Report on Identification of VMEs and Assessment of Impacts Caused by Trap and Longline Fishing Activities on VMEs and Marine Species

Canada
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1. Name of the Participating State

Canada

2. Name of the fishery

Seamount long-line hook and long-line trap fishery.

3. Status of the fishery

The seamount long-line fishery began in the 1970's and has been active ever since. Currently four seamount aggregations (beyond the border of Canada's EEZ) are fished, via long-line hook and long-line trap gear, by Canadian vessels.

4. Target species

Since the inception of the fishery, the target species of both the hook and trap harvesters has been sablefish (*Anoplopoma fimbria*).

5. Bycatch species

Dover sole (*Microstomus pacificus*), Pacific Ocean Perch (*Sebastes alutus*), Rougheye/Blackspotted Rockfish (*Sebastes aleutianus/S. melanostictus*), Shortspine Thornyhead (*Sebastolobus alascanus*), Longspine Thornyhead (*Sebastolobus altivelis*), Skilfish (*Erilepis zonifer*), and Canary Rockfish (*Sebastes pinniger*).

6. Overview of the fishery and recent level of fishing efforts

(1) Overview of the fishery

The seamount sablefish fishery is currently limited by several input and output control tools. Input controls limit the amount of effort that a fishery can exert on the stock/fishing ground. For the seamount fishery (including those seamounts that lay beyond Canada's exclusive economic zone (EEZ)) the effort is limited by seasonal closures, the number of vessels that can participate in the fishery, the gear permitted to be used and the size of fish that can be legally landed.

The seamount fishery is open annually from April to September; however, in any given month only one vessel is permitted to fish the southern seamount region (i.e. the region that includes actively fished seamounts that fall outside of Canada's EEZ in the Northeast

Pacific Ocean). Mobile fishing gear is not permitted in the seamount fishery; rather gear is restricted to long-line hook and long-line trap. Traps must be equipped with escape holes to reduce bycatch of juvenile sablefish and rot panels to reduce ghost fishing should gear be lost. Additionally, vessels are not permitted to land sablefish that are less than 55cm in fork length, to further reduce impact to juveniles of the target species.

Output controls limit the amount of fish that can be landed during one trip. For the seamount fishery, monthly vessel limits of 75,000 pounds of sablefish, 5,000 pounds of rougheye rockfish and 1,000 pounds of other rockfish, sole and flounder (all in round weight pounds) have been in place since 2011.

In addition to the fishing limitations, mandatory reporting and monitoring requirements of the seamount fishery provide accurate estimates of catch which are verified by a fishery-independent service provider. At-sea monitoring, via Electronic Monitoring (EM) systems, captures details of each fishing event including date, time, latitude, longitude and depth of the gear. The EM system also video records 100 percent of both retained and released catch. Harvesters are required to keep accurate records of all fishing events and catch information in their fishing logbooks. The logbooks are then audited, by an independent service provider to ensure that it represents the most accurate record of catch. Dockside monitoring is also mandatory for vessels participating in the seamount fishery. All landings are monitored by an independent dockside validator in order to verify that the number of fish landed at the dock is equivalent to the amount recorded in the logbooks.

Due to the limited capacity for research and assessment beyond Canada’s EEZ, vessels that participate in the seamount fishery are also required to take biological samples. For vessels fishing on seamounts outside the EEZ three random samples of 20 sablefish from each seamount fished during a trip must be collected for research purposes.

(2) Number of fishing vessels

The seamount fishery is managed through a lottery system in which one vessel per month, for the months of April to September, is permitted to participate in each of the northern and the southern seamount fisheries. Seamounts that are fished beyond Canada’s EEZ are limited to the southern area of the fishery, thus, in any given month from April to September, one vessel may be fishing the seamounts outside of Canada’s EEZ. The vessel that wins the lottery in any given month can choose not to fish outside the EEZ in the month they win the lottery. Due to the limited entry of vessels it is possible that no vessels would fish the seamounts beyond Canada’s EEZ in a given year, and a maximum of six vessels per year could fish these areas.

In the past 5 years (2007-2011), 10 vessels have been active in the southern seamount fishery.

(3) Tonnage of each fishing vessel

On average the gross volume of these 10 vessels is 443 cubic meters and the average length of these 10 vessels is 24.5 m.

(4) Fishing period and number of fishing days or days on the fishing grounds

The southern seamount fishery (which includes the seamounts beyond Canada's EEZ) is open to one vessel per month for the months of April through September (six month season).

Vessels that are selected to fish in the southern seamount fishery receive a licence amendment that enables them to fish for exactly 1 month on the southern seamounts. For instance, a vessel that wins the lottery for April would be permitted, through licence conditions, to fish from April 1 to April 30 in the southern seamount region, including the outside EEZ seamounts. Between 2007 and 2011, southern seamount trips ranged from 2 to 21 days in length, averaging 7 days. A total of 15 southern seamount trips were made from 2007-2011, with 96 total days spent fishing.

(5) Fishing effort (total operating hours for trawl, # of hooks per day for longline, # of pots per day for pot fishing, total length of net per day for gillnet)

A total of 316 fishing events (setting of either long-line hook or long-line trap gear) were made on the seamounts beyond the EEZ from 2007-2011. These included only 7 sets which used long-line hook gear with the remainder of the sets using long-line trap gear.

(6) Total catch by species

Table 1: Total catch (metric tonnes) by species, per year (2007-2011), outside Canada's Pacific EEZ

Species	**2007**	**2008**	**2009**	**2010**	**2011**
Sablefish	9.587	6.404	23.583	15.729	16.188
Dover Sole	NA	NA	0.001	NA	NA
Pacific Ocean Perch	NA	NA	0.01	NA	NA
Rougheye/Blackspotted Rockfish	0.017	0.352	0.85	0.418	0.626
Shortspine Thornyhead	0.003	0.005	0.038	0.026	0.027
Longspine Thornyhead	NA	NA	0.002	NA	NA
Skilfish	0.004	NA	0.027	0.115	0.075
Canary Rockfish	NA	NA	0.001	NA	NA

*source commercial fishing logbooks/landing slips

(7) Names of seamounts fished or to be fished

Four seamount aggregations that fall outside of Canada’s EEZ are actively fished by Canadian vessels and are managed as part of the Canadian Southern Seamount Fishery. These are listed here, and shown in Figure 1:

- Eickelberg Seamounts – Eickelberg and Eickelberg South
- Warwick Seamount
- Cobb Seamounts – Cobb, Far Cobb and Cobb South
- Brown Bear Seamounts – Brown Bear and Brown Bear North

7. Analysis of status of fishery resources

**Note that much of the material in this section is taken from Canadian Science Advisory Secretariat Research Document 2011/063 (Cox et al. 2011).*

Sablefish (*Anoplopoma fimbria*) inhabit shelf and slope waters to depths greater than 1500 m, from central Baja California to the Bering Sea and Japan. Genetic studies suggest a single population throughout the range, with the sablefish fished by Canadian industry on seamounts outside the Canadian EEZ likely making up a very small fraction of the total biomass. Patterns in sablefish recruitment, growth and the movement of tagged fish indicate the presence of northern and southern stocks in British Columbia waters that mix in a zone off north western Vancouver Island.

Spawning occurs from January to March along the continental shelf at depths greater than 300 m. Larval sablefish are found in surface waters over the shelf and slope in April and May.

Juveniles migrate inshore over the following six months and rear in near shore and shelf habitats until age 2-5 when they migrate offshore and recruit to deeper waters where they become vulnerable to trawl; longline trap and longline hook fisheries. Sablefish can be highly migratory, with tagged fish traveling from the inside waters of Hecate Strait and mainland inlets to the offshore waters of B.C., as far north as the Aleutian Islands, and south to U.S. waters off Oregon. Growth is rapid, with mature females reaching an average length of 55 cm, and a maximum of 80 cm, in 3 to 5 years. The oldest fish recovered from British Columbia was aged at 92 years. Age, growth and maturity parameters vary considerably among areas and depths. Maximum sizes are reported at approximately 110 cm fork length. Large year classes occur infrequently, with stock production characterized by periods of moderate to relatively low recruitment.

Given that the primary risk to conservation is the coastal multi-gear fishery targeting sablefish, stock assessment research focuses on these fishing grounds (i.e., the waters within the Canadian EEZ not including seamounts). A brief summary of coastal sablefish stock assessment research is provided here, with a more detailed description provided in Appendix 1.

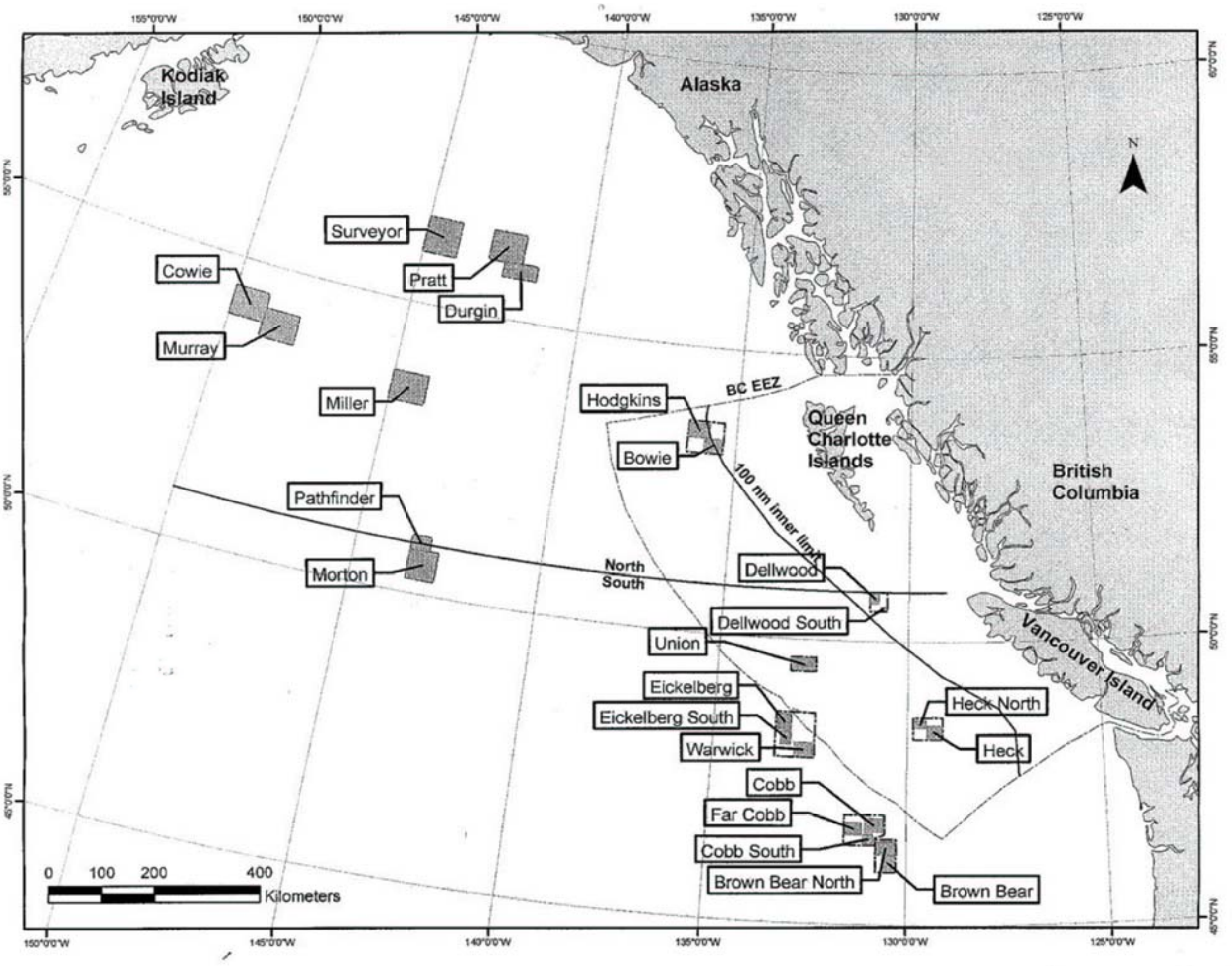

Figure 1: Location of Northeastern Pacific Seamounts. Those located outside of the Canadian EEZ and which are utilized by the Canadian seamount sablefish fishery are the Eickelberg, Warwick, Cobb, and Brown Bear seamount aggregations.

(1) Data and methods used for analysis of the coastal fishery within the Canadian EEZ

Since 2009, management of the coastal sablefish fishery has been based on a Management Strategy Evaluation (MSE). MSE is the systematic determination of the expected performance of a fishery management plan against a set of objectives. For sablefish, the relative performance of eight management procedures was compared based on performance statistics related to conservation, catch, and inter-annual stability of catch to identify a procedure that best met competing stock and fishery objectives.

Objectives for the coastal sablefish fishery were chosen based on review of the Fisheries and Oceans Canada Sustainable Fisheries Framework, as well as ongoing consultations with fishery managers and industry stakeholders. Conservation and catch objectives included:

1. Maintain spawning stock biomass above the limit reference point 0.4*B*MSY in 95% of years measured over two sablefish generations (~36 years);

2. Ensure the probability of stock decline over the next 10 years does not exceed an acceptable level defined by increasing the probability linearly from very low (0.05) at the limit reference point to moderate (0.5) at the target reference point;
3. Maintain the spawning biomass above the target reference point of *B*MSY in 50% of the years measured over two sablefish generations; and,
4. Maximize the average annual catch over 10 years subject to meeting Objectives 1-3.

Within the MSE framework, analysis is accomplished by fitting several population dynamics model "scenarios" to historical data, where each scenario reflects assumptions about uncertain natural mortality, growth and future recruitment processes. The sablefish population dynamics model is structured by age and by growth group and is fit to annual retained catch (1965-2010), annual at-sea releases (1996-2010 for trawl, 2006-2010 for longline trap and hook gears), a legacy "standardized" trap-gear survey (1990-2009), a stratified random trap-gear survey (2003-2009), commercial trap gear catch per unit effort (1979-2009), and proportions-stage determined from sampling the two surveys and the trap fishery. In contrast to the age-/size-structured operating model used to simulate the sablefish population, management procedures for setting future Total Allowable Catches (TACs) used an aggregated (ages, sexes, sizes combined) surplus production model fitted to only landed catch and the three historical abundance indices.

Estimated fishery reference points include (1) the spawning biomass at MSY, *B*MSY, and (2) the annual harvest rate of legal-size sablefish at MSY, *U*MSY.

(2) Results of analysis

Fitting the operating model to historical data under the different population dynamics scenarios suggest that (1) the spawning stock biomass is currently estimated to be below *B*MSY, and in the mid- to upper-Cautious Zone to the low-Healthy Zone, and (2) the harvest rate of legal-sized sablefish is close to the harvest rate at maximum sustained yield, *U*MSY, regardless of the stock scenario, largely due to the series of reductions in Total Allowable Catch from 4,600 t to 2,300 t between 2007 and 2010.

(3) Identification of uncertainties in data and methods, and measures to overcome such uncertainties

Scenarios focused on B.C. sablefish stock productivity, growth, and future recruitment variability. Although these uncertainties are amongst the most critical to evaluate in management strategy simulations, these scenarios do not capture the broader range of uncertainties associated with the B.C. sablefish stock and fishery. Advice is subject to several limitations based on current representation of sablefish population dynamics in the operating model scenarios, assumptions about gear selectivity, and the ability to anticipate change in the allocation of catch among gear types as the integrated groundfish fishery management program evolves. In addition, sablefish are distributed along the entire west coast of North America and undergo long distance movement among management jurisdictions. Management of U.S. sablefish stocks may therefore be an important determinant of management performance in B.C., so future work should examine trans-boundary movement hypotheses aimed at determining the best management procedures to apply in B.C. in response to stock trends in U.S. waters.

8. Analysis of status of bycatch species resources

(1) Data and methods used for analysis

See section 6(6) above.

(2) Results of analysis

Indices of abundance of bycatch species are not currently available for the seamount fishery; therefore the status of these species has not been assessed.

(3) Identification of uncertainties in data and methods, and measures to overcome such uncertainties.

See above.

9. Analysis of existence of VMEs in the fishing ground

(1) Data and methods used for analysis

Information on the species that occur in the area is based on historical submersible trips to Cobb Seamount in the 1960's, 1980's, and 1990, Canadian General Status reports from the Pacific Coast of Canada for corals, personal communications with taxonomic experts, and the scientific literature on specific corals and sponges.

(2) Results of analysis

The work carried out by Birkland (1971) and Parker and Tunnicliffe (1994) concentrated on the biota and dispersal mechanism of the biota in areas shallower then 300 m on Cobb Seamount. They found that the biota is closely aligned to the biota found in the marine areas affected by the California current (southern British Columbia, Washington State, Oregon, and California).

In the General Status report, over 80 corals were identified in B.C. waters (Boutillier and Gillespie, in prep.) while 101 deep water corals were reported by Whitmire and Clarke from California to Washington region in the NOAA coral status report on deep water corals in the USA (Lumsden et al. 2007). There are a number of overlaps in species between these two reports, and the required next steps are to look for those animals that overlap in the reports which are known to occur in this same California current bioregion and within the depth range of the fishery impact. Once this is done, information will be gathered on what, if anything is known about the recovery potential characteristics of the potentially impacted species. Generally speaking, many of the species that may be in this region are known to have life history characteristics that will make them vulnerable with poor recovery potentials.

(3) Identification of uncertainties in data and methods, and measures to overcome such uncertainties

The current or past biodiversity (except for the fish catches) in the areas impacted by the fishery is not known, because the gear does not retain sessile organism (DFO, 2010 and Boutillier et al. 2011). It is speculated that the corals and sponges may be similar to those found in equivalent depth ranges on the coastal shelf areas.

This may not be all that accurate as seamounts are often associated with a high degree of endemism and upon further study to look more carefully at some of these regions, new records and new species are constantly found. Henry Reiswick (pers. comm.) has recently been working on describing two species of glass sponges from the Brown Bear seamount.

10. Impact assessment of fishing activities on VMEs or marine species including cumulative impacts, and identification of SAIs on VMEs or marine species, as detailed in Section 5 above, Assessment of SAIs on VMEs or marine species

DFO carried out a Canadian Science Advisory peer-reviewed science meeting to document the pathways of effect and benthic impact of all non-mobile fishing gear (DFO 2010). In the review of trap gear it was noted that traps can impact biogenic structures (e.g., sponges, corals) through crushing or entanglement. Crushing and scouring effects can result during deployment of the gear and during retrieval if traps are dragged across the bottom during retrieval or during periods of strong currents (e.g., storms, tides).

(1) Data and methods used for analysis: Cobb Seamount Impact Assessment

Preliminary assessment of fishing activities on VMEs at Cobb Seamount were undertaken to address (a) the intensity or severity of the impact at the specific site being affected; (b) the spatial extent of the impact relative to the availability of the habitat type affected, and; (c) the sensitivity/vulnerability of the ecosystem to the impact.

Data and methods used in the assessment are summarized here and described in more detail in Appendix 2.

(a) The intensity or severity of the impact at the specific site being affected

For the years 1995-2011 the sablefish fishery (a long-lined trap fishery) on Cobb Seamount was carried out at depths ranging from 300-1600 m. Locations, depths, long-line length, and trap size from each fishing event (sets; n = 611) were recorded in logbook and observer programs and obtained from Fisheries and Oceans Canada databases (PacHarv and GFFOS; 1995 - 2011). These metrics were used to determine the area impacted by the fishery under two scenarios. The total length of the long-line string was used in the analysis, as the long-line is also capable of impacting VMEs through entanglement and by shearing actions during retrieval. The two scenarios were:

Scenario 1: area impacted = string length * trap size

Scenario 2: area impacted = string length * (trap size * 1.5) – this assumes a moderate degree of gear dragging during the retrieval process.

(b) The spatial extent of the impact relative to the availability of the habitat type affected

The spatial extent of the impacts were calculated for each 100 m depth range by dividing the total area impacted for that depth range by the total area available in that depth range.

(c) The sensitivity/vulnerability of the ecosystem to the impact

Ecosystem components for which sensitivity/vulnerability are to be assessed are corals and sponges that meet some or all of the criteria outlined for VMEs in the FAO International Guidelines for the Management of Deep-sea Fisheries in the High Seas (FAO 2009) and the Canadian Policy for Managing the Impact of Fishing on Sensitive Benthic Areas (DFO 2012). Any dislocation or damage to the organisms considered in this report is assumed to cause mortality and have a significant adverse impact (as defined by FAO and the guidance document for this RFMO).

(2) Results of analysis: Cobb Seamount Impact Assessment

The main area of focus for the fishery on Cobb Seamount is between 600-900 m. The Average annual percentage of the area impacted by each depth strata varied from .001-.324% for scenario 1 and .001-.485% for scenario 2. It varied annually for many depths with the exception of 700 and 800 meters which were consistently fished over the period of fishery examined. Over the 17 year period of the fishery reported in this analysis, the largest impacts to habitats were in the 700+, and the 800+ meter depth strata. If one assumed no overlap between the gear sets over time (which is a highly unlikely assumption) the accumulated maximum percentage of the total area impacted by gear set using scenario 1 and 2 in the 700+ and 800+ depth strata were 4.4-5.5% respectively for scenario 1 and 6.7-8.8% respectively for scenario 2, over the 17 year period.

Kaiser et al. (2006) recognized that even a low level impact that occurs on a large scale (i.e., spatially or temporally) can result in serious ecological consequences. This is true especially when the impact is large compared to the scale of the ecosystem feature being impacted, or if that feature has a crucial ecological role. Even an infrequent impact can have serious ecological consequences if the feature being impacted is rare, highly vulnerable, and slow to recover. Chronic impacts that are widespread may be hard to distinguish from the natural variations that occur outside the realm of proper management and therefore their severity may be challenging to evaluate until it is too late and the biodiversity is extirpated and ecosystem function is compromised.

(3) Identification of uncertainties in data and methods, and measures to overcome such

uncertainties.

There are a number of uncertainties that need to be addressed to really understand the risks of this fishery in the region, including:

i) A need to know what the biota is in the region being impacted.

ii) Work to address the uncertainty associated with the extent and nature of impacts of the traps and groundline on marine habitats, which is dependent on a variety of factors (DFO 2010). Such work will need to account for overlaps and understand the true footprint of the gear during setting and retrieval. It should be noted that restricting the fishing to good weather months should reduce the footprint of the gear as the vessel should be able to keep on-top of the gear more effectively and reduce dragging it along the bottom. Other characteristics that might impact the footprint of the gear include:
   - Characteristics of the bottom where sets are made (sediment type, relief and depth);
   - Weight, size, and construction material of traps;
   - Retrieval methods and sea state (i.e., weather, tides, currents, etc.);
   - Type of rope (floatlines are less likely to entangle bottom structures);
   - Soak time;
   - Use of anchors or weights; and
   - String configuration (e.g., length) can affect degree of entanglement on bottom.

iii) The assessment of the impacts needs to understand the cumulative effects of all nations fishing activities or other activities in this same region.

iv) More information (either through directed experiments or comparative studies) is required on recovery rates of VMEs. Kaiser et al. (2007) did note that a measure of abundance may adequately describe comparisons for some fauna; it may not adequately describe recovery for larger biota such as sponges and corals. Biota with large body-sizes is generally more vulnerable and has lower intrinsic rates of production. It was suggested that if data could be collected, then indicators such as the slope of the body-size spectrum of the benthic assemblage may provide a good measure of the state of the entire assemblage in response to disturbance treatments (Duplisea & Kerr 1995, Duplisea et al. 2002, Jennings et al. 2002). They suggest that future studies on the direct effects of fishing activity should quantify changes in body-size of fauna in addition to changes in abundance.

No detailed work has been conducted on these remaining three factors for the high seas area to date: (a) the ability of an ecosystem to recover from harm, and the rate of such recovery; (b) the extent to which ecosystem functions may be altered by the impact; and (c) the timing and duration of the impact relative to the period in which a species needs the habitat during one or more life-history stages.

However, there has been some work carried out to address domestic issues based on an assessment framework for addressing fisheries and other anthropogenic impacts on sensitive benthic areas (Boutillier et al. 2010 and Boutillier et al. 2011). This framework has been recently modified to incorporate the questions outlined in the Canadian Species at Risk Act Revised Protocol for Conducting Recovery Potential Assessments (DFO 2007) and the criteria developed for DFO Ecologically and Biologically Significant Areas (DFO 2004) and Ecologically Significant Species. Although the framework has been developed to address issues within Canada's EEZ, an improved understanding of anthropogenic impacts to VMEs, and the methodologies required to assess these, will be facilitated by this framework, and could be applied to other regions in the future.

Appendix 3 provides a summary of the types of questions that could be the focus of and guide the assessment framework for addressing fisheries and other anthropogenic impacts on sensitive benthic areas.

11. Other points to be addressed

A joint DFO/NOAA team undertook a joint ROV/AUV survey of Cobb Seamount in July 2012. Two of the objectives for the program were to: 1) document the occurrence, location, abundance and size of the flora, fauna and habitats to characterize the benthic community structure; and 2) to document and characterize evidence of fishing gear impacts. This report can be updated once the results are analyzed.

12. Conclusion

The current Canadian seamount fishery does not pose a conservation concern to sablefish populations. Input controls used to manage the Canadian fleet, which control effort and when the fishery takes place, have been effective to date. However, measurable policy objectives for management of the seamounts outside the EEZ should be in place in order to determine what level of impact is acceptable to allow for fishing activity. To implement these policy objectives, more data needs to be gathered in order to assess impacts, and additional mitigation measures to remove potential hazards should be considered.

Appendix 1

Coastal Sablefish (Anoplopoma fimbria) Stock Assessment Summary

Since 2009, management of the coastal sablefish fishery has been based on a Management Strategy Evaluation (MSE). This approach was initially explored on a pilot basis and subsequently adopted for the 2009/2010 and future fishing years due to the high degree of uncertainty in many features of stock dynamics (e.g. natural mortality, growth, recruitment) and observational data sets (e.g. catch, age/size sampling, indices of abundance) used in stock assessment. The MSE approach also enabled the establishment of a consistent, repeatable, and collaborative process for developing a fisheries management system, which is consistent with Canada's fisheries policies.

MSE is the systematic determination of the expected performance of a fishery management plan against a set of objectives. Such evaluation implements the Precautionary Approach by dealing explicitly with multiple levels of uncertainty (e.g. data, modelling, implementation) when choosing a management strategy. Analysis is accomplished by fitting several population dynamics model "scenarios" to historical data, where each scenario reflects assumptions about uncertain natural mortality, growth and future recruitment processes. Each resulting stock scenario is used to generate future data available for assessment and decision-making, as well as sablefish stock responses to exploitation. Simulation projections are used to test the performance of alternative choices for survey data, stock assessment methods, harvest control rule specification, and future at-sea release regulations. Each unique combination of these elements defines a management procedure. For sablefish, the relative performance of eight management procedures was compared based on performance statistics related to conservation, catch, and inter-annual stability of catch to identify a procedure that best met competing stock and fishery objectives.

The sablefish fishery objectives for sablefish were chosen based on review of the Fisheries and Oceans Canada Sustainable Fisheries Framework and ongoing consultations with fishery managers and industry stakeholders. Conservation and catch objectives included:

1. Maintain spawning stock biomass above the limit reference point 0.4*B*MSY in 95% of years measured over two sablefish generations (~36 years);

2. Ensure the probability of stock decline over the next 10 years does not exceed an acceptable level defined by increasing the probability linearly from very low (0.05) at the limit reference point to moderate (0.5) at the target reference point;

3. Maintain the spawning biomass above the target reference point of *B*MSY in 50% of the years measured over two sablefish generations; and,

4. Maximize the average annual catch over 10 years subject to meeting Objectives 1-3.

The sablefish population dynamics model is structured by age and by growth group, where the latter dimension is required to allow evaluation of size-based at-sea releases and potential measures to mitigate the impact of post-release mortality. Sexes are combined and a stochastic Beverton-Holt stock-recruitment relationship is assumed. Leading model parameters include stock recruitment steepness, natural mortality, and un-fished equilibrium spawning biomass. Estimated fishery reference points include (1) the spawning biomass at MSY, *B*MSY, and (2) the annual harvest rate of legal-size sablefish at MSY, *U*MSY. Fishery reference points are set relative to a target spawning biomass at maximum sustained yield (MSY), *B*MSY, with limit and upper stock reference points at 0.4*B*MSY and 0.8*B*MSY, respectively. The model is fit to annual retained catch (1965-2010), annual at-sea releases (1996-2010 for trawl, 2006-2010 for longline trap and hook gears), a legacy "standardized" trap-gear survey (1990-2009), a stratified random trap-gear survey (2003-2009), commercial trap gear catch per unit effort (1979-2009), and proportions-stage determined from sampling the two surveys and the trap fishery. Four base stock scenarios were constructed based on assumptions about natural mortality and growth rate and four additional scenarios were developed by assuming auto-correlation in future recruitment and by selecting a "low probability, low productivity" case. The performance of procedures against these latter four "robustness testing" scenarios was considered relative to Objective 1, i.e., to ensure that the limit reference point was not breached in greater than 5% of the years over two sablefish generations.

In contrast to the age-/size-structured operating model used to simulate the sablefish population, management procedures for setting future Total Allowable Catches (TACs) used an aggregated (ages, sexes, sizes combined) surplus production model fitted to only landed catch and the three historical abundance indices. It is important to note that only one or two fishery-independent survey indices are used by the production model in the future. Production model performance was adjusted, or "tuned", by setting the precision of Bayesian prior distributions on key management parameters to be relatively high or low. Production model outputs are translated into retained catch using a PA-compliant harvest control rule (DFO 2006) configured to reduce the removal rate at either 80% or 60% of the estimated *B*MSY.

Operating model fitting to historical data under the four base scenarios suggest that (1) the spawning stock biomass is currently estimated to be below *B*MSY, and in the mid- to upper-Cautious Zone for three scenarios and the low-Healthy Zone for the other, and (2) the harvest rate of legal sablefish is close to the harvest rate at maximum sustained yield, *U*MSY, for all four scenarios largely due to the series of quota reductions from 4,600 t to 2,300 t between 2007 and 2010.

The performance of management procedures evaluated through closed-loop simulation projections indicates that Objective 1 is highly likely to be met, regardless of the procedure or the operating model scenario, because all procedures tended to produce both short-term and long-term stock growth. The ability of management procedures to meet Objectives 2 and 3 depended on the operating model scenario, because these two objectives were tied to reference points, which differed among scenarios. For instance, under the more pessimistic scenarios (i.e., current biomass in mid-Cautious Zone, lower productivity), all procedures allowed the spawning biomass to grow towards *B*MSY, but none could maintain spawning biomass above *B*MSY in 50% of years because the time horizon (36 years) is simply too short. Even a perfect information procedure failed to achieve Objective 3 in some of these cases. On the other hand, procedures generally maintained the spawning biomass in the Healthy Zone in at least 50% of years for all scenarios except the most pessimistic one.

Appendix 2

Cobb seamount fishing impact assessment methodology

For the years 1995-2011 the sablefish fishery (a long-lined trap fishery) on Cobb Seamount was carried out at depths ranging from 300-1600 m. Data for this analysis were obtained from logbook and observer programs as well as published reports on the nature of the impacts.

The data were used in the following manner to determine the area of impact of the fishery:

- 611 fishing events (sets) from Fisheries and Oceans Canada databases (PacHarv and GFFOS; 1995 - 2011).
- String length was determined by the number of traps set multiplied by the distance between traps. This does not include additional line to set anchors at either end of the string (likely another 46 m at each end).
- In 2006, 2007, and 2008 fishing event records did not include the number of traps or distance between traps. For these years string length was estimated as 60 traps set 46 m apart.
- Trap size used in all calculations was 137 cm. Some records report traps that are 122 cm and some records do not report trap size.
- Two scenarios for area impacted were investigated. The total length of the long-line string was used in this calculation, as the long-line is also capable of impacting VMEs through entanglement and by shearing actions during retrieval:
    - Scenario 1: Area impacted = string length * trap size
    - Scenario 2: Area impacted = string length * (trap size * 1.5) – this assumes a moderate degree of gear dragging during the retrieval process (based on some observed impacts).
- Depth for each fishing event was calculated at the mid-point of the string.
- Analysis was carried out for 100m depth intervals (e.g. 300-399; 400-499 etc.).
- There are no mid-points that fell into the 1300m or 1400m bins, but there are fishing events that cross these depths.
- There are 14 sets in which no depth was recorded; thus depth was documented as unknown.

Appendix 3

Assessment Framework for Addressing Fisheries and Other Anthropogenic Impacts on Sensitive Benthic Areas

The framework will try to provide science advice on the following questions:

- What are the species (populations) of flora and fauna that are going to be impacted? An accurate description of the species in the area of impact is essential to undertake an ecosystem assessment, especially to evaluate species rarity – the existence of a species at a relatively low abundance in an ecosystem.
- Age and/or-size compositions are complementary to abundance if available.
- What is the role of the species in the ecosystem? Understanding the ecological role of the species in the area will give us an idea of the risk to the ecosystem functioning (again at various scales). Ecologically Significant Species outlines some of the key roles species may play which if impacted significantly could change the functioning of the ecosystem.
    - Forage species – Small schooling fish (or other marine taxa) that serve as an important source of food for marine predators, including other finfish and invertebrates, seabirds and marine mammals (e.g. zooplankton, kelps and sea grasses, marine invertebrates, herring, sand lance, eulachon, harbour seals).

    - Highly influential predators – Species that, in food webs, have high interaction strengths as predators. They are connected to a large number of prey species given the overall richness of the food web, and consume enough of those prey to influence their prey's population dynamics.

    - Nutrient importing/exporting species – Species which play a crucial role in maintaining ecosystem structure and function through the transfer of energy or nutrients that would otherwise be limiting to an ecosystem, into the area from sources outside the spatial boundaries of the ecosystem in question. This attribute can include all migratory species.

    - Structural species – Species which create habitat that is used preferentially by other species, either emergent from the seafloor or through burrowing into the substrate (e.g. eel grass beds, kelp beds, mussel beds, and sponge dominated communities). To be ecologically significant, the dominant species or type should be abundant enough and sufficiently widely distributed to influence the overall ecology (biodiversity) of that habitat.

    - Harmful and non-indigenous species (invasive species) – Marine or freshwater animals species or aquatic plant species that have been introduced or could potentially be introduced into a new aquatic ecosystem that cause or potentially cause harmful impacts to the natural resources in the native aquatic system and /or human use of the resource.

  - Harmful or toxic species – Harmful algae includes phytoplankton species that are harmful to marine organisms, humans, other animals or the environment. Non-toxic species may be considered harmful if they detrimentally affect other organisms by physical or chemical means.

- What is the current status and trajectory of the species (or population)? This will need to be completed at various scales i.e. globally, regionally (Pacific region of Canada); and the bioregional scale. The first two will give the status of the biodiversity at the species level the finer scale assessment will give the potential status at potentially the population level (this will be informed by various pieces of information but ultimately genetic markers are the most reliable). In the absence of information on what constitutes a population, the approach used in many fisheries is to manage on a finer scale. For example, prawns are managed on a sub-area basis while geoducks are managed on a bed basis. To determine the finer scale impact, it is important to have sampling inside and outside the impacted area and that the data be reported in a manner that would allow an assessment of the population of the biodiversity element and the loss of the population attributed to the effects of the activity and finally if it will be a permanent loss or a temporary loss that will allow for recovery. Population-substructure and genetic diversity may be complementary either to abundance or range.

- What is the duration of each of the identified effects? Understanding the nature (consequences) and extent (duration) of the impact is important to inform the recovery potential of the various biodiversity elements and the significance of the impact on critical habitat. The duration of the effect then needs to be considered in relation to the recovery potential of that effect.

- What are biologically reasonable recovery targets and timeframes to reach recovery for the species for the outlined pathways of effects (considering its nature and duration)? This will be informed by sensitivity – a species easily depleted by at least some human activities and when affected is expected to recover over a long period or not at all which takes into account both the tolerance to, and the time needed for recovery from the stressor. The metrics to evaluate sensitivity require that the following features are considered:

  1. Recruitment processes
  2. Mobility at various life stages
  3. Regenerative ability: rate of regeneration, growth rate
  4. Habitat requirements: temperature, salinity, oxygen and substrate requirements
  5. Fragility, e.g. body structure, physical form

- What features characterize the habitat of each species? This is part of describing the relationship between the habitat and the elements of biodiversity. This would provide the information that would inform the following question on defining the habitat for each component of the biodiversity. If sampling is not undertaken in a sufficient manner in the impacted and un-impacted areas with similar bioregional characteristics then results from habitat suitability or species distribution models may help inform the process. It is also the question that would take into account the EBSA attribute and the metrics they provide. EBSA attributes will mainly be used to assess the impacts on habitat and ecosystem form and function. The scaling factors for evaluation the EBSA attributes include:

- Uniqueness: A criteria ranked from areas whose characteristics are unique, rare, distinct, and for which alternatives do not exist to areas whose characteristic are widespread with many areas which are similar in most important features. Uniqueness may be considered in a regional, national or global scale.

- Aggregation – this is ranked:
    - From areas where: 1) most individuals of a species (population) are aggregated for some part of the year; 2) most individuals use the area for some function in their life history; 3) some structural feature or ecological process occurs with exceptionally high density

    - To areas where: 1) individual of a species are widespread and even areas of comparatively high density do not contain a substantial portion of the total population; 2) individual may congregate to perform life-history function, but the area in which they perform the function varies substantially over time; 3) structural property or ecological process occurs in many alternative areas.

- Fitness Consequences: Ranked from areas where the life history activity undertaken make a major contribution to the fitness of the population or species present to areas where the life history activity undertaken make on marginal contributions to fitness. This dimension generally applies to functional properties of areas, and in most cases reflects contributions to reproduction and or survival of a species (population) but it can also apply to cases which may influence survival or reproduction indirectly as well as directly.

- Where is the habitat found at present, how much habitat is known to exist currently, and how much habitat was known to exist historically, how much habitat will be impact and will the nature of the effect allow the habitat to recover and support the same biodiversity in the future? Critical to this exercise is a need to undertake landscape mapping of the coast based on bathymetric, geological and physical and chemical oceanographic features (basically a fine scale bioregionalization of the coastline). Scaling for this question will be based on the level of fragmentation and connectivity of habitat of the area impacted to total range or area occupied. The metric that used will be estimating is the isolation of the species or population, which in turn will affect rescue potential and the ability of the species/population to re-colonize.

- What are all the current threats to the species (population) and its habitats? It is important to understand the cumulative effects on the biodiversity elements. Habitat itself was not generally considered to be appropriate to include as a component of a recovery *target* but may play a major role in the recovery *plan* when it has been lost or damaged. The exception to this general guideline is when habitat restoration or recovery is deemed to not be technically feasible. This admission that it is impossible to fully recover a population is a serious concession of DFO’s fundamental conservation mandate and should not be made lightly. Rather, the burden of proof is reversed in these instances, and it should be assumed that sufficient habitat can be protected or restored to support populations which have met their abundance and/or range targets, unless there is compelling evidence to the contrary.

Appendix 4

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