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REASSESSMENT OF THE ECOLOGICALLY AND BIOLOGICALLY SIGNIFICANT AREAS (EBSAs) IN THE PACIFIC NORTHERN SHELF BIOREGION

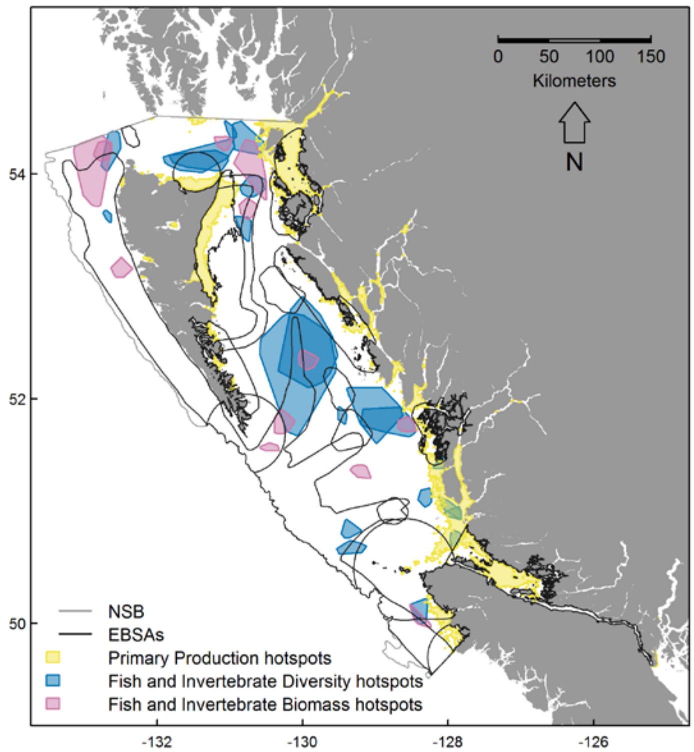

Figure 1. The Northern Shelf Bioregion (NSB) study area showing the original Ecologically and Biologically Significant Areas (EBSAs, Clarke and Jamieson 2006b, black lines) with overlays of Getis Ord Gi hotspots of fish and invertebrate diversity (blue areas, Shannon H') and biomass (pink areas); and primary production hotspots (yellow areas). The latter were identified by taking the top decile of mean near-surface Chlorophyll A concentration. Areas with overlapping indicators appear darker.*

Context:

DFO has developed guidance for the identification of Ecologically and Biologically Significant Areas (EBSAs; DFO 2004, 2011), and has endorsed the scientific criteria used by the Convention on Biological Diversity (CBD[1]) for identifying EBSAs (CBD, 2008). EBSAs in the Pacific Northern Shelf Bioregion (NSB) were identified in 2006 (Clarke and Jamieson 2006a, 2006b) and peer reviewed in 2012 (DFO 2013). DFO Oceans Sector of the Ecosystems Management Branch has requested DFO Science to review previously identified EBSAs in the NSB using available biological data. The information arising from this Canadian Science Advisory Secretariat Regional Peer Review can be used to support the refinement of existing EBSA boundaries, and help to inform MPA network planning in the NSB, including the Pacific North Coast Integrated Management Area Plan.

This Science Advisory Report is from the Nov 1-2, 2017 Reassessment of the Ecologically and Biologically Significant Areas (EBSAs) in the Pacific Northern Shelf Bioregion Regional Peer Review. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule](#) as they become available.

[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.

SUMMARY

- Ecologically and Biologically Significant Areas (EBSAs) are areas of relatively higher ecological or biological significance than surrounding areas, where greater risk aversion is required in the management of activities and which are important for the healthy functioning of the oceans and the services they provide (DFO 2004, CBD 2008).
- Following a recommendation that EBSAs should be re-evaluated and updated with new information every five years (DFO 2011) re-assessment of the original EBSAs in the Pacific Northern Shelf Bioregion (Clarke and Jamieson 2006a,b, DFO 2013) was carried out with available empirical data, to increase understanding of the underlying ecological support for the existing EBSAs.
- Available and appropriate research and commercial fishing data was collated for 44 species or species groups listed as important to the original EBSAs.
- The bootstrapping method used to compare biological data for each species inside and outside of the EBSAs was determined to be appropriate for assessing empirical support for existing EBSAs.
- Empirical support was found for all EBSAs where information was available and appropriate for analysis. Support for some EBSAs was also found for additional species that were not originally identified in those EBSAs' designation.
- A method (Getis-Ord Gi*) was presented and determined to be adequate for identifying areas of high habitat richness in the nearshore; a region not comprehensively addressed in previous EBSA processes. The extent to which the nearshore habitat richness layer can be used as a proxy for species diversity should be validated with species-specific data when available.
- Methods were presented to identify hotspots of productivity and diversity, two EBSA criteria not evaluated in the first process. Several areas were identified as having high biodiversity or high biomass (as a potential proxy for productivity) via two complementary approaches (Getis-Ord Gi* and top decile of Kernel Density Estimates (KDE)). Some of the resulting hotspots occur outside of existing EBSAs.
- The glass sponge reef EBSAs were updated with new geological signature information to include newly found reefs in Chatham Sound and several fjords.
- Areas of high habitat richness, high biodiversity, and high biomass identified in this process should be fully evaluated against the EBSA criteria using the template developed in Ban et al. (2016) prior to being designated as EBSAs.
- The data used in the EBSA reassessment were limited to what was available at the scale of the NSB for each of the species of interest. Spatial and seasonal gaps exist in some datasets. Future iterations of EBSA assessment should attempt to include a seasonal and temporal component to ensure the inclusion of migrating or transient species and to account for seasonal shifts in productivity, and climate change impacts.
- Traditional Ecological Knowledge, Local Ecological Knowledge, and First Nations Knowledge are not included in the analyses but efforts should be made to include it in future iterations. In addition, First Nations science program data should also be incorporated where possible.

INTRODUCTION

Ecologically and Biologically Significant Areas (EBSAs) are areas of relatively higher ecological or biological significance than surrounding areas, where greater risk aversion is required in the management of activities (DFO 2004, CBD 2008). Areas identified as EBSAs do not automatically trigger new management measures. 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.

Canada is committed to maintaining biological diversity and productivity in the marine environment under the *Oceans Act* (1997). Identifying EBSAs is a key component of this commitment and Fisheries and Oceans (DFO) and the Convention on Biological Diversity (CBD) have developed guidelines and criteria to identify these areas. EBSAs were identified in the Northern Shelf Bioregion (NSB) in 2006 (Clarke and Jamieson 2006a,b) using a two-phase expert-driven approach. In response to a science advice request from Oceans Sector, and following DFO Science's recommendation that EBSAs should be re-evaluated and updated with new information every five years, the existing NSB EBSAs were re-evaluated with available empirical data.

The previous EBSA process (Clarke and Jamieson 2006a,b) was completed prior to the development of the CBD (2008) EBSA criteria and relied on the DFO (2004) criteria to identify EBSAs. DFO subsequently endorsed the CBD EBSA criteria (DFO 2011), which requires identifying areas of high biodiversity and productivity to fulfil Canada's commitments as a signatory on the CBD. Although the previous process included high productivity as a justification in several existing EBSAs, quantitative metrics of productivity were not explicitly mapped. An approach for identifying areas of higher relative species diversity, higher relative habitat diversity, and higher relative productivity with resulting maps that can be used to identify EBSAs in NSB has now been included.

ASSESSMENT

Scope

The original EBSAs have been reassessed with available data to increase understanding of the underlying ecological support for the existing EBSA boundaries.

The reassessment process:

- Was limited to previously assessed species.
- Only includes adjustments of existing boundaries for the Sponge Reef EBSA
- Is strictly limited to ecological and biological importance.
- Does not include a comprehensive assessment of nearshore features. Assessment of nearshore features against the EBSA criteria is addressed in a separate CSAS process.
- Is limited by the data available for use in the reassessment analysis.

Reassessment of Existing EBSAs

To assess empirical support for the existing EBSA boundaries (Figure 2), species listed as important for each existing EBSA were summarized (Table 1). Species used to evaluate each EBSA, hereafter referred to as “important species”, were selected based on the original EBSA reports. To be included in the reassessment, the species or faunal group had to be listed as a justification of the EBSA in at least one of the following publications: Clarke and Jamieson (2006a,b), DFO (2013), or Jamieson and Levesque (2014). In addition to the justification description, the EBSA criteria for each important species or species group that was fulfilled by the area was also identified from the reports. For example, the McIntyre Bay EBSA was in part justified as an EBSA because the area is important to the fitness (specifically, feeding) for Humpback Whale and Pacific Herring (Table 1).

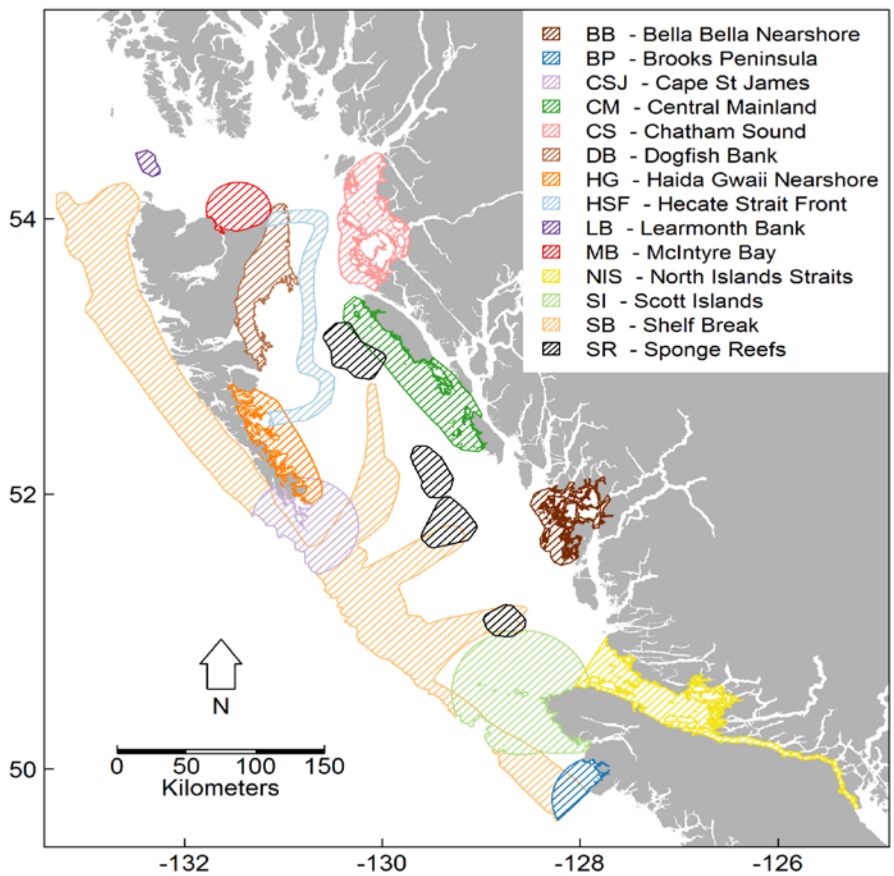

Figure 2. Existing EBSAs in the NSB (Clarke and Jamieson 2006b, DFO 2013). Bella Bella Nearshore (BB), and Haida Gwaii Nearshore (HG) were added and Central Mainland (CM) was expanded (referred to as Caamaño Sound in Clarke and Jamieson 2006b) after the CSAS RPR in 2012. EBSA #18, “River mouths and estuaries” not mapped.

Existing DFO biological survey, and other governmental, academic, and commercial data sources were used in the analysis to provide a cursory assessment of empirical support for EBSA boundaries where sampling was adequate. Survey or commercial catch data that was readily available, included metadata, and spatially covered the majority of the NSB, was collated. Data collation was limited to the species identified as important to the 17 EBSAs.

Datasets were grouped in six broad groups: fish, invertebrates, marine birds, marine mammals, diversity and productivity.

Diversity was measured by calculating species richness and Shannon diversity, using catch records from the DFO synoptic trawl. Catch per unit effort (CPUE, kg/hr) was calculated for species-level taxa within each tow. Richness and diversity were calculated separately for fishes and invertebrates. Productivity was assessed using surface chlorophyll (ChlA) data from the MODIS satellite (NASA Ocean Color).

Table 1. Summary table of "important species" by EBSA. Rows include the number and name of the EBSA and columns indicate EBSA criteria. The species listed in the cells are the species identified as important for that criterion for each EBSA. Information was summarized from Clarke and Jamieson (2006a,b), DFO (2013), and Jamieson and Levesque (2014). Species or species groups not assessed for a particular EBSA in this reassessment shown in grey italicized font.

Original EBSA Number	EBSA Name	Uniqueness or rarity	Threatened, endangered, or special concern	Fitness - Spawning, Breeding or Rearing	Fitness - Feeding	Fitness - Migration routes	Aggregation
1	Hecate Strait Front (HSF)	-	-	-	-	-	*Zooplankton*
2	McIntrye Bay (MB)	-	Killer Whale	Pacific Halibut	Pacific Herring, Humpback Whale	*Scoters*	Dungeness Crab, *zooplankton, seabirds, geese, ducks, Eulachon, Razor Clam, Weathervane Scallop*
3	Dogfish Bank (DB)	-	-	*Pacific Cod, Arrowtooth Flounder, Petrale Sole, Butter Sole, Rock Sole, Dover Sole, English Sole*	-	*Scoters*	Dungeness Crab, *shearwaters, phalaropes, Herring Gull, Ancient Murrelet*
4	Learmonth Bank (LB)	-	-	-	*Alcids*	Grey Whale	Fin Whale, coral
5	Brooks Peninsula (BP)	-	-	Lingcod, Common Murre, Tufted Puffin, Glaucous-winged Gull, Rhinoceros Auklet, *Black-legged Kittiwake*	-	*Shearwaters, phalaropes*	Sea Otter, *Green Sturgeon, Olympia Oyster*
6	Cape St. James (CSJ)	-	-	Pacific Halibut, Steller Sea Lion	-	-	Humpback Whale, Blue Whale, Fin Whale, coral, sponge, *shearwaters*
7	Shelf Break (SB)	-	Sperm Whale, Blue Whale, Fin Whale	Sablefish, Dover Sole, Pacific Ocean Perch, Yellowtail Rockfish, Yellowmouth Rockfish, Cassin's Auklet, *Ancient Murrelet,* Rhinoceros Auklet, Tufted Puffin, storm petrels	Humpback Whale, *Eulachon, Northern Fur Seal*	Pacific Hake, Grey Whale	Tanner Crab, coral, sponge

Original EBSA Number	EBSA Name	Uniqueness or rarity	Threatened, endangered, or special concern	Fitness - Spawning, Breeding or Rearing	Fitness - Feeding	Fitness - Migration routes	Aggregation
8	Scott Islands (SI)	-	-	Pacific Cod, Lingcod, Sablefish, Steller Sea Lion, Cassin's Auklet, Rhinoceros Auklet, Tufted Puffin, Common Murre, cormorants, Pigeon Guillemot, storm petrels, Glaucous-winged Gull, Arrowtooth Flounder, Petrale Sole, Butter Sole, Rock Sole, Dover Sole, English Sole, *Pacific Sand Lance,* Widow Rockfish	Pacific Hake, Pacific Herring, Grey whale, *Black-footed Albatross, Northern Fulmar, shearwaters, Herring and Thayer's Gulls, Northern Fur Seal*	-	Humpback Whale, Sea Otter
9	North Island Straits (NIS)	-	Killer Whale	Rhinoceros Auklet, storm petrels	Grey Whale	*Sockeye and Coho Salmon, Steelhead, Pacific Herring*	Humpback Whale, shrimp, Spot Prawn, Green Sea Urchin, Sea Otter
10, 11, 12, 13	Sponge Reefs (SR)	Sponge reef	-	-	-	-	-
14	Chatham Sound (CS)	-	-	Pacific Herring, *Walleye Pollock*	Killer Whale, Humpback Whale	*Scoters*	Green Sea Urchin, Dungeness Crab, shrimp
15	Haida Gwaii Nearshore (HG)	-	-	Pacific Herring, Pacific Cod, Arrowtooth Flounder, Petrale Sole, Butter Sole, Rock Sole, Dover Sole, English Sole, Steller Sea Lion	-	Grey Whale	Fin Whale, Humpback Whale, Red Sea Urchin, Red Sea Cucumber, Northern Abalone, *shearwaters*
16	Central Mainland (CM)	-	-	Steller Sea Lion, Sablefish, *Walleye Pollock*	Killer Whale, Humpback Whale, Fin Whale	Grey Whale	*Shearwaters*, Sea Otter, Red Sea Cucumber
17	Bella Bella Nearshore (BB)	-	-	Pacific Herring	*Steller Sea Lion*	Killer Whale	Sea Otter, Geoduck, Red Sea Urchin, Red Sea Cucumber, *Manila Clam,* shrimp

To test for empirical support for existing boundaries, the data were summarized into “inside” and “outside” samples. Summary statistics were calculated (mean species density, species %presence, mean diversity and mean productivity) to compare the inside and outside EBSA samples. Each EBSA was evaluated by comparing the value of each summary statistic within the EBSA to the area outside of the EBSA. In addition to the value of the summary statistic, the degree of overlap of 95% confidence intervals (calculated via a bootstrapping method) around the statistic was used to evaluate the level of support the species had for being listed as important within the EBSA. Using the 95% confidence intervals, species were semi-quantitatively categorized as having strong, moderate, or no empirical support. EBSAs were categorized as have “strong support” for a particular species when a summary statistic was greater within an EBSA than outside EBSA areas with no overlap in confidence intervals. “Moderate support” occurred when a summary statistic was greater within an EBSA than outside EBSA areas with limited overlap in confidence intervals (inside EBSA upper bound greater than outside upper bound and within EBSA lower bound greater than outside EBSA lower bound). EBSAs with “no empirical support” for a particular species occurred when a summary statistic was lower within an EBSA than outside EBSA or when complete overlap occurred between inside and outside EBSA confidence intervals (no inside/outside difference detected).

There was adequate data to test empirical support for at least a subset of important species for 16 of 17 EBSAs (Table 2). In general, there was empirical evidence for at least one important species listed in the original EBSA justification in all EBSAs except for the Hecate Strait Front. Furthermore, for all EBSAs with available data, we found additional important species or species groups that appear to be associated with the EBSAs. Although all existing EBSA boundaries do an adequate job of capturing at least a portion of areas important to the ecology and fitness of multiple species, the shape and configuration of the EBSA boundaries could likely be refined as more data become available.

Table 2. Summary table of empirical support by species for each EBSA. Empirical support (strong, moderate, or no) was assessed for species originally used to justify identification of each EBSA (Table 2), based on presence or density of each species inside and outside of the EBSA boundaries (see Figure 5–18). New species are species not previously identified for a particular EBSA. Diversity and productivity indices are listed as high ("strong empirical support"), moderate, or low ("no empirical support") for a particular EBSA. Criteria for strong, moderate or no support are defined in Section 2.3. Note that several datasets used in these analyses were not collected in all seasons. The average seasonal range across datasets was from March to October. Species that migrate or exhibit seasonal movements may not be fully represented.

EBSA Name	Strong empirical support inside	Moderate empirical support inside	No evidence for empirical support inside	New species – Strong support inside	New species – Moderate support inside	Fish and Invertebrate Diversity	Primary Productivity
Hecate Strait Front (HSF)	–	–	–	Dungeness Crab, English Sole, Pacific Halibut, Pacific Herring, Pacific Cod, Rock Sole	–	Moderate	Moderate
McIntrye Bay (MB)	Dungeness Crab	–	Pacific Halibut, Pacific Herring, Humpback Whale, Killer Whale	Arrowtooth Flounder	Pacific Cod, Petrale Sole	Low	High
Dogfish Bank (DB)	Dungeness Crab	–	–	–	–	–	High
Learmonth Bank (LB)	–	–	Coral, Fin Whale, Grey Whale	–	–	–	Low
Brooks Peninsula (BP)	Lingcod, Sea Otter, Tanner Crab, Tufted Puffin	Glaucous-Winged Gull	–	Cassin's Auklet, cormorants, storm petrels	–	–	High
Cape St. James (CSJ)	Steller Sea Lion, Fin Whale	Humpback Whale	Pacific Halibut, Blue Whale, coral, sponges	Cassin's Auklet, Common Murre, Lingcod, Pacific Hake, Pacific Ocean Perch, Tanner Crab, Tufted Puffin	Northern Abalone, Sablefish, Sperm Whale, storm petrels	Low	Low

EBSA Name	Strong empirical support inside	Moderate empirical support inside	No evidence for empirical support inside	New species – Strong support inside	New species – Moderate support inside	Fish and Invertebrate Diversity	Primary Productivity
Shelf Break (SB)	Blue Whale, Fin Whale, Humpback Whale, Pacific Hake, Pacific Ocean Perch, Sablefish, Sperm Whale, storm petrels, Tanner Crab, Tufted Puffin, Yellowmouth Rockfish	Cassin's Auklet	Coral, Dover Sole, Grey Whale, Rhinoceros Auklet, sponges, Yellowtail Rockfish	Cormorants, Lingcod, Steller Sea Lion	Pacific Halibut	Moderate	Low
Scott Islands (SI)	Cassin's Auklet, Common Murre, cormorants, Glaucous-Winged Gull, Pigeon Guillemot, Rhinoceros Auklet, storm petrels, Tufted Puffin, Sea Otter, Steller Sea Lion	Arrowtooth Flounder, Humpback Whale, Lingcod, Pacific Cod, Sablefish, Widow Rockfish	Butter Sole, Dover Sole, English Sole, Grey Whale, Pacific Herring, Pacific Hake, Petrale Sole, Rock Sole	Tanner Crab	Sperm Whale	Low	Low
North Island Straits (NIS)	Green Sea Urchin, Spot Prawn, Rhinoceros Auklet, Sea Otter, storm petrels	Killer Whale	Grey Whale, Humpback Whale, shrimp	Northern Abalone, Dungeness Crab, Geoduck, Red Sea Cucumber, Red Sea Urchin	–	–	High
Sponge Reefs (SR)	Sponge reef	–	–	Fin Whale, Pacific Ocean Perch, Spot Prawn, shrimp, Steller Sea Lion	–	Moderate	Low
Chatham Sound (CS)	Dungeness Crab, Green Sea Urchin, Pacific Herring spawn	Killer Whale	Humpback Whale	Northern Abalone, Geoduck, Spot Prawn, Red Sea Cucumber, Red Sea Urchin, sponge reef	Rhinoceros Auklet	–	High

EBSA Name	Strong empirical support inside	Moderate empirical support inside	No evidence for empirical support inside	New species – Strong support inside	New species – Moderate support inside	Fish and Invertebrate Diversity	Primary Productivity
Haida Gwaii Nearshore (HG)	Northern Abalone, English Sole, Pacific Herring spawn, Humpback Whale, Petrale Sole, Red Sea Cucumber, Red Sea Urchin	–	Arrowtooth Flounder, Butter Sole, Dover Sole, Fin Whale, Grey Whale, Pacific Cod, Rock Sole, Steller Sea Lion	Geoduck, Green Sea Urchin, Tufted Puffin	Spot Prawn	Moderate	Low
Central Mainland (CM)	Red Sea Cucumber, Sea Otter, Steller Sea Lion	–	Fin Whale, Grey Whale, Humpback Whale, Killer Whale, Sablefish	Northern Abalone, Geoduck, Green Sea Urchin, Pacific Halibut, Red Sea Urchin, Rhinoceros Auklet	Pigeon Guillemot	–	High
Bella Bella Nearshore (BB)	Geoduck, Red Sea Cucumber, Red Sea Urchin, Sea Otter, shrimp	–	Pacific Herring spawn, Killer Whale	Northern Abalone, Dungeness Crab, Green Sea Urchin, Spot Prawn	Sablefish, sponge reef	–	High

Identification of areas of high biodiversity and productivity

The previous EBSA process (Clarke and Jamieson 2006a,b) was completed prior to the development of the CBD (2008) EBSA criteria and relied on the DFO (2004) criteria to identify EBSAs. DFO endorsed the CBD EBSA criteria (DFO 2011), so identifying areas of high biodiversity and productivity is important to fulfil Canada's commitments as a signatory on the CBD. Although the previous process included high productivity as a justification in several existing EBSAs (e.g., Hecate Strait Front, Scott Islands, Chatham Sound, and Haida Gwaii nearshore; DFO 2013), quantitative measures of productivity were not explicitly mapped.

A hotspot approach was presented to identify areas of higher relative species diversity, higher relative habitat diversity, and higher relative productivity in the NSB. The term "hotspot" is used to describe an area or a region with a higher diversity at the ecosystem, species or genetic levels (Reid 1998, Hoekstra et al. 2005) and to refer to areas of high density of individual species or groups of species (e.g., Kenchington et al. 2014, Kuletz et al. 2015).

Two complementary methods (top decile kernel density estimates [KDE] and Getis-Ord Gi*) were used to identify hotspots for fish and invertebrate species diversity, and for fish and invertebrate biomass (proxy for productivity hotspots). Getis-Ord Gi* was used to identify hotspots of habitat richness, and the top decile threshold was used to identify primary productivity hotspots.

Kernel Density Estimator

Kernel Density Estimator (KDE) is a non-parametric density estimator where kernel estimators smooth out the contribution of each observed data point over a local neighbourhood. KDEs are a commonly used technique to identify areas of high use or high biomass of species or groups of species (e.g., Horsman and Shackell 2009, Kenchington et al. 2011). Areas with high density values are often called core-use areas, or hotspots. Often, core-use areas are areas of importance for life history stages (e.g., foraging, spawning, nesting, etc.) or areas of high diversity or biomass, making this approach suitable for identifying EBSAs. KDE is also a recognized approach for identifying EBSAs by the CBD (2012) particularly when used with a threshold to pull out the highest density values. To delineate the KDE hotspots, the top decile (i.e., the 90^{th} percentile threshold) of data from the KDE outputs was taken.

Getis-Ord Gi*

The Getis-Ord Gi* statistic was used to determine if measures of diversity and biomass cluster spatially. Getis-Ord Gi* is spatial hotspot approach that detects spatial clustering of either high or low values (density, relative abundance, diversity). "Hotspots" are identified where the spatial pattern of clusters are greater than expected from spatial patterns generated from random processes (Getis and Ord 1992). For example, one site with a high value of fish CPUE may be interesting but will not be identified as a statistically significant hotspot unless the neighbouring sites also have high values.

Nearshore habitat richness

Although there are extensive surveys in targeted areas along the coast of BC, there are no systematic surveys of nearshore species that span the entire coastline of NSB. To address a lack of spatial coverage for species level data, an approach was developed to map habitat richness using a measure of habitat complexity as a proxy for species diversity. A nearshore polygon to delineate the spatial extent of the analysis was created. In general, the nearshore polygon was defined as 2km from the coastline and up to 20m depth. Within the nearshore polygon, eight habitat features (eelgrass, surfgrass, canopy-forming kelp, estuaries, areas of high rugosity, and hard, mixed, and soft) were included in the habitat richness analysis. The Getis-Ord Gi* habitat hotspot analysis identified 5.8% or 2164 km^2 of coastal areas as habitat richness hotspots within the highest (99% confidence) category (Figure 3). The hotspots in the highest confidence category were concentrated in the central coast area around Calvert Island and Bella Bella. Other, scattered, high confidence hotspots were located in Chatham Sound and in multiple inlets and bays on Haida Gwaii.

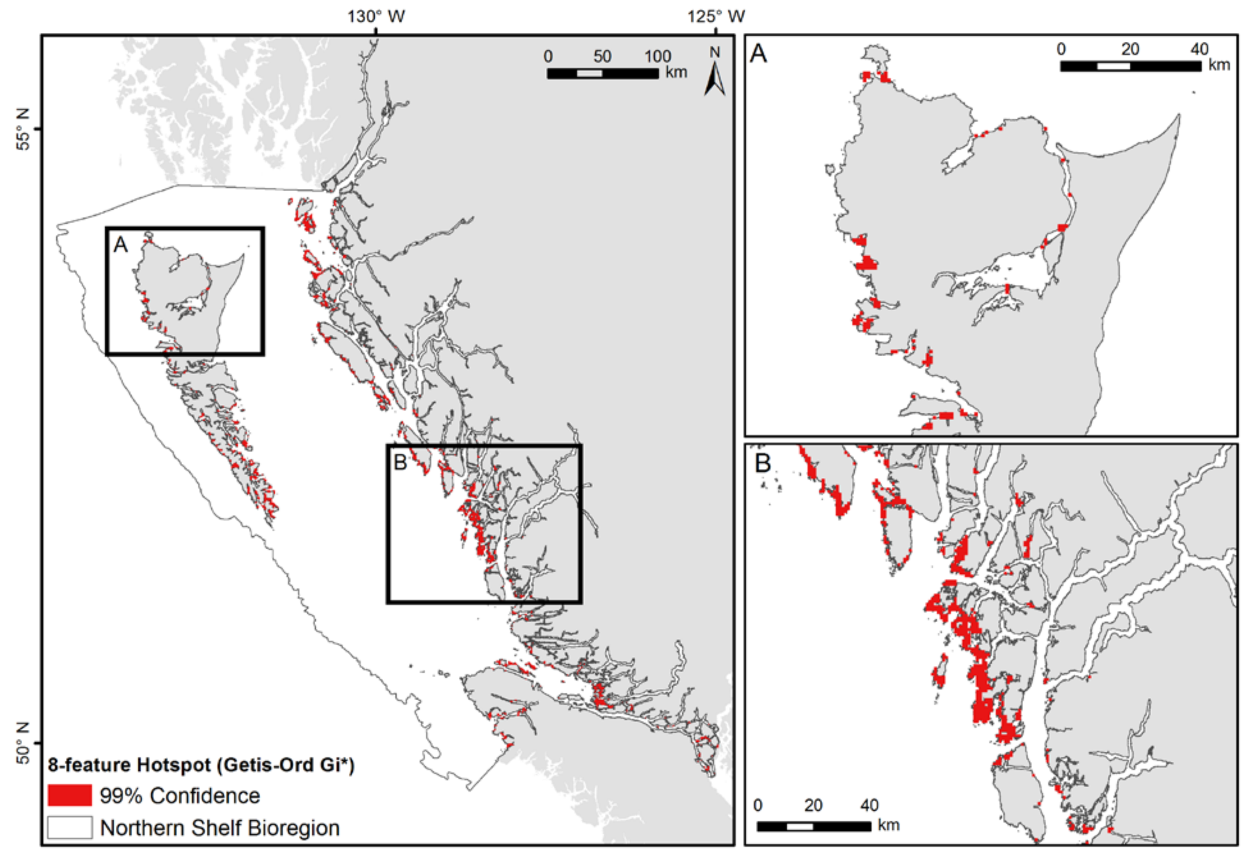

Figure 3. Example close view of hotspots identified for the number of habitat features (maximum of 8) occurring within 1 km planning units using the Getis-Ord Gi hotspot analysis, showing for only the highest hotspot category (99% confidence). A) Graham Island, Haida Gwaii; B) Queens Sound, Central Coast.*

Fish and Invertebrate Diversity hotspots

To examine the spatial distribution of alpha diversity on the shelf, Shannon Diversity was calculated using catch records from the DFO synoptic trawl (fish and invertebrates) and Pacific Halibut Management Area (PHMA) longline surveys (fish only). The two surveys have complementary spatial coverage, with the PHMA surveys occurring in more coastal areas (20–260 m) and the synoptic trawl surveys occurring on deeper shelf areas (50–1300 m).

The results of the Getis-Ord Gi* fish diversity hotspot analysis using the synoptic trawl data produced fewer hotspots but covered more area of the NSB than the synoptic KDE top decile approach (Figure 4). For the synoptic surveys the Getis-Ord Gi* approach resulted in eight fish diversity hotspots that covered 9,398 km^2, or 9.3%, of the area of NSB (Figure 4). The results of the spatial hotspot approach indicate that the Moresby Trough area, in particular, had clusters of high diversity that were higher than expected due to chance processes.

Similar to the fish diversity analysis, the KDE top decile approach identified more hotspots that covered less area than the Getis-Ord Gi* hotspot approach. The Getis-Ord Gi* approach identified 12 invertebrate diversity hotspots that covered 8,394 km^2, or 8.3%, of the NSB (Figure 4). In general, both the KDE and Getis-Ord Gi* method identified similar areas; with a large hotspot in Moresby Trough and smaller ones in the eastern area of Dixon Entrance on the north coast. Both of these areas overlap with the fish diversity hotspots, strengthening support that these areas are important for species diversity.

Fish and invertebrate biomass hotspots

Fish and invertebrate biomass were used as a proxy for examining spatial patterns of productivity in the NSB. To examine the spatial distribution of productivity on the shelf, the total biomass (total CPUE) recorded in the DFO synoptic trawl was calculated. CPUE (kg/hr) was summed across all taxa (species-level and higher-level taxa) within each tow or set. Fish and Invertebrates were run separately. Kernel density estimates and Getis-Ord Gi* hotspot analyses, as described above, were carried out for each dataset. Areas of high CPUE indicating high fish production were located on the north coast on the east side of Dixon Entrance, the area just off the northwestern tip of Haida Gwaii, and the areas off northwestern Vancouver Island. These are also areas of high fish diversity identified in the diversity hotspot analysis above.

Invertebrate biomass hotspots were identified in the waters off the northwestern tip of Haida Gwaii (Figure 4) in a similar area to the fish diversity hotspot and the fish biomass hotspots from both approaches. Other areas identified as invertebrate biomass hotspots include the area on the eastern side of Dixon Entrance off the north coast and two areas in Moresby Trough (also an invertebrate diversity hotspot).

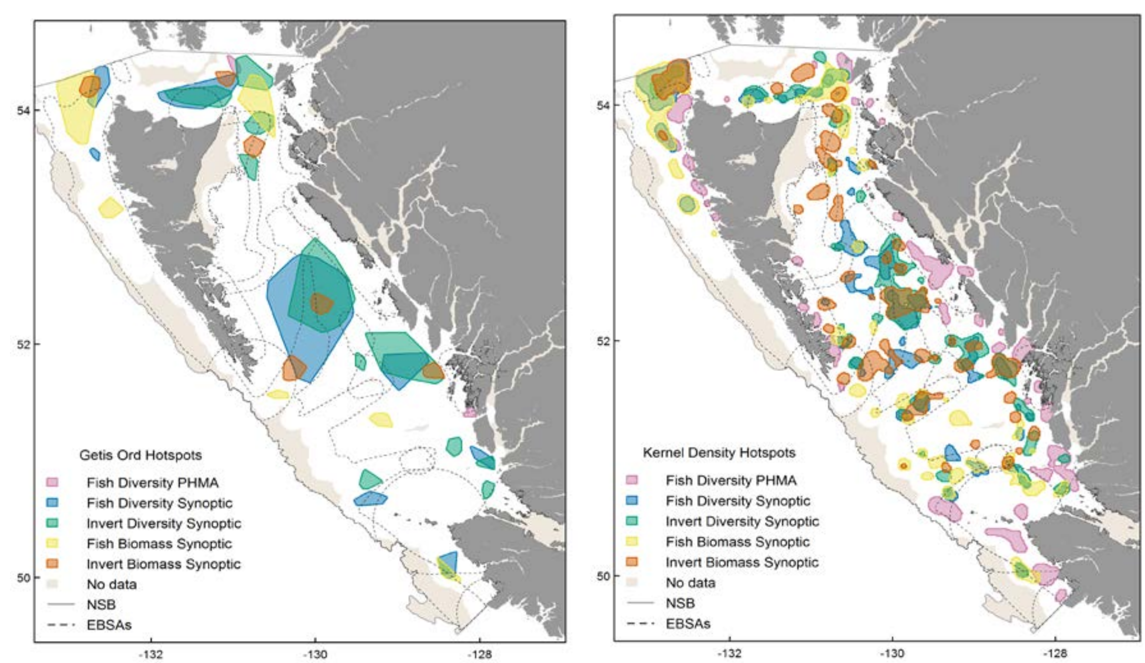

Figure 4. Hotspots of diversity and biomass determined using the Getis-Ord Gi method (left) and the KDE top decile method (right).*

Primary production hotspots

Hotspots of primary production were delineated from near-surface mean chlorophyll a concentration using the top decile threshold method. The hotspot map (Figure 5) can be used to highlight areas important for primary productivity for the EBSA process.

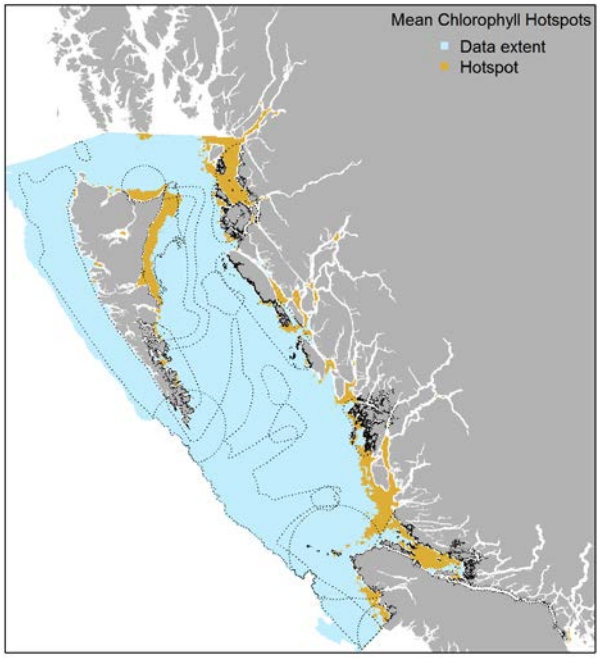

Figure 5. Hotspots of primary production derived from the top decile of mean chlorophyll A concentration (left) in the Northern Shelf Bioregion. The productivity index was derived from near-surface chlorophyll data from the MODIS satellite at a resolution of 1 by 1 km. ESBA boundaries demarcated by the dotted lines.

Comparison of Hotspot Approaches

The two hotspot approaches generally identified similar regions, but Getis-Ord Gi*, which utilizes spatial information, was more conservative in the number of areas that qualified as a hotspot. The utility of each hotspot approach depends upon the research objective. If the objective is focused on highlighting a species' distribution or core-use areas, then the KDE threshold (in this case top decile) approach is useful because the user can define the threshold based on the ecology of the species and the research question. Alternatively, if the objective is focused on highlighting the most important areas (based on the metric of interest) as opposed to the range of values across space, then the Getis-Ord Gi* approach has some advantages. First, the Getis-Ord Gi* approach is more objective because it accounts for spatial patterns in the data and not a single user-defined cut-off point. It also provides a confidence value associated with the hotspot delineation, allowing for an assessment of uncertainty associated with the resulting hotspots. Both approaches are useful methods for identifying high use, aggregations or hotspots to inform the EBSA process.

Updated Sponge Reef EBSA

Since the original EBSA process in 2006, new sponge reefs have been discovered, including geological reef signatures in Chatham Sound and several inland fjords (Figure 6; Shaw et al. 2018). Ecological surveys of the reefs are underway and there is variation in the amount of live sponge present; however, only a small fraction of the reef area has been surveyed to date. Besides the reefs' ecological importance, which is well documented, the geological signature for the reef structure alone is enough for these areas to be designated EBSAs given their global uniqueness (Krautter et al. 2001). An updated map of Sponge Reef EBSAs using the geological signature of sponge reefs was presented, buffering the geological signature reef polygons by 1 km to indicate the importance of sedimentation risk from nearby activities (the buffer size needed will vary greatly based on the area of live sponge on the reef, the substrate type surrounding the live sponge, and the currents so will need to be assessed on an individual basis). Research on the status of sponge reefs in the Pacific Region is ongoing and will be critical in informing management about how to protect and monitor these unique ecological communities[2] (DFO 2017).

[2] Dunham, A., Mossman, J., Archer, S., Davies, S., Pegg, J., Archer, E. In press. Glass sponge reefs in the Strait of Georgia and Howe Sound: Status assessment and ecological monitoring advice. DFO Can. Sci. Advis. Sec. Res. Doc.

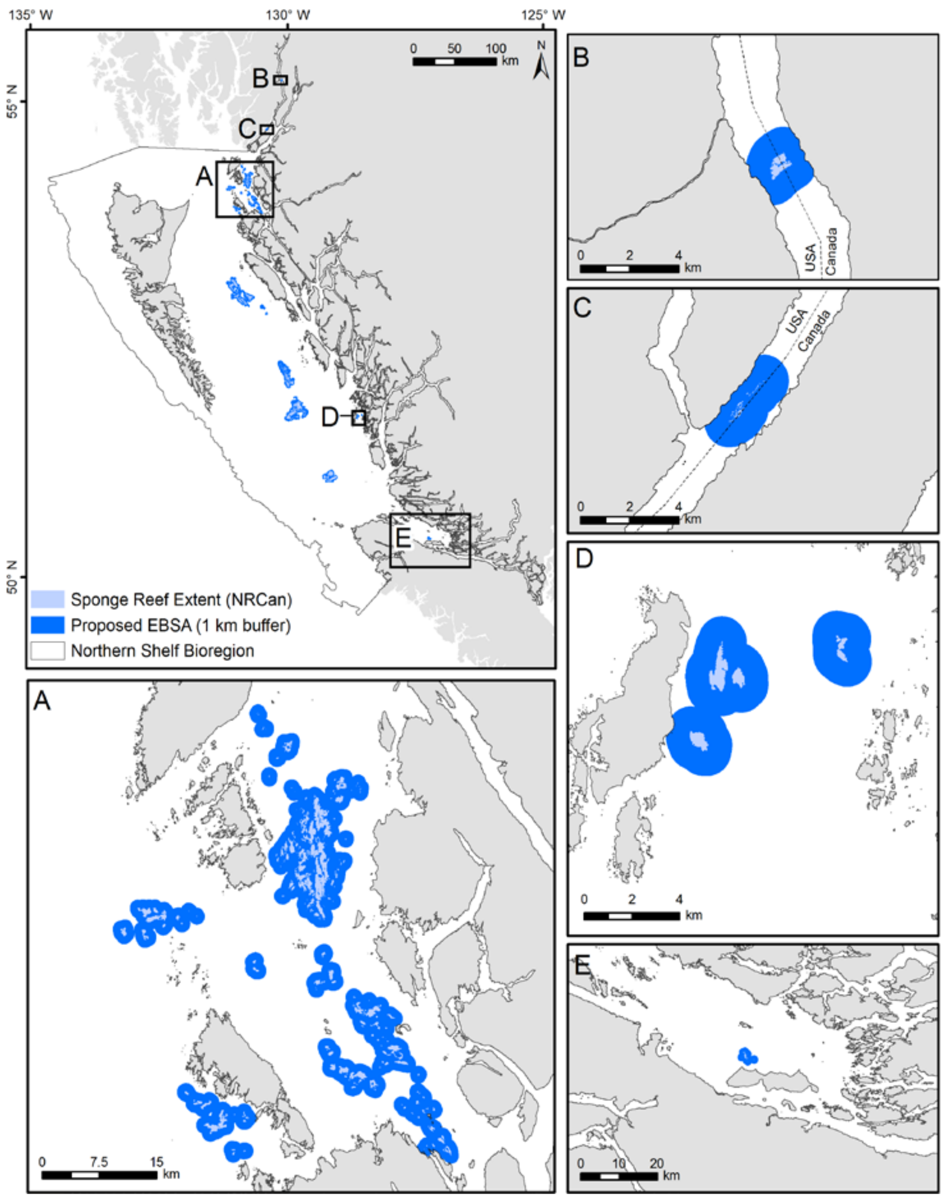

Figure 6. Extent of proposed updated Sponge Reef EBSA, which includes a 1 km buffer around all known hexactinellid sponge reef complexes in the NSB, as identified through multibeam signatures. Insets show updates to Sponge Reef EBSA from Clarke and Jamieson 2006a. A) Chatham Sound, B) Portland Canal, C) Pearse Canal, D) Central Coast, and E) Johnstone Strait.

Sources of Uncertainty

- Spatial and seasonal gaps exist in several datasets. Specifically, the majority of data were collected on surveys conducted in spring and summer months only. This may limit the ability to detect aggregations, migration, and spawning that occur seasonally and/or include species that do not frequent the area year round.
- There are more biological surveys available for individual EBSAs, but they are not available at the spatial extent of the NSB. Analyses at finer spatial scales, or at the scale of individual EBSAs, may be able to integrate local or regional datasets into the evaluation in the future.

- Traditional Ecological Knowledge, Local Ecological Knowledge, and First Nations Knowledge are not included in the analyses but efforts should be made to include it in future iterations. In addition, First Nations science program data should also be incorporated where possible.
- The use of DFO research surveys CPUE as a proxy for production does not account for biomass extraction via fisheries. Therefore, highly productive areas may not be identified as "biomass hotspots" because they are maintained at a lower biomass due to extraction.
- The sponge reef geological signature method may not capture smaller sponge reefs and sponge aggregations, and does not necessarily reflect the extent of live sponge.

Future Work

- Biomass has been used as indicator of productivity. An assessment of the validity of this approach as well as any other methods to assess the productivity of the region would improve the identification of high productivity areas.
- Predictive ecological and oceanographic models are an additional tool to assess or provide refinements of boundaries and track future changes and could be included in the EBSA process.
- Naturalness criteria was not evaluated through this reassessment but should be included in future iterations.
- Species diversity data may be used in the future to validate the habitat richness hotspots where available, to test the assumption that high habitat richness is correlated with high species diversity.
- To explicitly test and revise EBSA boundaries, targeted surveys are needed to both inform gaps in ecological information, and provide adequate spatial coverage for important species inside and outside those boundaries. For example, targeted nearshore and deep-water fjord surveys will help fill spatial gaps, particularly for fish species, and to identify coral and sponge aggregations.
- Surveys could be designed to fill seasonal gaps to ensure species that migrate or are transient are represented, as well as seasonal shifts in productivity.

CONCLUSIONS AND ADVICE

- The inside-outside method used to test empirical evidence for previously-defined EBSAs is robust and suitable for its intended purpose of evaluating empirical support for previously – delineated EBSAs. The results confirm that empirical support exists for all EBSA's where data was available and appropriate for analysis, and provide additional support for existing EBSAs for species that had not previously been identified as important for some EBSAs
- Two approaches (Getis Ord Gi* and KDE top deciles) have been accepted as appropriate to delineate hotspots of species diversity and biomass. The research objective for identifying hotspots should be considered when identifying which method is most appropriate.
- The habitat richness measure used in the nearshore has been identified as adequate for EBSA identification. However, the extent to which the nearshore habitat richness layer can be used as a proxy for species diversity should be validated with species-specific data when available.

- Several areas were identified as having high species diversity, and biomass (a potential proxy for productivity). Some of these areas occur outside of existing EBSAs and could be evaluated as future EBSAs (Example: Eastern Dixon Entrance).
- The sponge reef EBSA has been updated with new information, however smaller sponge reefs and aggregations may not be captured in current data layer.

OTHER CONSIDERATIONS

- EBSAs are vulnerable to climate change and human activities (this includes potential range shifts in the ecological components within EBSAs).

SOURCES OF INFORMATION

This Science Advisory Report is from the Nov 1-2, 2017 Reassessment of the Ecologically and Biologically Significant Areas (EBSAs) in the Pacific Northern Shelf Bioregion Regional Peer Review Meeting. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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APPENDIX: PEER REVIEW PARTICIPANTS

Last Name	First Name	Affiliation
Ban	Natalie	University of Victoria
Ban	Stephen	British Columbia Parks
Barron	Alexandra	Canadian Parks and Wilderness Society (CPAWS)
Caron	Chantelle	DFO Fisheries Management
Chaves	Lais	Haida Oceans Technical Team
Clarke-Murray	Cathryn	DFO Science
Davies	Sarah	DFO Science
Dudas	Sarah	DFO Science/Vancouver Island University
Dunham	Anya	DFO Science
Dupuis	Britt	DFO Science National Headquarters
Finney	Jessica	DFO Science
Frid	Alejandro	Central Coast Indigenous Resource Alliance (CCIRA)
Gale	Katie	DFO Science
Gregr	Ed	SciTech Consulting
Hillier	Joy	DFO Oceans
Lacarella	Josie	DFO Science - postdoc
Ladwig	Aleria	DFO Fisheries Management
Lee	Lynn	Parks Canada
Lok	Erika	Environment Canada (CWS)
MacDougall	Lesley	Centre for Science Advice Pacific (CSAP)
McIsaac	Jim	Commercial Fisheries Caucus (CFC)
Morgan	Ken	Environment Canada
Nephin	Jessica	DFO Science
Norgard	Tammy	DFO Science
O	Miriam	DFO Science
Pena	Angelica	DFO Science
Petersen	Shane	DFO Groundfish
Robb	Carrie	DFO Science
Robinson	Cliff	DFO Science
Rubidge	Emily	DFO Science
Steiner	Nadja	DFO Science
Therriault	Tom	DFO Science
Wells	Nadine	DFO Science NL

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Centre for Science Advice
Pacific Region
Fisheries and Oceans Canada
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

Telephone: (250) 756-7208
E-Mail: csap@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

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