass (based on BCMCA and some new data), and an ArcGIS tool based on Gregr et al. (2013) to convert the bioband lines into depth-bounded polygons. At present, the analysis does not cover the full NSB, and was specifically designed for use in broad-scale estimates of carbon storage as part of the Hakai Institute's Geospatial Nearshore mapping. These eelgrass polygons (Reshitnyk et al. 2016) represent coarse estimates of the areal extent of seagrass in BC based on current databases; however, uncertainty is high in some areas, and the approach needs refining prior to its use in fine-scale mapping of eelgrass meadows on our coast. It was therefore not incorporated into the EBSA Eelgrass layer. Ground-truthing, including incorporation of updated seagrass distribution data, is needed to improve map accuracy. Other tools (e.g., remote sensing using new satellite and UAV technologies) should also be assessed for their contribution to this spatial dataset.

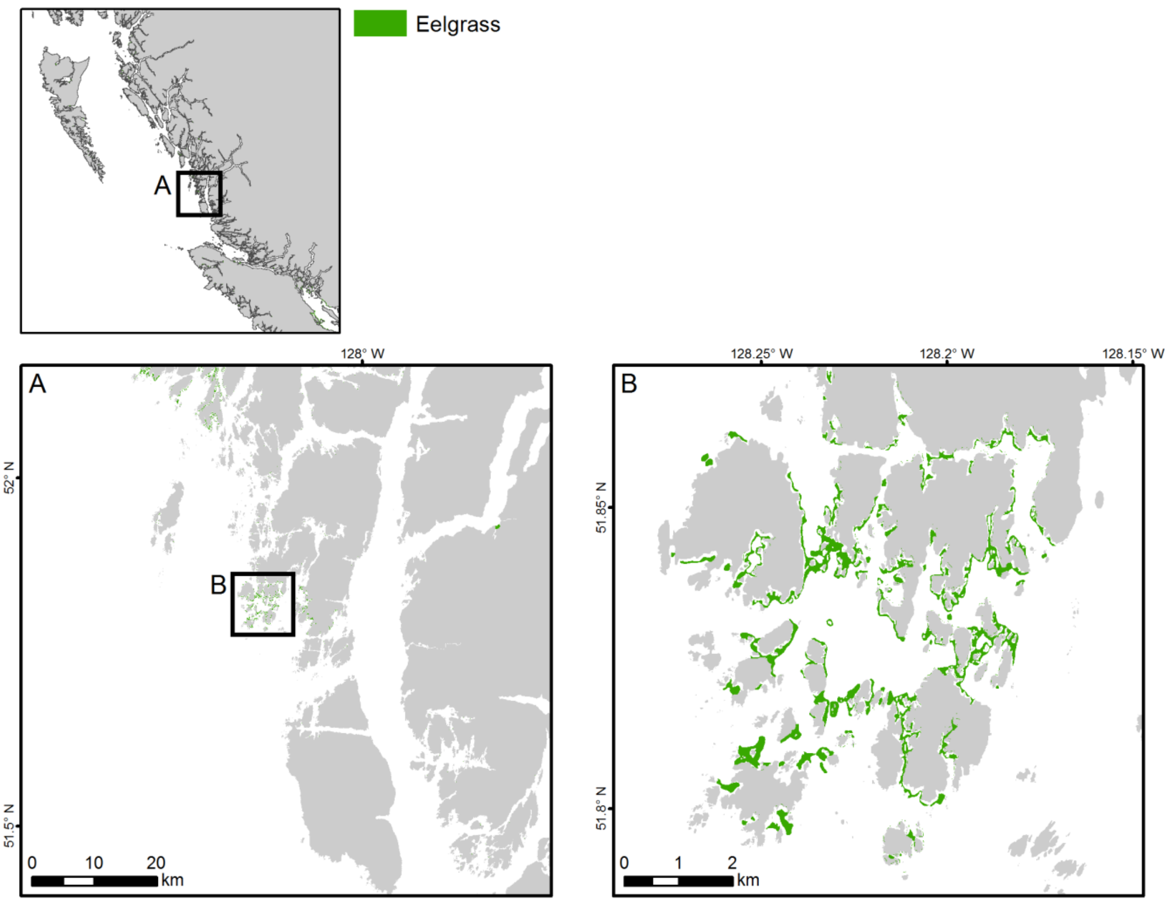

Figure 5. An example of the eelgrass meadow layer in the central portion of the Northern Shelf Bioregion.

2.2.3. Feature description

Eelgrass meadows are often monospecific in the NSB, but can also include widgeon grass (*Ruppia maritima*) at higher tidal elevations. Dwarf seagrass (*Zostera japonica*), an introduced species, is found in the Strait of Georgia and on the west coast of Vancouver Island, but has not yet been recorded in the NSB (Gillespie 2007). While BC is near the northern limits of the range of *Z. japonica* (Shafer et al. 2014), it is spreading north and may occupy the NSB in the future. It occupies higher tidal elevations than *Z. marina*, but can also overlap (Phillips 1984). Two forms of eelgrass meadows have been defined; flat and fringing (Berry et al. 2003). Flat eelgrass meadows consist of large vegetated areas at a similar depth, while fringing beds consist of narrow vegetated bands along a shoreline. The expansion and maintenance of eelgrass meadows is primarily accomplished by vegetative growth (horizontal rhizome extension; Phillips 1983), limiting the capacity for meadow recovery and colonisation.

Eelgrass meadows are highly influential in altering the surrounding marine environment. For instance, the extensive rhizome network of seagrasses binds the soft sediments in which they anchor, helping to prevent erosion (Duarte 2002). Eelgrass plants also oxygenate both the water column and sediment through photosynthesis and active transport of oxygen into the sediment (Pregnall et al. 1984; DFO 2009). Lastly, the high density and three-dimensional structure of the seagrass leaves create friction as currents and waves pass over them, baffling water motion and further reducing erosion (Peterson et al. 2004). This slowing of water is also beneficial because it increases deposition of sediments and other particles (including larvae), increasing the clarity of the water passing through it (Hemminga et al. 1991; Green and Short 2003). This deposition of larvae due to reduced currents may contribute to the role of eelgrass meadows as nursery habitats. In addition to the provisioning services to fisheries through providing nursery habitats, and the shore stabilization services, eelgrass meadows are also very important in carbon storage and sequestration. On a per area basis, salt marshes and seagrasses can bury carbon in their sediments at levels that exceed storage rates in boreal and temperate forests (Fourqurean et al. 2012).

Eelgrass plants have high turnover rates of leaves during periods of high growth (summer months). Furthermore, winter storms can contribute to the disturbance of seagrass beds and shedding of plant material. Together, this leads to large amounts of loose plant material that is either retained within eelgrass meadows, or transported to adjacent ecosystems, including as wrack in riparian habitat (Hemminga et al. 1991; Duarte and Krause-Jensen 2017). The high productivity of eelgrass meadows is due to this frequent turnover of seagrass leaves, as well as the associated epiphytes, and has been estimated at 350–380 g carbon/m^2/yr (Kentula and McIntire 1986; Thom 1990). Plant material produced in eelgrass meadows has been shown to contribute nutrients to many other ecosystems (Heck et al. 2008); it is estimated that 30-70% of material produced in an eelgrass meadow is transported to other ecosystems (Bach et al. 1986; Duarte and Krause-Jensen 2017).

In BC, eelgrass meadows support a diverse biological community of fish and invertebrates. Beach seines in 13 eelgrass meadows on Haida Gwaii identified 52 species of fishes (Robinson et al. 2011). Other studies have also shown that eelgrass meadows support high densities of fishes and invertebrates (Hemminga and Duarte 2000; Murphy et al. 2000; Johnson and Thedinga 2005). More than a thousand juvenile Pink Salmon were captured in a single beach seine haul on the eelgrass meadow at Flora Bank in the Skeena River estuary (Carr-Harris et al. 2015), and over 20,000 Chum Salmon were captured in a single beach seine haul in an eelgrass meadow in southeastern Alaska (Johnson and Thedinga 2005). Moore et al. (2015) report that more than twice as many juvenile salmon were found in eelgrass surveys on Flora Bank than in other parts of the Skeena estuary. The Flora Bank eelgrass meadow is also used for spawning by Pacific Herring, rearing for juvenile Dungeness Crabs, and has higher abundances of juvenile Steelhead than other locations in the Skeena estuary (Moore et al. 2015). The three-dimensional structure of eelgrass provides food, shelter and habitat, likely contributing to the high diversity and abundance of fishes in eelgrass meadows (Orth et al. 1984; Jackson et al. 2001). Many species of fish and invertebrates with pelagic larval stages also rely on eelgrass meadows as habitat to bridge their early planktonic existence with later adult habitats (Beck et al. 2001; Smith and Sinerchia 2004).

Eelgrass was identified as a conservation priority for the NSB MPA network (DFO 2017) based on its important role as a habitat-forming species. Many of the species that use and depend on eelgrass meadows for critical stages in their life history have also been identified as ESSs and conservation priorities for NSB MPA network planning (Table 4), including Pacific salmon species, Pacific Herring, Lingcod, and several species of rockfishes.

Table 4. Known uses of eelgrass meadows by species identified as conservation priorities, including ecologically significant species for the MPA network in the NSB.

Species Conservation Priority	Habitat Use Type	References
Coho Salmon	Rearing/Nursery	Simenstad and Wissmar 1985; juday and Thedinga 2005
Pink Salmon	Rearing/Nursery	Magnhagen 1988; Johnson and Thedinga 2005
Chum Salmon	Rearing/Nursery	Simenstad and Wissmar 1985; Johnson and Thedinga 2005; Moore et al. 2015
Chinook Salmon	Rearing/Nursery	Levings 1985; Semmens 2008
Steelhead	Rearing/Nursery	Moore et al. 2015
Sockeye Salmon	Rearing/Nursery	Moore et al. 2015
Lingcod	Rearing/Nursery	Cass et al. 1990; Petrie and Ryer 2006; Lucas et al. 2007; Jeffery 2008
Pacific Cod	Rearing/Nursery	Hoos 1975; Jewett and Dean 1997; Dean et al. 2000
Black Rockfish	Rearing/Nursery	Murphy et al. 2000; Jeffery 2008; Studebaker and Mulligan 2009
Copper Rockfish	Rearing/Nursery	Murphy et al. 2000; Jeffery 2008; Studebaker and Mulligan 2009; Olson 2017
Yellowtail Rockfish	Rearing/Nursery	Murphy et al. 2000; Moore et al. 2015
Bocaccio	Rearing/Nursery	Murphy et al. 2000; Jeffery 2008; Robinson et al. 2011
Pacific Herring	Rearing/Nursery; Spawning	Hoos 1975; Thayer and Phillips 1977; Johnson et al. 2010; Stick et al. 2012; Moore et al. 2015
Dungeness Crab	Rearing/Nursery	Thayer and Phillips 1977; Dinnel et al. 1993; McMillan et al. 1995; Moore et al. 2015
Great Blue Heron	Feeding	Butler 1995
Brant Goose	Feeding	Ganter 2000; Shaughnessy et al. 2012
Grey Whale	Feeding	Darling et al. 1998

2.2.4. Feature conditions and trends

Globally, eelgrass is in decline, largely due to anthropogenic disturbances (Giesen et al. 1990; Short et al. 1996; Green and Short 2003; Hanson 2004; Gaeckle et al. 2007; Waycott et al. 2009).The general status of eelgrass in the NSB is uncertain due to the paucity of monitoring and scientific studies across the region. Although long-term eelgrass monitoring sites do exist within the NSB (e.g., Gwaii Haanas National Park Reserve, by Parks Canada; and Calvert Island and surrounding area, by Hakai Institute), there is a need for a more widespread effort to map and survey eelgrass throughout the region. Past efforts such as stewardship activities within the community mapping network, and the on-going Seagrass Conservation Working Group have contributed to eelgrass mapping; however, a lack of continued funding and inconsistent data archiving have limited this contribution.

Nearshore human activities known to negatively impact eelgrass health and distribution include:

- Contamination from vessel discharge, oil spills, and run-off from land (Phillips 1984);
- Increased nutrient input from sewage outfalls, agriculture and aquaculture (Phillips 1984; Hauxwell et al. 2003; Vandermeulen 2005);
- Sedimentation from logging practices, nearshore and watershed development or dredging (Phillips 1984; Vandermeulen 2005);
- Physical removal (due to nearshore development, dredging, boat anchoring, etc.) (Harrison 1990; Unsworth 2017);
- Habitat loss by shoreline alteration and constructions (i.e., shoreline armouring) (Phillips 1984; Thom et al. 2011);
- Ships' wakes and propeller wash (Thom et al. 2011);
- Logging practices including dumping and storage (Phillips 1984);
- Shading by coastal constructions such as aquaculture pens, docks and float homes (Vandermeulen 2005);
- Invasive species (such as Green Crabs[7])(Vandermeulen 2005; Garbary et al. 2014); and
- Trampling by frequent intertidal use, particularly in populated areas (giesen et al. 2017).

Recovery from damage caused by these disturbances is usually slow or nonexistent (Neckles et al. 2005; Orth et al. 2006; Boese et al. 2009; Duarte et al. 2009). Slow recovery of eelgrass meadows by physical disturbance is exacerbated by the fact that in the Pacific Northwest, eelgrass meadows rely mainly on vegetative growth for expansion and maintenance, which is relatively slow and can only occur where eelgrass persists (Phillips 1983).

Impacts to eelgrass also have the potential to alter the habitat value of eelgrass meadows for species such as juvenile salmon, even if the plants themselves are not fully removed. Studies have shown significantly reduced juvenile salmon prey items in eelgrass meadows persisting in areas with high anthropogenic disturbances (such as ferry terminals) (Hass et al. 2002).

[7] Green Crab populations have established in the Central Coast, and DeRivera et al. (2006) predicted their northern physiological limit could be as far north as southern Alaska.

2.2.5. Assessment against EBSA criteria

Characteristics of eelgrass meadows were assessed against the EBSA criteria to evaluate whether they should be included as nearshore EBSAs (Table 5).

Table 5. Assessment of eelgrass meadows against the eight EBSA criteria (Boxes 1 and 2). Insuffic. Info.: insufficient information.

<table>
<tr><th rowspan="2">EBSA Criteria</th><th colspan="4">Ranking of criterion relevance</th></tr>
<tr><th>Insuff. Info.</th><th>Low</th><th>Medium</th><th>High</th></tr>
<tr><td>Uniqueness or rarity</td><td></td><td>X</td><td></td><td></td></tr>
<tr><td colspan="5">Rationale: Seagrasses, including eelgrass, are unique among flowering plants because they are the only group of plants capable of completing sexual reproduction while submerged in a marine environment (Scagel 1971). However, because eelgrass meadows are ubiquitous in BC, and not unique to the NSB, they are scored as Low rather than High for this criterion.</td></tr>
<tr><td>Special importance for life-history stages of species</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td colspan="5">Rationale: Eelgrass is highly important for many species, particularly juvenile fish as it provides nursery habitat for multiple species. Eelgrass plants support high densities of harpacticoid copepods that are the main prey item for outmigrating juvenile salmon (Simenstad et al. 1999); one study in Washington found that the primary prey item for Chum Salmon was largely produced in eelgrass habitat (Hass et al. 2002). Access to these prey items improves the fitness of salmon when they first enter the marine environment (Moore et al. 2015). Eelgrass also provides protection from predation, further improving marine survival for outmigrating salmon (Simenstad et al. 1999); juvenile Chinook Salmon in eelgrass meadows were shown to have increased survival compared to those in nearby unvegetated habitats (Semmens 2008).
Studies have also shown that rockfishes rearing in eelgrass have a higher energetic content in their tissues than those rearing in the other vegetated habitats sampled (Byerly 2001; Olson 2017). These rockfishes also had higher measures of stomach fullness, which can result in increased fitness.
Eelgrass is also required for the survival of eelgrass-dependent biota such as the Bay Pipefish (de Graaf 2006).</td></tr>
<tr><td>Importance for threatened, endangered or declining species and/or habitats</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td colspan="5">Rationale: Eelgrass meadows were assessed as High for this criterion because of their importance to several species of conservation concern. For example, Bocaccio have been found in eelgrass meadows as juveniles (Murphy et al. 2000; Jeffery 2008; Robinson et al. 2011), and are currently listed as Endangered by COSEWIC. Juvenile salmon (Pink, Chum, Coho, Chinook and Sockeye) are found in eelgrass in high numbers in the period immediately following emigration from freshwater (Murphy et al. 2000; Moore et al. 2015). More than 160 stocks of these species in the Skeena River system are considered of conservation concern, or at risk of extinction (Morrell 2000; Connors et al. 2018).</td></tr>
</table>

<table>
<tr><th rowspan="2">EBSA Criteria</th><th colspan="4">Ranking of criterion relevance</th></tr>
<tr><th>Insuff. Info.</th><th>Low</th><th>Medium</th><th>High</th></tr>
<tr><td>Vulnerability, fragility, sensitivity, or slow recovery</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td colspan="5">Rationale: Eelgrass plants are highly vulnerable to a wide variety of stressors including physical damage and environmental degradation (Short and Wyllie-Echevarria 1996). Entire eelgrass meadows have been lost in coastal areas due to environmental changes such as eutrophication, decreased light penetration or anoxia (Hauxwell et al. 2003; Plus et al. 2003). Extensive damage to meadows has also been documented from dredging and anchoring (Short and Wyllie-Echeverria 1996).
Eelgrass meadows can also be slow to recover once damaged or lost (Neckles et al. 2005; Boese et al. 2009), and recovery can be nonexistent where large areas of plants have been completely removed (Orth et al. 2006; Duarte et al. 2009). This may be exacerbated by the fact that eelgrass meadows in the Pacific Northwest rely largely on vegetative growth for meadow expansion and maintenance, which is relatively slow and only occurs where eelgrass already exists (Phillips 1983). Restoration efforts for eelgrass meadows have been made in many parts of the world, but success rates are generally low (Eriander et al. 2016). Despite this, some restoration attempts in the Pacific Northwest have been successful where transplant conditions are highly suited to eelgrass growth (Gayaldo et al. 2001).</td></tr>
<tr><td>Biological productivity</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td colspan="5">Rationale: Eelgrass is an important primary producer, and epiphyte productivity in eelgrass meadows can equal that of the eelgrass itself, thereby doubling the overall productivity of the area (Penhale 1977). Eelgrass meadows rank among the most productive ecosystems in the world (Hemminga and Duarte 2000; DFO 2009). Much of the primary production from eelgrass meadows is incorporated into detrital food chains that support higher trophic levels (McConnaughey and McRoy 1979).
Eelgrass meadows are also considered nursery habitats for species such as Pacific salmon, thereby supporting the productivity of commercial fisheries (Lucas et al. 2007; Moore et al. 2015). For some tropical species, a reduction in the extent of seagrass vegetation is expected to have direct impacts on commercial fisheries (Hemminga and Duarte 2000), and the same may be true for eelgrass meadows in the NSB.</td></tr>
<tr><td>Biological diversity</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td colspan="5">Rationale: Eelgrass meadows were scored High for this criterion because many studies have shown that eelgrass meadows support a high diversity of fish and invertebrates. For example, 45 fish species were identified from 44 beach seine hauls in eelgrass meadows in southeastern Alaska (Johnson and Thedinga 2005), and 52 fish species were identified from numerous beach seine hauls at 13 eelgrass locations in Gwaii Haanas, Haida Gwaii, BC (Robinson et al. 2011). Additionally, there are hundreds of locally adapted and genetically distinct salmon populations that use eelgrass meadows as juveniles in the region (Morrell 2000).</td></tr>
<tr><td>Naturalness</td><td>Variable</td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Rationale: There are many threats to the health of eelgrass meadows in the NSB, including shoreline development, eutrophication, overhead structures, and log storage (DFO 2005; Hall 2008; Thom et al. 2011). However, there are also many coastal areas in the region where these activities have not occurred, and where eelgrass meadows remain relatively pristine (e.g., much of Haida Gwaii, and the Great Bear Rainforest). Because of this, eelgrass meadows exist in varying states of naturalness throughout the region. A more thorough analysis of human impact across eelgrass meadows within the NSB is needed to highlight more pristine meadows.</td></tr>
</table>

EBSA Criteria	Ranking of criterion relevance			
	Insuff. Info.	Low	Medium	High
Aggregation				X

Rationale: Many studies have demonstrated that eelgrass meadows support high densities of invertebrates and juvenile and adult fishes (Hemminga and Duarte 2000; Murphy et al. 2000; Johnson and Thedinga 2005), which has lead to the score of high for this criterion. More than a thousand juvenile Pink Salmon were captured in a single beach seine haul on Flora Bank in the Skeena River estuary (Carr-Harris et al. 2015), and more than 20,000 Chum Salmon were captured in a single beach seine haul in an eelgrass bed in southeastern Alaska (Johnson and Thedinga 2005).

The high density of many fishes in eelgrass meadows is likely due to the three-dimensional structure of the leaves that provide food, shelter and habitat (Orth et al. 1984; Jackson et al. 2001), and the entrainment of larvae from the plankton due to the slowing of water currents through eelgrass meadows (Jackson et al. 2001).

2.2.6. Summary

Eelgrass meadows were scored High for all criteria (6/8) except Uniqueness and Naturalness for which they scored Low and Variable, respectively. These scores are sufficient to support the designation of eelgrass meadows as EBSAs. Although all eelgrass meadows are ecologically and biologically significant, they vary in size, degree of human disturbance and/or threats, and the richness of biological communities they support. More research on characterizing BC eelgrass meadows by these attributes will increase our understanding of which eelgrass meadows EBSAs should be prioritized further. The eelgrass meadow highlighted in this assessment is the one on Flora Bank, which is already within the boundary of the Chatham Sound EBSA (Clarke and Jamieson 2006b), and within the Skeena River estuary (see next section). The Flora Bank eelgrass meadow is one of the largest in the NSB and makes up 50–60% of the eelgrass in the entire Skeena Estuary (Hoos 1975). This eelgrass meadow is a very important juvenile habitat for all five species of Pacific salmon (Higgins and Schouwenburg 1973; Carr-Harris et al. 2015; Moore et al. 2015), and is under pressure from human activity and several development proposals. Targeted surveys of other eelgrass meadows will aid in the identification of additional priority eelgrass EBSAs.

2.3. ESTUARIES

Figure 6. Kowesas River estuary, in the Central Coast of British Columbia (photo credit: Sam Beebe, licenced under CC BY).

2.3.1. Introduction

Estuaries are typically defined as a "semi-enclosed body of water with a free connection to the open sea where the seawater is measurably diluted with fresh water derived from land drainages" (Pritchard 1967). Estuaries serve important ecological roles and provide many ecosystem services. In BC, they comprise less than 3% of the province's coastline but these productive and diverse habitats are seasonally or annually important for multiple taxa including fish, birds, mammals and invertebrates (Ryder et al. 2007). River mouths and estuaries were previously assessed and designated as EBSAs by Clarke and Jamieson in 2006 under the aggregation and fitness consequences criteria (Clarke and Jamieson 2006a,b; DFO 2013); however, a map of estuaries was not provided in the previous process, and they were not formally assessed against the CBD EBSA criteria.

2.3.2. Distribution

Estuaries exist where terrestrial, freshwater, and marine ecosystems meet, and are characterized by highly variable oceanographic characteristics such as temperature and salinity. In BC, estuaries account for less than 3% of the total shoreline (NRTEE 2005 in Lucas et al. 2007). Four exceptionally large estuaries (>1000 ha) exist in BC, two of which are in the NSB: the Nass and Skeena River estuaries (Ryder et al. 2007). Ryder et al. (2007) identified and ranked 442 estuaries on the coast of BC (approximately half of which occurred in the NSB) by their biological importance to waterbirds. Three large estuaries in the NSB received scores in the top importance class: the Nass, Skeena and Kitimat River estuaries. The Skeena River estuary is the largest in the NSB, and is geomorphologically unique because it does not have a single, distinct delta (Ryder et al. 2007).

Spatial dataset

The Pacific Estuary Conservation Program (PECP) estuary map was used to represent estuaries. These data were most recently updated in 2014, but originally developed in 2007 (Ryder et al. 2007) (Figure 7). Briefly, the PECP estuaries were delineated by identifying large rivers from Terrain Resource Inventory Mapping basemaps and the BC Watershed Atlas, and adding intertidal, supratidal, and other connected habitat features (e.g., marsh and swamps). PECP ranked the estuaries based on biological importance to waterbirds according to habitat and forage requirements. The spatial distribution of estuaries are presented here without rankings; however, those rankings in conjunction with assessment of other criteria, could be used to prioritize the estuary EBSAs based on use by a particular species. For example, to highlight estuary importance to salmon species, we are compiling information on salmon escapement and salmon species diversity within the watershed to rank estuaries by importance to salmon (C. Robb and E. Rubidge, unpublished data[8]).

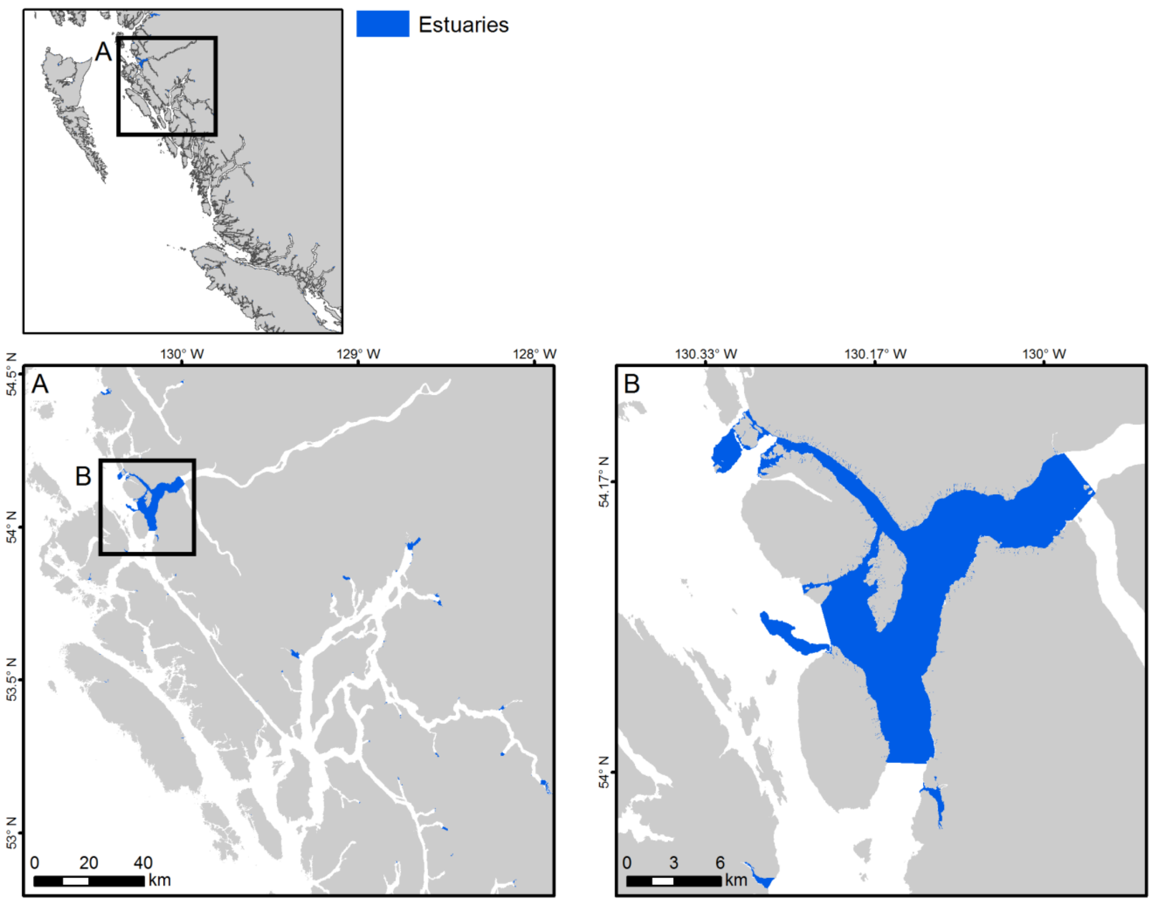

Figure 7. An example of the estuary layer in the northern portion of the Northern Shelf Bioregion. The highlighted estuary is the Skeena River estuary, the largest estuary in the Northern Shelf Bioregion.

[8] Fisheries and Oceans Canada, Victoria, BC, 2019.

2.3.3. Feature description

Estuaries are highly productive habitats at the confluence of fresh and saltwater ecosystems. Productivity in estuaries is driven by high nutrient levels delivered via rivers, oceanic sources, and internal detrital sources (Naiman and Sibert 1979). These nutrients fuel both benthic and pelagic primary production (Moore et al. 2015), which supports high densities of fishes and invertebrates, especially juveniles, contributing to the role of estuaries as a nursery habitat. High turbidity in estuaries and the abundance of vegetation (salt marsh plants, eelgrass, macroalgae) protect juveniles of species such as Pacific salmon from predators, enhancing the nursery role of estuaries for these species (Macdonald et al. 1988; Semmens 2008).

Clarke and Jamieson (2006b) assessed the biological significance of estuaries and determined that the geographically-restricted nature of estuaries created aggregations of anadromous species (notably salmon and Eulachon) by funnelling these species into a confined space prior to their migration upriver. For instance, at least 448 genetically distinct salmon spawning stocks have been documented in the Skeena River estuary (Morrell 2000). In addition to salmon, the Skeena River, its estuary, and adjacent waters are important for Steelhead, trout, whitefish, Rock Sole, Pacific Cod, Pacific Halibut, Surf Smelt, and Pacific Herring (Hoos 1975).

Clarke and Jamieson (2006b) also noted that estuaries had fitness consequences for salmon smolts. This is supported by studies that have found increased marine survival for juvenile salmon after experiencing higher growth rates resulting from superior feeding opportunities in estuaries (Moulton 1997; Mortensen et al. 2000). The improved fitness afforded by the Skeena River estuary is of paramount importance because many of the salmon stocks rearing there are either “at risk of extinction” or “of some concern” (Morrell 2000).

A variety of habitats comprise estuaries, including salt marshes, eelgrass meadows and mud flats. These habitats provide many ecosystems services including water filtration, nutrient enrichment and recycling, detritus processing, and energy provisioning to support near-shore food-webs (Ryder et al. 2007). Many of these habitats are also important for waterbirds, some of which are of conservation concern, including BC blue-listed Brant, Long-tailed Duck, Tundra Swan, Yellow-billed Loon, Black Scoter, Surf Scoter, Horned Grebe, and Eared Grebe, and BC red-listed Western Grebe (Ryder et al. 2007; BCCDC 2017).

Many of the species that use estuaries for feeding, rearing and migration have been identified as conservation priorities for the MPA network planning process in the NSB (Table 6).

Table 6. Known uses of estuaries by species identified as conservation priorities, including ecologically significant species, for the MPA network in the NSB.

Species Conservation Priority	Habitat Use Type	References
Pacific Cod	Feeding	Hoos 1975; Simenstad et al. 1982; Beamish and McFarlane 2014
Ocean-going salmonids (Chinook, Chum, Pink, Sockeye, and Coho Salmon; Steelhead)	Rearing/Nursery; Migrating; Aggregation (adults)	Higgins and Schouwenburg 1973; Simenstad et al. 1982; Groot and Margolis 1991; Simmons et al. 2013; Moore et al. 2015
Cutthroat Trout	Feeding	Simenstad et al. 1982; Aitkin 1998
Bay Ghost Shrimp	Aggregation	Feldman et al. 2000
Eulachon	Migrating	Hart 1973; Willson et al. 2006
Dungeness Crab	Rearing/Nursery	Gunderson et al. 1990
Waterbirds[9]	Migrating; Feeding	Ryder et al. 2007

2.3.4. Feature conditions and trends

Estuaries face a myriad of threats including habitat loss, shoreline development and dredging, trampling, eutrophication, resource extraction, freshwater diversion, chemical contamination, and pollution (Kennish 2002). Many anthropogenic disturbances stem from coastal development, and human activities within the estuaries (Kennish 2002), and are expected to increase along with coastal populations (Robb 2014). Anthropogenic disturbances also occur in upland areas that drain into estuaries, increasing estuarine sediment, nutrient and pollutant concentrations (Robb 2014). Historically, use of estuaries to support logging in BC was widespread. While some logging activities have slowed, their residual effects remain, albeit not well studied coastwide.

Consequently, estuaries are considered one of the most threatened ecosystems in the world (Ryder et al. 2007), and most have been impacted to some degree by human activities. Degradation of estuaries will impact their ecosystem value, particularly as a juvenile rearing habitat; studies of juvenile salmon have shown that salmon survival is reduced in industrialized estuaries. For instance, Chinook Salmon survival was three times lower in estuaries with high levels of development (Magnusson and Hilborn 2003). However, on average, estuaries within the NSB face fewer threats from human activities than those in the southern portion of the province (Robb 2014). Additionally, a greater proportion of northern estuaries have some measure of conservation designation (Robb 2014), which may limit future disturbances.

Restoration within estuaries (namely saltwater marsh and eelgrass habitat) has been attempted with varying levels of success (Roni et al. 2002). Generally, restoration can be useful for

[9] As reported in Ryder et al. (2007), many species of ducks, geese, swans, loons and grebes rely on estuaries for feeding and migrating. At least 13 of these species have been identified as conservation priorities for the MPA network in the NSB (DFO 2017).

restoring biodiversity and ecosystem function in already degraded systems, but these restored habitats do not necessarily provide the biodiversity and natural resources of a system that was not previously impacted (Moore et al. 2015).

2.3.5. Assessment against EBSA criteria

Characteristics of estuaries were assessed against the EBSA criteria to evaluate whether they should be included as nearshore EBSAs (Table 7).

Table 7. Assessment of estuaries against the eight EBSA criteria (Boxes 1 and 2). Insuffic. Info.: insufficient information.

<table>
<tr><th rowspan="2">EBSA Criteria</th><th colspan="4">Ranking of criterion relevance</th></tr>
<tr><th>Insuffic. Info.</th><th>Low</th><th>Medium</th><th>High</th></tr>
<tr><td>Uniqueness or rarity</td><td></td><td></td><td>X</td><td></td></tr>
<tr><td colspan="5">Rationale: Estuaries are unique among marine habitats because they comprise a transition zone between terrestrial, fresh and marine systems, unlike other coastal features that are strictly marine. However, because estuaries are not globally rare, nor are they rare in the NSB, they are scored as Medium rather than High for this criterion. Individual estuaries in the region may be considered highly unique because they host Eulachon, a species that is found in very few estuaries along the coast of BC, during adult spawning migrations and juvenile outmigration (Lucas et al. 2007).</td></tr>
<tr><td>Special importance for life-history stages of species</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td colspan="5">Rationale: Estuaries are scored High for this criterion because they are essential to the survival of all anadromous species, which must pass through estuaries as both spawning adults and out-migrating juveniles (Clarke and Jamieson 2006b).
Estuaries are especially important to the fitness of salmon. Studies have shown that estuaries are valuable stopover locations on the outmigration routes of juvenile Pacific salmonids (Moore et al. 2015) that provide optimal prey resources, protection from predation, and suitable environmental conditions for the physiological transition to a marine environment (Simenstad et al. 1982). Estuaries have been considered critical habitat for Chinook Salmon by some (Moore et al. 2016). The high growth rates afforded by the feeding opportunities in estuaries have been linked to increased marine survival (Moulton 1997; Mortensen et al. 2000). Additionally, the relative magnitude of this increase is proportional to the state (i.e., pristine versus degraded) of the estuary for Chinook Salmon (Magnusson and Hillborn 2003). Enhanced feeding and growth has even been documented in species that pass quickly through estuaries as they migrate seaward (e.g., Pink and Sockeye Salmon) (Weitkamp 2014).
Estuaries also support higher growth for juvenile Dungeness Crabs compared to non-estuary habitats due to higher temperatures and greater food supplies (Gunderson et al. 1990). Finally, estuaries support large populations of waterbirds that aggregate for many reasons, including feeding, resting and breeding (Baldwin and Lovvorn 1994; Ganter 2000; Ryder et al. 2007). Other species also use estuaries for certain aspects of their life history as outlined in Table 6.</td></tr>
</table>

EBSA Criteria	Ranking of criterion relevance			
	Insuffic. Info.	Low	Medium	High
Importance for threatened, endangered or declining species and/or habitats			X	
Rationale: Estuaries were assessed as Medium for this criterion because of the importance of certain estuaries to several species of conservation concern. For example 30 genetically distinct stocks of Chinook Salmon in the Skeena River were identified as either “at risk of extinction” or “of some concern” by Morrell (2000), and it is likely that there are other stocks of conservation concern throughout the NSB that have not yet been assessed. Chinook Salmon rely on estuarine habitats for maximal growth during their first weeks or months in the marine environment (Groot and Margolis 1991; Moore et al. 2015), and estuaries have been considered Chinook critical habitat by some (Moore et al. 2015). It has been found that the state of an estuary (i.e., pristine versus degraded) used by juvenile Chinook Salmon impacts the rate of marine survival (Magnusson and Hillborn 2003). Chum and Pink Salmon in the Skeena River are also of conservation concern (Morrell 2000), and are known to form large schools during early sea life (Groot and Margolis 1991). Juveniles have been found in abundance in the Skeena River estuary (Carr-Harris et al. 2015). It is generally accepted that rapid growth during the early marine stage spent in estuaries reduces the vulnerability of salmonids to predation (Moulton 1997), thus estuarine habitats are likely important for the survival and recovery of these species. Several species of red and blue listed waterbird species are also reported to use estuarine habitats (Ryder et al. 2007; BCCDC 2017). Finally, endangered and special concern populations of Eulachon (endangered- Central coast population; Special Concern- Nass/Skeena populations) pass through estuaries as adults and juveniles.				
Vulnerability, fragility, sensitivity, or slow recovery			X	
Rationale: Many studies have documented degradation in estuaries caused by multiple stressors (Borja et al. 2010). For example, it has been shown that diversity and ecological connectivity are reduced in estuaries subjected to cumulative stressors (de Juan et al. 2013), as is species abundance (Ryder et al. 2007). The habitat value of estuarine habitats can also be reduced by anthropogenic disturbances (Hass et al. 2002). Additionally, two dominant habitats that occur in estuaries, salt marshes and eelgrass, are both considered to be highly susceptible to degradation and have slow recovery rates (Hauxwell et al. 2003; Plus et al. 2003; Neckles et al. 2005; Boese et al. 2009; Borja et al. 2010). However, estuaries are inherently dynamic features, highly influenced by changing ocean and riverine conditions (Elliott and Whitfield 2011). Natural physical disturbance within estuaries may contribute to their ecosystem-level resilience to stressors (Boesch 1974; Geden et al. 2011), which lead to their score of Medium rather than High for this criterion.				
Biological productivity				X
Rationale: Estuaries are widely considered to be highly productive (Nixon et al. 1986; Ryder et al. 2007; Elliott and Whitfield 2011). Productivity in estuaries is made possible by high levels of nutrients delivered via rivers, oceanic sources, as well as internally derived nutrients from detrital decomposition (Naiman and Sibert 1979) that fuel both benthic and pelagic primary production (Moore et al. 2015). The microbes and phytoplankton that are produced within estuaries are consumed by zooplankton and benthic invertebrates that, in turn, support an abundance of higher trophic level species and contribute to very high levels of secondary production in estuaries (Moore et al. 2015).				

EBSA Criteria	Ranking of criterion relevance			
	Insuffic. Info.	Low	Medium	High
Biological diversity				X
Rationale: Estuaries comprise a high diversity of habitats, including eelgrass meadows, mud flats, wetlands, tidal marshes (Emmett et al. 2000), containing a diverse array of plant and animal species (Emmett et al. 2000; BC MOE 2006). In BC, it is estimated that, despite their relatively small overall area, estuaries are used by 80% of all coastal wildlife at some point in their lives (NRTEE 2005 in Lucas et al. 2007), including a large number of marine bird species (Ryder et al. 2007). The Skeena River estuary, for example, is used extensively by six species of salmonids, from populations originating in the Skeena River, its drainages, and surrounding areas, thus integrating diversity from a large area of the north coast of BC (Carr-Harris et al. 2015). At least 448 genetically distinct salmon spawning stocks have been documented in the estuary (Morrell 2000). These factors combine for the overall score of High for this criterion.				
Naturalness	Variable			
Rationale: Estuaries face many threats, including eutrophication, resource extraction, freshwater diversion, shoreline development, aquatic invasive species, and chemical contamination (Kennish 2002; Ryder et al. 2007). However, there are also many coastal areas in the region where these activities have not occurred, and where estuaries remain relatively pristine; over 40% of mapped estuaries in BC were minimally affected by known threats, and a large proportion of these were in the NSB (Robb 2014). Because of this, estuaries exist in varying states of naturalness throughout the region and thus are scored collectively as Variable for this criterion.				
Aggregation				X
Rationale: All estuaries act as bottlenecks that aggregate anadromous species (e.g., salmon, Eulachon) during adult and juvenile migrations between fresh and marine waters, which is one of the reasons they were previously identified as EBSAs (Clarke and Jamieson 2006b). It is well documented that juvenile Chum and Pink Salmon form large schools during early sea life (Groot and Margolis 1991), and large schools of these species have been observed in the Skeena River estuary (Carr-Harris et al. 2015). High abundances of juvenile Steelhead, Pacific Herring, Surf Smelt and juvenile Dungeness Crabs have also been documented in the Flora Bank region of the Skeena River estuary (Moore et al. 2015). For these reasons, estuaries are scored as High for this criterion.				

2.3.6. Summary

Estuaries were designated as EBSAs in 2012 (DFO 2013). To update and support this designation, a formal assessment against the DFO and CBD criteria is presented here in the standardized template developed by Ban et al. (2016). Estuaries score High on 4/8 criteria and Medium on 3/8 criteria. Estuaries were scored High for Aggregation, Biological Diversity, Special Importance for Life History stage and Productivity, and Medium on Vulnerability, Uniqueness, and Importance for threatened species. The Naturalness criterion was scored as Variable since this assessment was on estuaries as a coastwide feature, rather than on a specific estuary. Our assessment supports the previous designation of estuaries as EBSAs (Clarke and Jamieson 2006b). In addition to the updated assessment, a spatial dataset is provided to represent estuaries in the NSB, which was missing in the previous process. Finally, although individual estuaries were not assessed, given the size and the PECP rankings, the

Skeena, the Nass, and the Kitimat estuaries stood out as priority EBSAs in this assessment due to their size, and importance for birds (Ryder et al. 2007) and anadromous fish such as Eulachon and Pacific Salmon. Smaller estuaries of potential sub-regional importance were not highlighted here, but all estuaries meet the EBSA criteria.

2.4. SURFGRASS MEADOWS

Figure 8. Phyllospadix *sp. on Louise Island, Haida Gwaii. (photo credit: Sharon Jeffery)*

2.4.1. Introduction

Surfgrasses are species of seagrass[6] that belong to the phylum *Phyllospadix* (Phillips 1979). Three species within this genus are found in the NSB that differ in phenology, morphology, and zonation within rocky intertidal benthic habitat: *P. torreyi, P. scouleri*, and *P. serrulatus* (Phillips 1979; Gabrielson et al. 2000). The three species can dominate the intertidal zone, form extensive meadows with >80% cover, and pre-empt space from other organisms such as algae (Turner and Lucas 1985; Menge et al. 2005). Nearshore areas that support surfgrass meadows have not been previously assessed as EBSAs for the NSB.

Phyllospadix plants are long-lived, and the meadows they form have been shown to be very persistent (Turner 1985). However, *Phyllospadix* beds are also slow to recover from physical disturbance (Turner and Lucas 1985; Menge et al. 2005). Like other seagrasses, surfgrasses are highly productive with high leaf turnover rates (Ramirez-Garcia et al. 1998); abundant surfgrass leaves in the form of wrack provide nutrient subsidies for a variety of other ecosystems from the high intertidal to submarine canyons (Green and Short 2003).

2.4.2. Distribution

Surfgrasses can be found in intertidal and shallow subtidal regions (Druehl and Clarkston 2016). Surfgrass species are ecologically distinct from other seagrasses because they grow on rocky shores, and in high energy environments (Cooper and McRoy 1988). The intertidal distribution of the three species of surfgrasses are somewhat partitioned across depths, with *P. serrulatus* found in the mid-intertidal, *P. scouleri* in the low intertidal, and *P. torreyi* found at low intertidal to high subtidal depths (Phillips 1979).

Spatial dataset

The EBSA surfgrass layer is the BCMCA Surfgrass Bioband layer (Figure 9). While the biobands represent the best available intertidal habitat classification, the data are outdated in many areas and, as simple lines along the shore do not indicate the depths or extent inhabited by the species. Ground-truthing is recommended to assess the accuracy of this layer. In some areas, including deeper, rocky/cobble substrates, surfgrasses can grow intermixed with eelgrass.

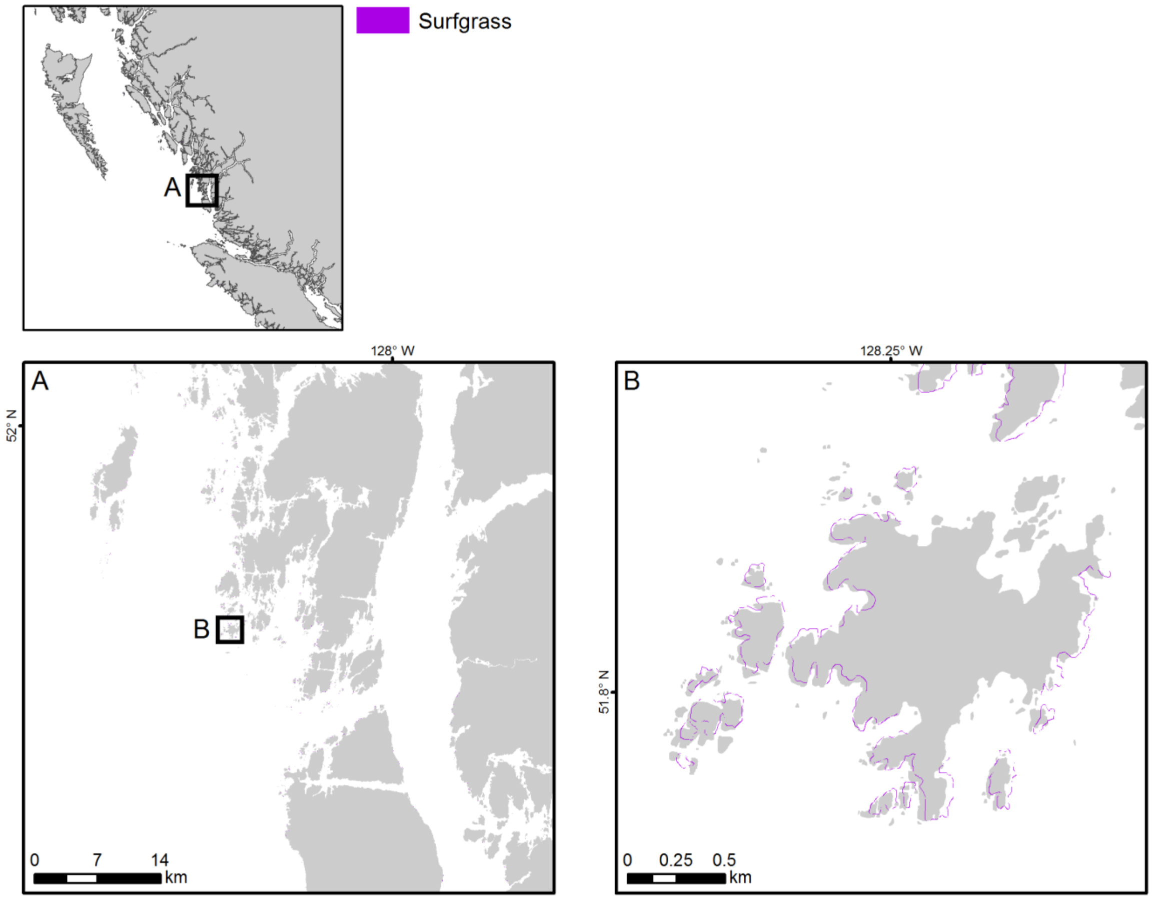

Figure 9. An example of the surfgrass layer in the central portion of the Northern Shelf Bioregion. Unlike the kelp and eelgrass features that include large polygons, the surfgrass data only includes line features (biobands) that can be difficult to visualize at broad scales.

2.4.3. Feature description

Phyllospadix sp. was identified as an ESS and a conservation priority for the NSB MPA network (DFO 2017) based on its important role as a habitat-forming species. Surfgrass meadows often cover extensive areas, with two or more species coexisting across a gradient of depths (Phillips 1979). They are considered dominant, late successional species that are facilitated by early and mid-successional plants (Turner 1983; Menge et al. 2005). Surfgrass species play important ecological roles in wave-exposed, intertidal habitats. Firstly, surfgrasses have a strong ability to buffer wave energy due to the length and density of their leaves (Phillips 1979), providing sheltered microhabitats within their canopies and root systems (Moulton and Hacker 2011). The root and rhizome systems of surfgrasses also play a role in stabilizing rocky shores and protecting them against erosion (Gibbs 1902). Sediments accumulate under the dense surfgrass canopy, and are bound within the thick rhizome mats, forming sediment layers up to one meter in depth that creates habitat for infaunal invertebrates (Gibbs 1902; Phillips 1979). It is thought that this trapping of sediment can help create terraces on surf swept shorelines (Gibbs 1902). Lastly, surfgrasses are highly productive plants (Ramirez-Garcia et al. 1998), producing over 8000 g dry weight/m^2/yr in areas with continuous surfgrass coverage, and annual leaf production rates of 17.8 and 22.6 leaves per shoot for *P. torreyi* and *P. scouleri,* respectively (Ramirez-Garcia et al. 1998). Much of this productivity is transported out of surfgrass meadows and provides nutrient subsidies to a variety of other ecosystems (Dugan et al. 2011).

Phyllospadix spp. have been considered habitat-forming, foundation species that improve environmental conditions for other species (Shelton 2010). Surfgrasses in the intertidal are important for moderating temperatures within tidepools, and the removal of surfgrass can generate significant shifts in plant and invertebrate community composition (Shelton 2010). Surfgrasses also provide habitat and protect macroinvertebrate communities; the leaves and rhizomes of surfgrasses provide protective habitat for macroinvertebrates in high wave energy environments, while the sediment trapped by the roots and rhizomes provides habitat for infaunal organisms that could not otherwise exist on a rocky beach (Moulton and Hacker 2011). Moulton and Hacker (2011) found that while both species were considered important habitat creators, *P. scouleri* provided better habitat for epifaunal species, while *P. serrulatus* accreted more sand and provided better habitat for infaunal species. Finally, *P. scouleri* is unique in its ability to survive in intertidal areas with constantly moving sand, and it is possible that these plants create refuge for other species in this otherwise hostile environment (Littler et al. 1983).

Pacific Herring, an ESS and species of conservation priority for the NSB, uses surfgrasses as a spawning habitat (Table 8).

Table 8. Known uses of surfgrass meadows by species identified as conservation priorities, including ecologically significant species, for the MPA network in the NSB.

Species Conservation Priority	Use of surfgrass	References
Pacific Herring	Spawning (Often not distinguished from eelgrass (*Z. marina*) in spawn surveys.)	Taylor (1964); von Carolsfeld (1997); Turner (2001); Barto (2008)

2.4.4. Feature conditions and trends

Undisturbed surfgrass meadows are dense, persistent, and old; they can exclude other vegetation (Turner 1985; Turner and Lucas 1985), and are resistant to storm waves (Turner 1985). However, surfgrasses are slow to recover from disturbance (>3 years for small patches) due to slow growing rhizomes and low survival of seeds and seedlings (Turner and Lucas 1985). *Phyllospadix* seeds must attach to an alga to settle and grow (Turner and Lucas 1985), and loss of seedlings is high (up to 93%, Turner 1985).

Risks to surfgrasses include:

- Desiccation and heat stress (Ramirez-Garcia et al. 1998)
- Sewage and oiling (Foster et al. 1971; Littler and Murray 1975; Juday and Foster 1990)
- Coastal development[10]
- Shoreline armouring programs (Craig et al. 2008)
- Eutrophication (Honig et al. 2017)

[10] Multi-agency Rocky Intertidal Network (MARINe) – Surfgrass

2.4.5. Assessment against EBSA criteria

Characteristics of surfgrass meadows were assessed against the EBSA criteria to evaluate whether they should be considered nearshore EBSAs (Table 9).

Table 9. Assessment of surfgrass against the eight EBSA criteria (Boxes 1 and 2). Insuffic. Info.: insufficient information.

EBSA Criteria	**Ranking of criterion relevance**			
	Insuffic. Info.	**Low**	**Medium**	**High**
Uniqueness or rarity		X		
Rationale: All seagrasses, including surfgrasses (and eelgrass), are unique among flowering plants because they are the only group of plants capable of completing sexual reproduction while submerged in a marine environment (Scagel 1971). However, because surfgrass meadows are ubiquitous in BC, and not unique to the NSB, they are scored as Low for this criterion.				
Special importance for life-history stages of species			X	
Rationale: *Phyllospadix* spp. are considered habitat-forming, foundation species, as they are able to modify the surrounding habitat to facilitate the presence of other species. Many species are able to survive on surf-swept shores only because of the presence of surfgrasses. For instance, *P. scouleri* survives in intertidal areas with constantly moving sand where the plants help to bind the substrate and provide habitat for other species in an otherwise hostile environment (Littler et al. 1983). Surfgrasses baffle wave energy (Phillips 1979) and provide sheltered microhabitats on highly wave exposed shorelines for a variety of intertidal species (Moulton and Hacker 2011). Lastly, surfgrasses trap sediment in their roots and rhizomes, providing habitat for infaunal organisms that could not otherwise exist on a rocky shore (Moulton and Hacker 2011). Surfgrasses are largely understudied, however, due to difficulties accessing intertidal meadows in wave-exposed environments. For this reason, their importance for many species is unknown, resulting in a score of Medium for this criterion.				
Importance for threatened, endangered or declining species and/or habitats	X			
Rationale: No endangered or declining species within the NSB are known to depend on surfgrasses for their survival or recovery. However, surfgrass habitat is largely understudied; thus, surfgrass meadows are scored as having insufficient information for this criterion.				
Vulnerability, fragility, sensitivity, or slow recovery			X	
Rationale: Surfgrasses are late-successional species whose recruitment is facilitated by primary successional algae species (Turner and Lucas 1985). Surfgrass species have high persistence and meadows are considered to be resistant to some types of disturbance (e.g., storm waves and other forms of mechanical disturbance) (Turner 1985). However, once disturbed, it has been shown that surfgrass species are very slow to recover. Removal experiments showed that rhizomes of *P. scouleri, P. torreyi* and *P. serrulatus* grew <8 cm/yr, and seedlings were very slow to establish (Turner and Lucas 1985). Surfgrasses are susceptible to threats such as desiccation and heat stress, sewage and oiling, coastal development, shoreline protection programs, and eutrophication (Foster et al. 1971; Littler and Murray 1975; Ramirez-Garcia et al. 1998; Craig et al. 2008; Honig et al. 2017). Surfgrass meadows would score Low for this criterion because of their stability and resistance to disturbance, but are given a score of Medium because of evidence of slow recovery and vulnerability to some threats.				

EBSA Criteria	Ranking of criterion relevance			
	Insuffic. Info.	Low	Medium	High
Biological productivity				X
Rationale: Surfgrasses are highly productive plants (Ramirez-Garcia et al. 1998) that grow at very high densities (Phillips 1979). As a result of these two factors, meadows with continuous surfgrass coverage can produce over 8000 g dry weight/m^2/yr, and annual leaf production rates are estimated at 17.8 and 22.6 leaves per shoot for *P. torreyi* and *P. scouleri,* respectively. (Ramirez-Garcia et al. 1998). Much of this productivity is transported out of surfgrass meadows to provide nutrient subsidies to a variety of other ecosystems (Dugan et al. 2011). As with other marine plants, surfgrass has a potential role in carbon sequestration and transfer (i.e., “Blue Carbon’), highlighting its role as an ecosystem service provider.				
Biological diversity	X			
Rationale: Surfgrass meadows are often cited as being important for a variety of species, and it is well documented that they provide habitat for a variety of invertebrates (Moulton and Hacker 2011). However, no references to specific species, or comparisons with other rocky, intertidal habitats could be found in the literature. For this reason, there is not enough information to confidently score this criterion at this time.				
Naturalness	Variable			
Rationale: There are many threats to the health of surfgrass meadows in the NSB, including shoreline armouring (Craig et al. 2008) and sewage (Littler and Murray 1975). However, there are also many coastal areas in the region where these threats are not present, and where surfgrass meadows remain relatively pristine (e.g., much of Haida Gwaii and the Great Bear Rainforest). Because of this, surfgrass meadows exist in varying states of naturalness throughout the region and have been scored as Variable for this criterion.				
Aggregation	X			
Rationale: Surfgrass meadows are extensive and are comprised of dense aggregations of *Phyllospadix* spp. plants. However, no studies could be found examining whether surfgrass meadows support aggregations of other species. Therefore, there is not enough information to confidently score this criterion at this time.				

2.4.6. Summary

Surfgrass meadows ranked High for Productivity, Medium for Vulnerability and Special Importance, and Low for Uniqueness. There was not enough information to score the other criteria, thus they were scored as Insufficient Information. DFO guidance suggests EBSA designation based on a High score for Uniqueness, Fitness Consequences or Aggregation (DFO 2004) or Medium to High scores on most criteria. There is no specific guidance from DFO on whether a High score on one CBD criteria is sufficient for EBSA designation. Given the limited information on ESSs, other than Pacific Herring, that regularly use surfgrass meadow habitat, there is not enough information to support an EBSA designation for surfgrass meadows at this time. Research is needed to fill these gaps.

2.5. HIGH TIDAL CURRENT PASSAGES

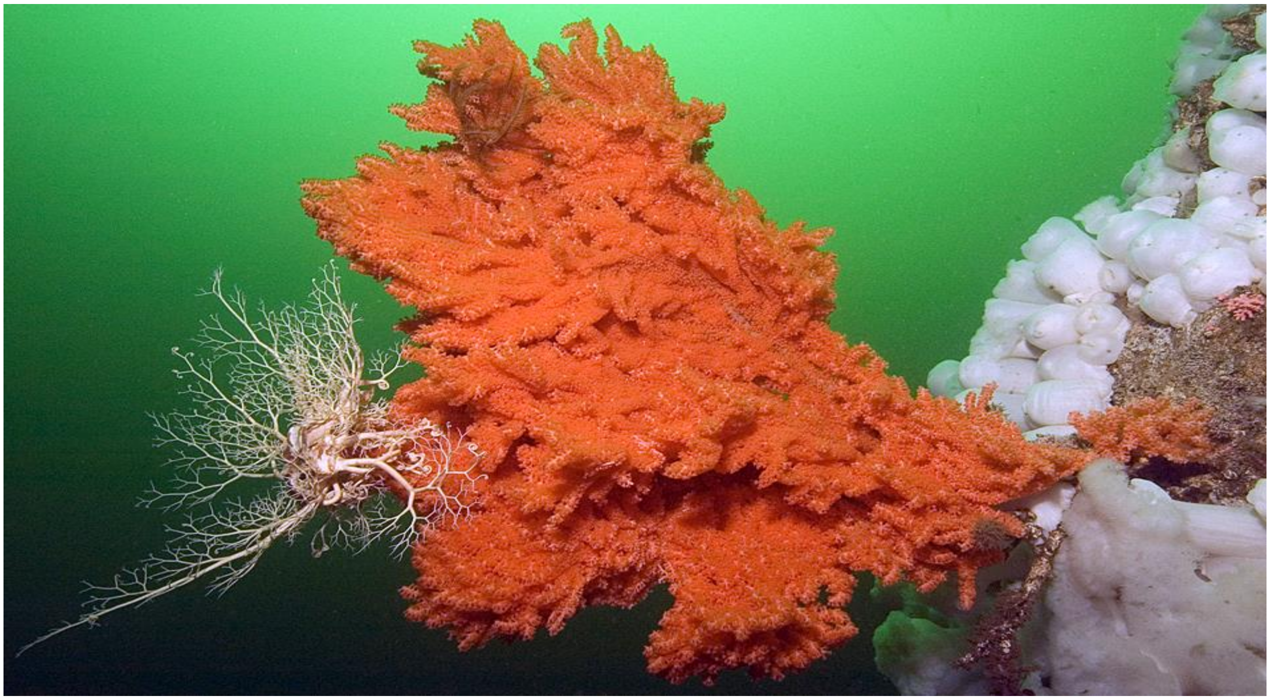

Figure 10. Primnoa pacifica *at Hoeya Head Sill in Knight Inlet. (photo credit: Neil McDaniel).*

2.5.1. Introduction

Oceanographic features such as currents, upwelling zones, and eddies are important drivers of ocean productivity and biological diversity (Crawford et al. 2007). Earlier in the EBSA process, the overlap between expert-identified, recurring regional oceanographic features and species' important areas was used to delineate EBSAs (Clarke and Jamieson 2006b); however, such oceanographic features were not assessed for the nearshore. In nearshore areas, high tidal current passages can create both areas of high mixing (e.g., in tidal rapids) and areas of local upwelling, where strong tides regularly bring deeper water to the surface. Such features can play a key role in shaping local productivity (Thomson 1981) and thus, species abundance and diversity patterns observed in coastal areas. This section highlights the importance of high tidal current in relation to diversity and productivity patterns in nearshore areas and provides an initial assessment for EBSA designation. Four locations are highlighted where biological information exists that can be used to characterize the ecological and biological importance of such areas.

2.5.2. Distribution

Given the topographic and bathymetric complexity of the NSB coastline, many areas of high tidal current likely occur throughout the nearshore region. High tidal current passages are defined here as areas where tidal flow is constrained by steep bathymetry increasing current. Although not currently comprehensively mapped, a general assessment of these features is provided against the EBSA criteria to evaluate their potential inclusion as nearshore EBSAs.

Spatial dataset

High tidal current passages occur in multiple nearshore locations, but very few targeted biological surveys are available for these locations. Here, four high tidal current passages with associated biological information are identified and mapped, highlighting their ecological value relative to the surrounding area. These areas are: Nakwakto Rapids, Hoeya Head Sill in Knight Inlet, Stubbs Island, and Mathieson Narrows (Figure 11 - Figure 14).

2.5.3. Feature description

In marine systems, the interaction among ocean currents, and between these currents and bathymetry, result in a variety of features that contribute to the mixing of deep and surface waters and thereby promote increased biodiversity and productivity. These features include: upwelling zones, eddies and plumes, and frontal zones (reviewed in Crawford et al. 2007), which can occur at oceanic, regional, or local scales. In the nearshore, these features include mixing in tidal passes, local upwelling, and internal waves, can play important roles in structuring nearshore biological communities (e.g., Tunnicliffe and Syvitski 1983; Baynes and Szmant 1989). These features take place in many passes where constricted tidal currents are deflected upward by underwater ridges, shoals, and other bottom features (e.g., Seymour Narrows, Campbell River; Thomson 1981).

Nakwakto Rapids

Nakwakto Rapids are located approximately 325 km northwest of Vancouver in the Seymour-Belize Inlet complex (Figure 11). Five interconnected basins within the Seymour-Belize Inlet complex (Belize Inlet, Seymour Inlet, Mereworth Sound, Alison Sound and Frederick Sound) are linked to Queen Charlotte Sound through a single, 300 m wide, 13 m deep passage known as Nakwakto Rapids (Thomson 1981). The rapids are situated at the eastern end of Slingsby Channel, and during extreme spring tides, currents surge at 8 m/s (16 knots) (Thomson 1981). Nakwakto Rapids has one of the fastest navigable tidal currents in the world (Spear and Thomson 2012) making this area globally unique. Nakwakto Rapids is well known within the recreational dive community for its biological diversity. Pacific Marine Life Survey Inc. (unpublished data[11]) has recorded over 240 species on dives within the rapids, including 42 algae, 16 sponges, 52 molluscs, and 17 fishes (including 11 rockfish species). The area is rated as one of the world's finest cold water dive sites, despite its hazards. Some of the species known to be abundant in the area include: Gooseneck Barnacles, parchment tube worms, rock scallops, demosponges, Plumose Anemones, Giant Pacific Octopus, and multiple species of rockfishes and other fishes (Howell 2012).

A unique subtidal variety of the Gooseneck Barnacle*, Pollicipes polymerus*, forms large aggregations at Nakwakto Rapids (Lamb and Hanby 2005). The "Nakwakto variety" of *P. polymerus*, is bright red as the hemoglobin in the barnacles' blood is visible. Subtidal populations do not need the black pigment found in the sun-exposed intertidal populations (Lamb and Hanby 2005). The red "Nakwakto variety" of *P. polymerus* has been recently reported in other subtidal areas including a sea cave on Calvert Island[12] on the central coast and Race Rocks[13] near Victoria. Because of its slow recovery rate after perturbations and its ecological role as a habitat-forming species, *P. polymerus* was identified as an ESS and conservation priority for the MPA network planning process in the NSB (DFO 2017).

[11] A. Lamb and D. Gibbs, Pacific Marine Life Survey Inc., Vancouver, BC, 2017.

[12] Biodiversity of the Central Coast – Goose neck barnacle

[13] Race Rocks Taxonomy – Goose neck barnacle

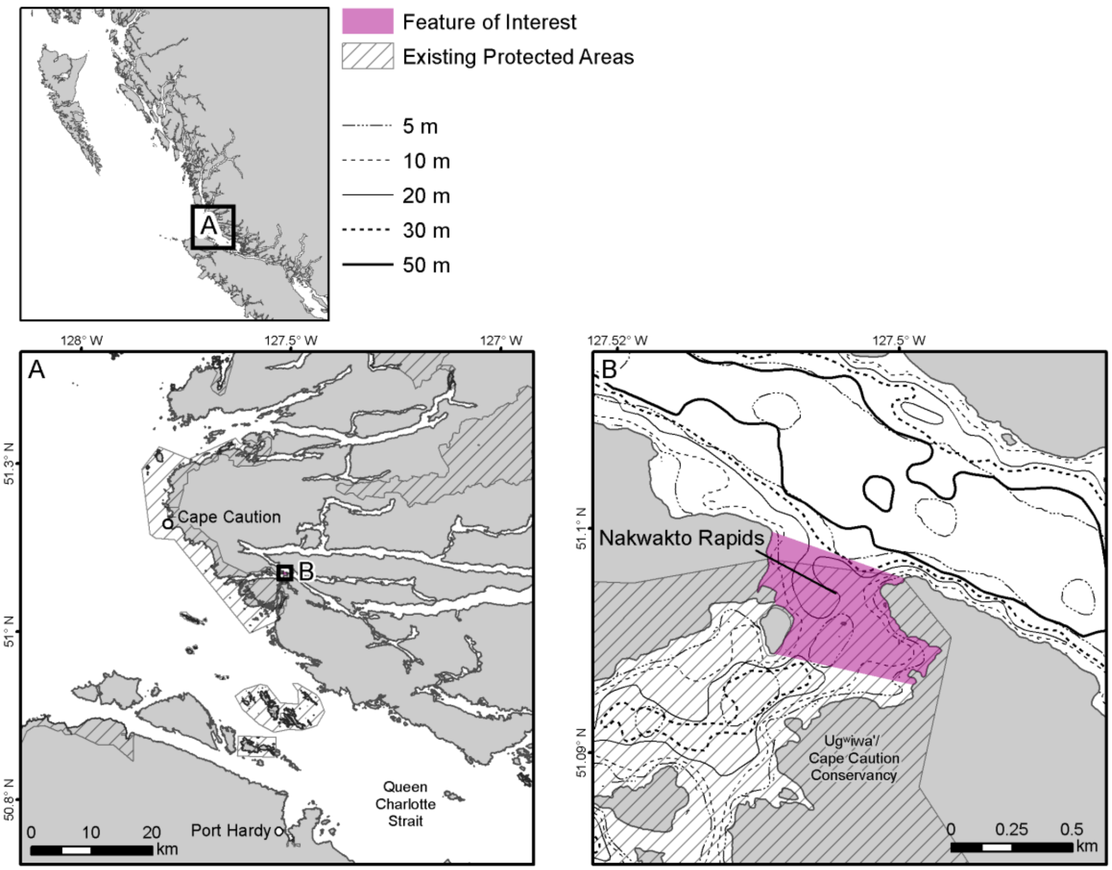

Figure 11. Nakwakto Rapids, a high tidal current passage where evidence suggests high diversity and productivity in the area. Pink areas highlight feature of interest for EBSA assessment. Final boundaries will require additional research.

Hoeya Head Sill in Knight Inlet

Knight Inlet is a fjord 300 km north of Vancouver, BC stretching 102 km into the mainland from the Queen Charlotte Strait (Figure 12). The inlet is 2–3 km wide with vertical sidewalls (Farmer and Smith 1980). Its average depth is 295 m, with a maximum depth of 540 m (Pickard 1961). There are two sills in the inlet, with the innermost sill off Hoeya Head rising up to a depth of 70 m (Thomson 1981). Hoeya Head Sill has been extensively studied because it generates internal gravity waves (e.g., Farmer and Smith 1980; Thomson 1981; Klymak and Gregg 2003; Chen et al. 2017). In this area, internal waves (waves within the water column rather than at the surface) occur during tidal cycles due to density differences between the fresh surface water and deeper salt water (Thomson 1981). Due to this tidal mixing, there is high biological productivity and diversity in the area surrounding the sill.

A recent review of biological information revealed high biodiversity at the site. Over 240 different species have been recorded on or around the sill, including several ESSs (Boutillier and Davies 2017[14]). For example, the Hoeya Head Sill contains at least 46 different species of corals, sponges and anemones. Of particular interest is the high density of Red Tree Coral, *Primnoa*

[14] Boutillier, J. and Davies, S. 2017. Evaluation of Hoeya Head Sill in Knight Inlet, Internal Report to DFO Fisheries Management.

sp., found here at shallower depths than elsewhere on the coast due to the unique oceanography of the area (Boutillier and Davies 2017[14]). Tall corals such as *Primnoa* sp. provide shelter for rockfish (*Sebastes* sp.) and crustaceans, and are used by suspension feeders (e.g., basket stars, anemones, and sponges) as perches into higher-flow waters (Krieger and Wing 2002). Corals including *Primnoa* sp. increase rockfish abundance at Learmonth Bank, Dixon Entrance (Du Preez and Tunnicliffe 2011). Corals and sponges have been identified as ESSs and conservation priorities for the MPA network in the NSB (DFO 2017) due to the biogenic habitat they provide. The known aggregations of these vulnerable groups at the Hoeya Head Sill highlight the ecological and biological significance of this area.

The Hoeya Head Sill has been identified by the province of BC and First Nations as an important ecological area in need of enhanced protection in their Marine Plan Partnership Initiative (MaPP). MaPP has zoned the area as a Protected Marine Zone (PMZ) as part of their marine spatial plan (Marine Planning Partnership Initiative 2015a). This zoning was due to the sill's ecological importance as a representative habitat of shallow-sill ecosystem comprised of coral fans and sponges, and the unique occurrence of deepwater and/or rare species at shallower depths (e.g., gorgonian corals, Soft Goblet Sponge, Cloud Sponge, Townsend Eualid Shrimp and Bigmouth Sculpin). This zoning limits human activities to commercial and public recreation and tourism activities within the Hoeya Head Sill PMZ. Research activities are “conditionally acceptable” as long as they do not impact the sensitive habitat in the area (Marine Planning Partnership Initiative 2015a).

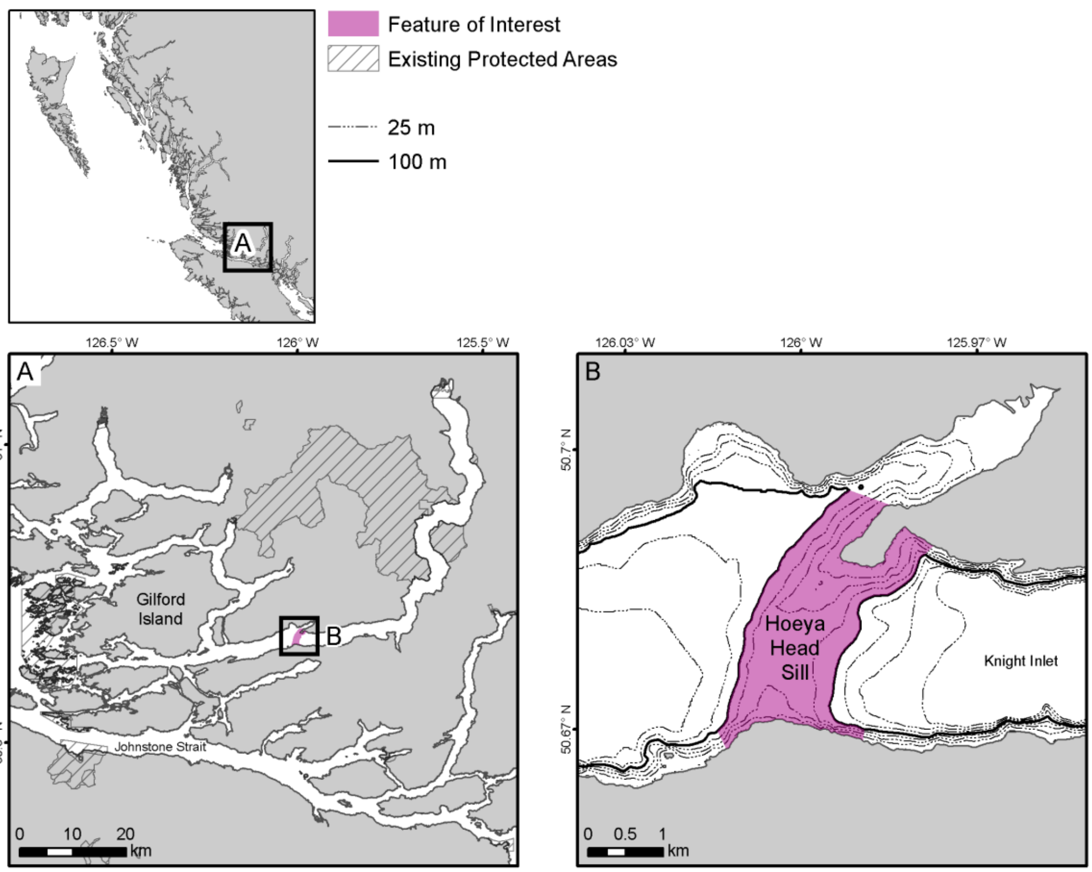

Figure 12. Hoeya Head Sill in Knight Inlet, a high tidal current passage where evidence suggests high diversity and productivity in the area. Pink areas highlight feature of interest for EBSA assessment. Final boundaries will require additional research.

Stubbs Island

Stubbs Island is situated in the Cormorant Channel Provincial Marine Park within the Pearse and Plumber group of islands at the western end of Johnstone Strait (Figure 13). The tidal channel near the island is a popular dive site with fringing kelp forests, thousands of Plumose Anemones on the steep slopes, and many soft corals, rockfish species (Dusky, China, Tiger, Quillback) and nudibranchs. Stubbs Island is located in the middle of the tidal flow and the terraced bathymetry surrounding the island forms a series of narrow ledges before a steep drop off to about 70 m (Figure 13B). Recreational divers frequent the site for its high diversity of fishes and conspicuous and colourful invertebrates (e.g., soft corals and nudibranchs). Pacific Marine Life Surveys (unpublished data[11]) has recorded 343 marine species in the area, including 54 algae, 26 different sponge species, 47 cnidarians, 74 molluscs, 33 arthropods, 23 cnidarians, and 28 fishes (including 11 rockfish species). The area of high biological diversity surrounding Stubbs Island is within the boundaries of critical habitat for the northern resident population of Killer Whales (DFO 2011b). The area of high tidal current is also within the boundaries of a larger area selected for a PMZ by MaPP in the North Vancouver Island Marine plan based on its importance to several species and habitats, including Pacific Herring, Humpback Whales and resident Killer Whales. Within the North Vancouver Island Marine Plan several activities and uses were considered inappropriate for this PMZ due to the risk to the ecology of the area, including finfish aquaculture, forestry operations, mining operations, wharves and facilities, float homes and lodges, and point source utilities (Marine Planning Partnership Initiative 2015a).

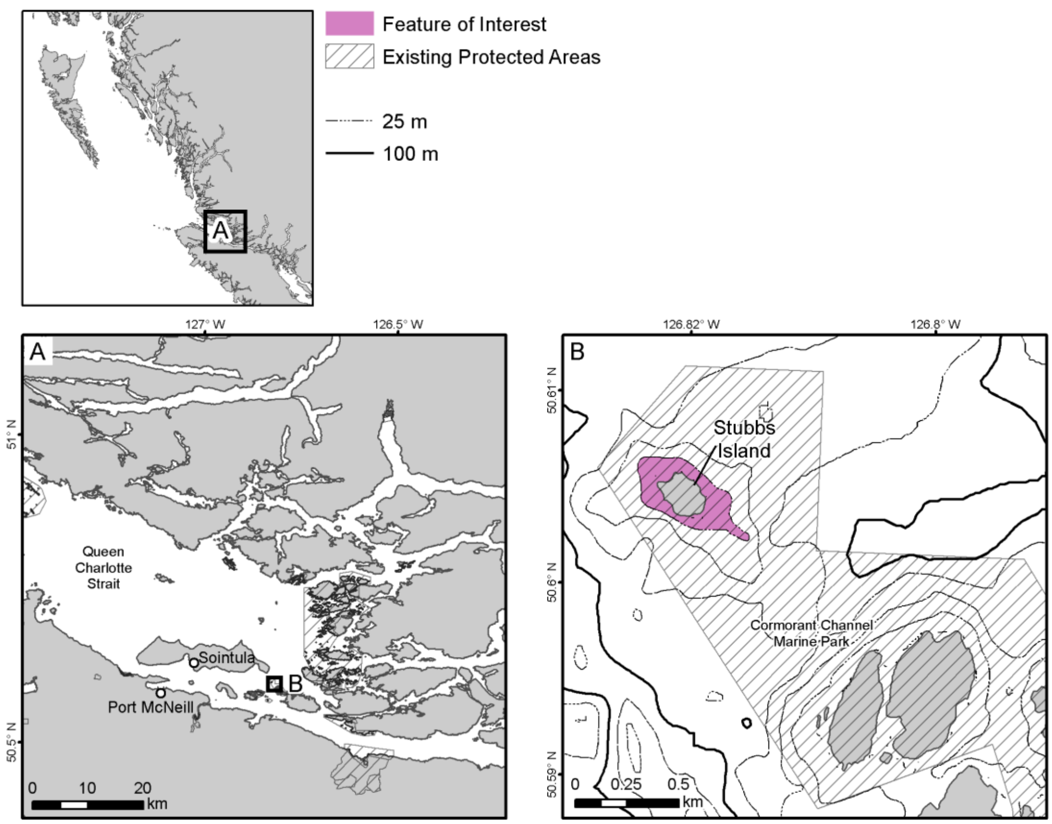

Figure 13. Stubbs Island, a high tidal current passage where evidence suggests high diversity and productivity in the area. Pink areas highlight proposed EBSA area of interest. Final boundaries will require additional research.

Mathieson Narrows

Biological surveys on the Central Coast of BC suggest that the high tidal current passage in the narrows between Pooley Island and the mainland, listed as Mathieson Narrows on marine charts (Figure 14), is important for biodiversity (Frid et al., 2016, 2018, and unpublished data[15,16]). Beginning in 2006–2007 and annually since 2013, the Heiltsuk, Kitasoo/Xai'xais, Nuxalk and Wuikinuxv First Nations have been collecting data on the population characteristics and habitats of rockfishes and other demersal fishes of the central coast (Frid et al. 2016, 2018). The systematic surveys include hook and line sampling and visual transects using a towed video camera or SCUBA. To date, the surveys have documented a diversity of biological features in Mathieson Narrows, including high abundances of Yelloweye and Quillback Rockfish, large crinoid aggregations, Cloud Sponges, and a Steller Sea Lion haulout (Frid et al., unpublished data[15,16]). Other species in the area include Lingcod, Kelp Greenling, and Copper, Dusky, Yellowtail, Black, and China Rockfish (Frid et al. 2016, 2018). Among the species recorded to date, Lingcod, Cloud Sponges, and Steller Sea Lions, as well as Copper, Quillback, and China Rockfish, have been identified as ESSs and conservation priorities for the MPA network in the NSB (DFO 2017; Table 10).

Notably, Mathieson Narrows has been identified by First Nations and the Province of BC as an important ecological area in need of enhanced protection (Marine Planning Partnership Initiative 2015b). Specifically, in the MaPP spatial plan it is part of PMZ 22—a proposed "high protection zone"—due to its high productivity, rich biodiversity and strong cultural significance to First Nations (Marine Planning Partnership Initiative 2015b). Mathieson Narrows is also adjacent to the Pooley Island Conservancy and within Fiordland Conservancy boundaries. Given the preliminary nature of the rich biological dataset in this area, it is recommended that Mathieson Narrows be highlighted as an area of interest for EBSA designation.

[15] Central Coast Indigenous Resource Alliance, Campbell River, BC, 2019.

[16] Frid et al. (2016, 2018) outline data collection and methods and provide a regional assessment of rockfish occurrence and diversity throughout the Central Coast. However, due to concerns from partner First Nations about the sensitivity of spatial data, these papers do not present maps or details specific to Mathieson Narrows. As of 2018, spatial data from these surveys, summarized at the scale of 4-km^2 planning units (including unit 13213, which encompasses Mathieson Narrows), are viewable on SeaSketch, an online mapping service used to support MPA network planning in the NSB.

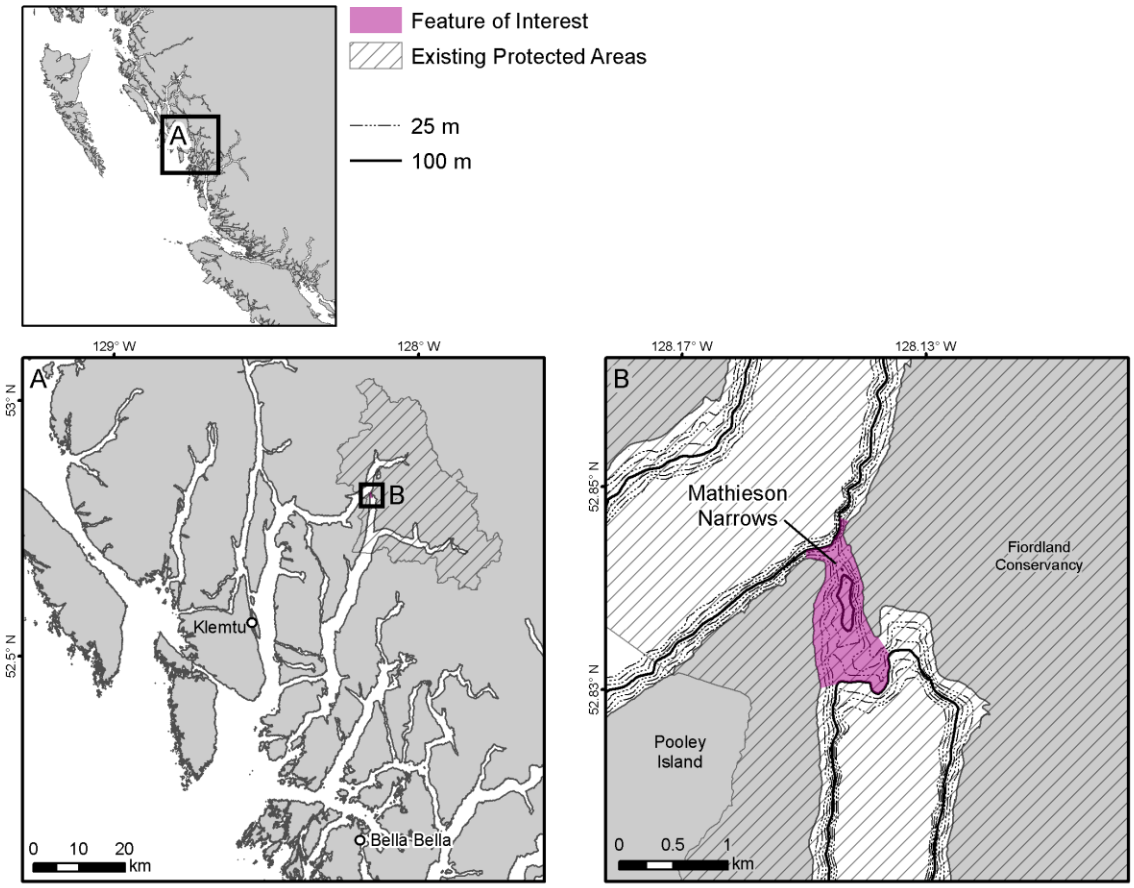

Figure 14. Mathieson Narrows, a high tidal current passage where evidence suggests high diversity and productivity in the area. Pink areas highlight feature of interest for EBSA assessment. Final boundaries will require additional research.

Species present at high tidal current passages

Several ESSs and species of conservation priority have been recorded at high tidal current areas (Table 10).

Table 10. Species identified as conservation priorities, including ecologically significant species, for the MPA network in the NSB, that have been confirmed to be present in high tidal current passages.

Species Conservation Priority	Location	Reference
Gooseneck Barnacle	Unique Nakwakto variety – Nakwakto Rapids	Lamb and Hanby 2005
Steller Sea Lion	Haulout (Aggregation) at Mathieson Narrows	Frid et al., unpublished data[15,16]
Yelloweye Rockfish	Present at Mathieson Narrows[16]	Frid et al. 2016, 2018
Copper Rockfish	Present at Mathieson Narrows[16]	Frid et al. 2016, 2018
China Rockfish	Present at Mathieson Narrows[16]	Frid et al. 2016, 2018
Quillback Rockfish	Present at Mathieson Narrows[16]	Frid et al. 2016, 2018
Lingcod	Present at Mathieson Narrows[16]	Frid et al. 2016, 2018
Corals	Aggregations at Hoeya Head Sill, present at Stubbs Island and Nakwakto Narrows	Boutillier and Davies 2017[14]; Marine Planning Partnership Initiative 2015a; Pacific Marine Life Surveys, unpublished data[11]
Cloud Sponge	Present at Hoeya Head Sill, and Mathieson Narrows	Boutillier and Davies 2017[14]; Frid et al. 2018

2.5.4. Feature condition and trends

The feature under assessment in this section, “high tidal current passage”, is a general feature, with many occurrences across the NSB. This physical habitat feature plays an important role in the spatial configuration of biological diversity found in these areas; however, the condition and trends of the feature will vary as a result of local physical dynamics. In the examples described above, the high current areas are a result of constricted tidal currents, the topography of the surrounding land, and bathymetric complexity of the area. Although erosion, and sea level rise may change the strength and fine-scale characteristics of the currents, it is unlikely that they will cease to exist or be degraded by human activity. However, the biological communities that are associated with these areas are under various threats due to human activities. More information on the spatial distribution and species composition of each area under consideration is needed prior to evaluating which activities threaten the biological communities associated with specific high current EBSAs. Furthermore, a generalized approach for categorizing and identifying “high tidal current passages” is needed, drawing on data and information from across the NSB. A method for mapping high tidal current passages is currently under development (J. Nephin, unpublished data[17]) and field surveys will be conducted to validate the model and collect data on the diversity and productivity of high tidal current areas compared to the surrounding area (led by S. Dudas).

2.5.5. Assessment against EBSA criteria

Characteristics of high tidal current passages were assessed against the EBSA criteria (Table 11).

Table 11. Assessment of areas with high tidal current passages against the eight EBSA criteria (Boxes 1 and 2). Insuffic. Info.: insufficient information.

<table>
<tr><th rowspan="2">EBSA Criteria</th><th colspan="4">Ranking of criterion relevance</th></tr>
<tr><th>Insuffic. Info.</th><th>Low</th><th>Medium</th><th>High</th></tr>
<tr><td>Uniqueness or rarity</td><td></td><td></td><td>X</td><td></td></tr>
<tr><td colspan="5">Rationale: There is evidence to suggest that particular areas of high current meet the Uniqueness criteria. For example, the Hoeya Head Sill in Knight Inlet generates an internal wave. Although internal waves occur throughout the ocean, on the BC coast, they are particularly pronounced in silled inlets and protected basins when they are covered by a thin layer of brackish water. These pronounced internal wave areas occur on Hoeya Head Sill in Knight Inlet and an area in Southern Strait of Georgia (Thomson 1981). Likely due to unique geomorphological structure of the sill and the oceanography of the area, several deepwater species are found at Hoeya Head Sill at shallower depths than normally reported (McDaniel and Swanston 2013; Boutillier and Davies 2017[14]).
Nakwakto Rapids have the highest tidal current recorded in the world, making the area globally unique (Thomson 1981). Large aggregations of the “Nakwakto variety” of the Gooseneck Barnacle found at Nakwakto rapids (Lamb and Hanby 2005) also contributes to the uniqueness of this area, despite this variety recently being discovered in other areas.
Because our assessment is limited given the lack of information on uniqueness across all the areas with high tidal current, the criterion was scored as Medium, even though Hoeya Head Sill and Nakwakto Rapids would individually score High for this criterion.</td></tr>
<tr><td>Special importance for life-history stages of species</td><td>X</td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Rationale: The information to confidently assess this criteria is limited.</td></tr>
<tr><td>Importance for threatened, endangered or declining species and/or habitats</td><td>X</td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Rationale: The information to confidently assess this criteria is limited.</td></tr>
<tr><td>Vulnerability, fragility, sensitivity, or slow recovery</td><td></td><td></td><td>Variable</td><td></td></tr>
</table>

[17] Fisheries and Oceans Canada, Victoria, BC, 2017.

EBSA Criteria	Ranking of criterion relevance			
	Insuffic. Info.	Low	Medium	High
Rationale: Not all areas of high tidal current have been surveyed for the presence of sensitive habitats or fragile species**.** However, high numbers of coral and sponge species, including shallowest known population of *Primnoa pacifica*, been recorded at Hoeya Head Sill in Knight Inlet (Tunnicliffe and Syviski 1983; McDaniel and Swanston 2013; Boutillier and Davies 2017[14]). Although Hoeya Head Sill would score High on this criteria, in general given the uncertainty in regards to unsampled areas, we have scored this as Variable until more information is gathered.				
Biological productivity				X
Rationale: Large tides on the BC coast generate strong tidal currents (Thomson 1981). These currents dominate the surface flows and result in strong tidal mixing. Tidal and wind-driven mixing are significant factors in the supply of nutrients to the surface and oxygen to bottom waters (Crawford et al. 2007). Biological surveys in areas associated with tidal passes and high current highlight the rich and diverse communities that thrive in these areas due to their high productivity. This includes the large aggregations of Gooseneck Barnacles at Nakwakto Rapids (Lamb and Hanby 2005), the high densities of large *Primnoa* sp. at Hoeya Head Sill (Tunnicliffe and Syvitski 1983; McDaniel and Swanston 2013; Boutillier and Davies 2017[14]), the crinoid aggregations and high rockfish densities at Mathieson Narrows (Frid et al. 2016, 2018, and unpublished data[15,16]) and the thousands of Plumose Anemones on the slopes around Stubbs Island. Secondary producers are highly abundant at these sites due to the high primary production at these high current sites.				
Biological diversity				X
Rationale: Areas of high current and local upwelling are highly productive, as described above. This increased productivity supports rich biological communities. Although systematic surveys have not been conducted across the coast, evidence from the four areas assessed support a high score for these areas in terms of biodiversity. Two-hundred and forty species have been reported at Hoeya Head Sill (Boutillier and Davies 2017[14]), and preliminary results of surveys at Mathieson Narrows highlight the area as ecologically important (Frid et al. 2016, 2018; Frid et al., unpublished data[15,16]). Around Stubbs island, 343 marine species have been recorded, including 54 algae, 26 different sponges, 47 cnidarians, 74 molluscs, 33 arthropods, 23 cnidarians, and 28 fishes (including 11 rockfish species) (Pacific Marine Life Surveys, unpublished data[11]). Both the area around Stubbs Island and Nakwakto Rapids are popular recreation dive sites due to their colourful and conspicuous diversity of life. Biological surveys will need to be conducted or assessed to confirm this score in areas of high tidal current not assessed here.				
Naturalness	Variable			
Rationale: Many areas of high current are heavily fished because of their productivity. The level of human impact is highly variable. Naturalness could be used as a criterion to prioritize areas for EBSA identification when a more comprehensive map of these areas is compiled. An evaluation of the effects of fishing on the sensitive habitats at Hoeya Head Sill is currently being completed (Boutillier and Davies 2017[14]), as negative impacts on *Primnoa* sp., have been reported (McDaniel and Swanston 2013). This analysis will be helpful in informing management about the impacts of human activities to the area's ecological community.				

EBSA Criteria	Ranking of criterion relevance			
	Insuffic. Info.	Low	Medium	High
Aggregation			X	

Rationale: Several species aggregate in high tidal current areas. This includes large aggregations of Gooseneck Barnacles at Nakwakto Rapids (Lamb and Hanby 2005), high densities of large *Primnoa* sp. at Hoeya Head Sill (Tunnicliffe and Syvitski 1983; McDaniel and Swanston 2013; Boutillier and Davies 2017[14]), crinoid aggregations and high rockfish densities at Mathieson Narrows (Frid et al. 2016, 2018, and unpublished data[15,16]), and thousands of Plumose Anemones on the slopes around Stubbs Island (Pacific Marine Life Surveys, unpublished data[11]). These aggregation areas are most likely related to the productivity in the area, rather than to a life history function or a seasonal aggregation. For this reason, and because this review is limited to areas where biological surveys or information has been collected, this criterion has been scored as Medium.

2.5.6. Summary

Areas of high tidal current were assessed against the EBSA criteria by considering select areas that have associated biological information. This was not a comprehensive assessment of all areas with high tidal currents in BC but rather a starting point to recognize that local tidal currents, topography and bathymetric complexity can play an important role in the creation of nearshore features that enhance biodiversity. Four specific high tidal current areas were scored as High for Productivity, and Biodiversity; and Medium for Aggregation and Vulnerability. This assessment can be used as the foundation for identifying other areas of high tidal current that may qualify for targeted biological surveys leading to EBSA designation. At this time, there is enough evidence to support the designation of Hoeya Head Sill, Nakwakto Rapids and Stubbs Island as nearshore EBSAs, although the boundaries need to be finalized. Mathieson Narrows is an area of interest for EBSA designation, and further analyses are needed to inform this designation.

3. CONCLUSIONS

Upon assessment of the eight combined DFO and CBD EBSA criteria, there is scientific support to designate canopy-forming kelp forests, eelgrass meadows, and estuaries as nearshore EBSAs. There was not enough evidence to designate surfgrass meadows as nearshore EBSAs at this time given the limited targeted biological surveys on this feature. Similarly, there is not enough spatial or paired biological information to designate all areas of high tidal current in the NSB as nearshore EBSAs. However, three specific high tidal current areas with associated biological information do have strong support for EBSA designation. These are: Hoeya Head Sill, Nakwakto Rapids, and the waters around Stubbs Island. There is building evidence to support Mathieson Narrows as an EBSA, but analyses are ongoing. It is therefore recommended that Mathieson Narrows be identified as an area of interest for future EBSA assessment.

Table 12. Summary table of nearshore features' score against 8 EBSA criteria. DFO science advice (DFO 2004) states that features or areas that rank "High" for one or more of uniqueness, fitness consequences, or aggregation, can be designated as an EBSA. A feature or area that ranks above average (Medium or High) across multiple criteria also meets the EBSA criteria (DFO 2004). ✓: the feature meets the criteria and can be considered an EBSA. ✗: the feature does not meet the criteria, or there is not enough information to complete the EBSA assessment, and at this time is not considered to be an EBSA.

Feature	Uniqueness	Life history	Threatened	Vulnerability	Productivity	Biodiversity	Naturalness	Aggregation	EBSA criteria met?
Canopy Forming Kelp	Medium	Medium	Medium	Low	High	High	Variable	High	✓
Eelgrass	Medium	High	High	High	High	High	Variable	High	✓
Surfgrass	Low	Medium	Insuff. info.	Medium	High	Insuff. info.	Variable	Insuff. Info.	✗
Estuaries	Medium	High	Medium	Medium	High	High	Variable	High	✓
High tidal current	Medium	Insuff. info.	Insuff. info.	Variable	High	High	Variable	Medium	✓*

* These are: Hoeya Head Sill, Nakwakto Rapids, and the waters around Stubbs Island. Other areas of high tidal current, including Mathieson Narrows require further research and assessment to confirm as EBSAs.

Spatial datasets were compiled for canopy-forming kelp forests, eelgrass meadows, and estuaries, and despite the limitations the available spatial datasets outlined in this report are currently the best available for these features. Areas of high tidal current have not been mapped for the entire NSB. We mapped four specific areas of high tidal current, where paired biological data exist, and three of these have been proposed as EBSAs as outlined above. The polygons of the proposed EBSAs for Hoeya Head Sill, Nakwakto Rapids, and Stubbs Islands, and Mathieson Narrows as an area of interest, are guides only as the delineation of the boundaries requires further analyses (Figures 10–13).

3.1.1. Next Steps

This assessment of nearshore features in BC represents the first step in the nearshore EBSA process by identifying features and areas that meet the EBSA criteria. The next step is to highlight or prioritize these features, based on additional criteria such as extent (or size), local diversity, naturalness/threats, and/or proximity to other nearshore EBSA features (see DFO 2018). These additional criteria require more information about the spatial extent, and biological community of the features, and more extensive analyses (e.g., multiple EBSA overlay, site optimization software or hotspot analyses) to adequately rank areas, or identify areas that support multiple nearshore ecologically important features.

As a starting point for estuaries, we recommend the use of the available rankings for Estuary EBSAs, recognizing the limitations. Estuaries have been ranked by the Pacific Estuary

Conservation Program (PECP); based on their size and use by seabirds (Ryder et al. 2007), the Skeena, the Nass, and the Kitimat estuaries stand out as priority estuaries in the NSB. However, further analyses are needed to address spatial gaps and to formally rank estuary importance by taxa in addition to birds. A recent unpublished analysis has ranked estuaries based on their importance to salmon diversity and salmon biomass (C. Robb and E. Rubidge, unpublished data[8]) that also highlighted the importance of the Skeena, the Nass and Kitimat estuaries. The regional importance of smaller estuaries on the coast should not be overlooked.

There is currently no system in place for ranking canopy-forming kelp forests and eelgrass meadows, into categories based on their ecological importance. Further research on the size (e.g., canopy or meadow extent), productivity (e.g., biomass, stipe or shoot density), diversity (e.g., species richness), and naturalness (e.g., threats, state of degradation, ecosystem intactness) across the NSB will be useful for identifying priority kelp forests or eelgrass meadows. Alternative methods such as habitat diversity hotspots, or feature overlay analyses could be used to identify areas where multiple EBSAs occur. Some of these methods were developed and highlighted in the reassessment of the existing NSB EBSAs in a Regional Peer Review Process in October 2017 (DFO 2018; Rubidge et al. 2018).

4. ACKNOWLEDGEMENTS

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