PROTECTING

BRITISH COLUMBIA'S CORALS AND SPONGES

A Report by Living Oceans Society

Jeff Ardron

July 2005

Acknowledgements

This research and report was funded by Lazar Foundation, EJLB Foundation, and Mountain Equipment Coop. The GIS software was made available through a grant from the ESRI Conservation Program.

Coral and sponge observer data used in this analysis were provided by Fisheries and Oceans Canada, Pacific Region. All maps and analyses by J. Ardron, Living Oceans Society.

Photo inset in Figure 1, Paragorgia coral, courtesy Alberto Linder. Images in Figure 2 courtesy the Geological Survey of Canada.

Copies of this report can be downloaded at **www.livingoceans.org**

Living Oceans Society
Box 320
Sointula, B.C. V0N 3E0
Canada

(250) 973-6580 (Phone)
info@livingoceans.org

Printed July 2005

© 2005 Living Oceans Society

Ardron, J.A. (2005) Protecting British Columbia's Corals and Sponges from Bottom Trawling. A report by Living Oceans Society (v. 1.0). Box 320, Sointula, BC, V0N 3E0.

Table of contents

List of Tables

List of Figures

Executive summary

Deep sea corals and sponges provide habitat for a range of different species and are extremely vulnerable to disturbances on the sea bottom due to their fragility, age, and slow growth. In British Columbia (BC), and globally, the greatest threat to their survival is groundfish bottom trawling or "dragging." From 1996 to 2004, 322 tonnes of corals and sponges were observed as bycatch in BC's groundfish bottom trawl fishery. The ongoing destruction is likely many times larger, and is in no way sustainable.

Worldwide, the importance of deep sea corals is being recognized. In Alaska, due to the cooperative work of scientists, environmentalists, and managers, the largest trawling closures in the world were unanimously passed in Feb. 2005. In British Columbia, there are no closures to protect corals, and only a few closures that partially protect the sponge reefs, while most of the coast remains open to bottom trawling.

Based on the analyses of observer data from this fishery, Living Oceans Society makes nine recommendations (below), the most important of which is the closure of twelve proposed Coral-Sponge Protection Areas. If protected under the Fisheries Act, the bycatch of corals and sponges would be reduced from between 80 to over 97 percent, depending on the species. These closures would occupy only 7½% of BC's continental shelf and slope (Figure 1).

Due to the fragile nature of deep water corals and sponges, their importance in the marine ecosystem, and the significant threat from bottom trawling, Living Oceans Society asserts that DFO must start implementing the first three recommendations immediately while the remaining 6 recommendations must be implemented by 2008.

"Bottom Trawling is the sub sea equivalent of collecting the entire farm when the goal is to bring in a bushel of apples." [1]

– Oceanographer Sylvia Earle

Recommendations

To be implemented immediately:

1 That the twelve areas (CSPAs) identified in this report-known to be enduring significant and ongoing damage to coral & sponges-be closed immediately to all bottom trawling.

2 That as a precautionary measure, all other areas not currently trawled be closed until research can be conducted to determine their importance as coral/sponge (or other) habitat.

3 That research be conducted to determine if other gear types are damaging coral and sponge habitat.

To be implemented by 2008:

4 That these twelve identified areas be surveyed to gain a better understanding of the species and assemblages found there; and, to better refine the closure boundaries.

5 That the trawl observer program provide the necessary training and taxonomic keys to enhance rudimentary identification of corals and sponges.

6 That the observer coral and sponge reporting categories be reviewed; and, that a separate category be created for Hexactinellid sponges.

7 That a sampling program be implemented whereby samples of landed corals and sponges along with their catch location, be sent to experts for full identification, so that a complete species inventory of BC can be developed.

8 That the preservation of habitat-forming corals and sponges become a priority of DFO scientists and managers working within groundfish and habitat sections.

9 That full-resolution spatial data for all relevant bottom fisheries, with start, mid, and end points, be provided to researchers interested in furthering this and related work.

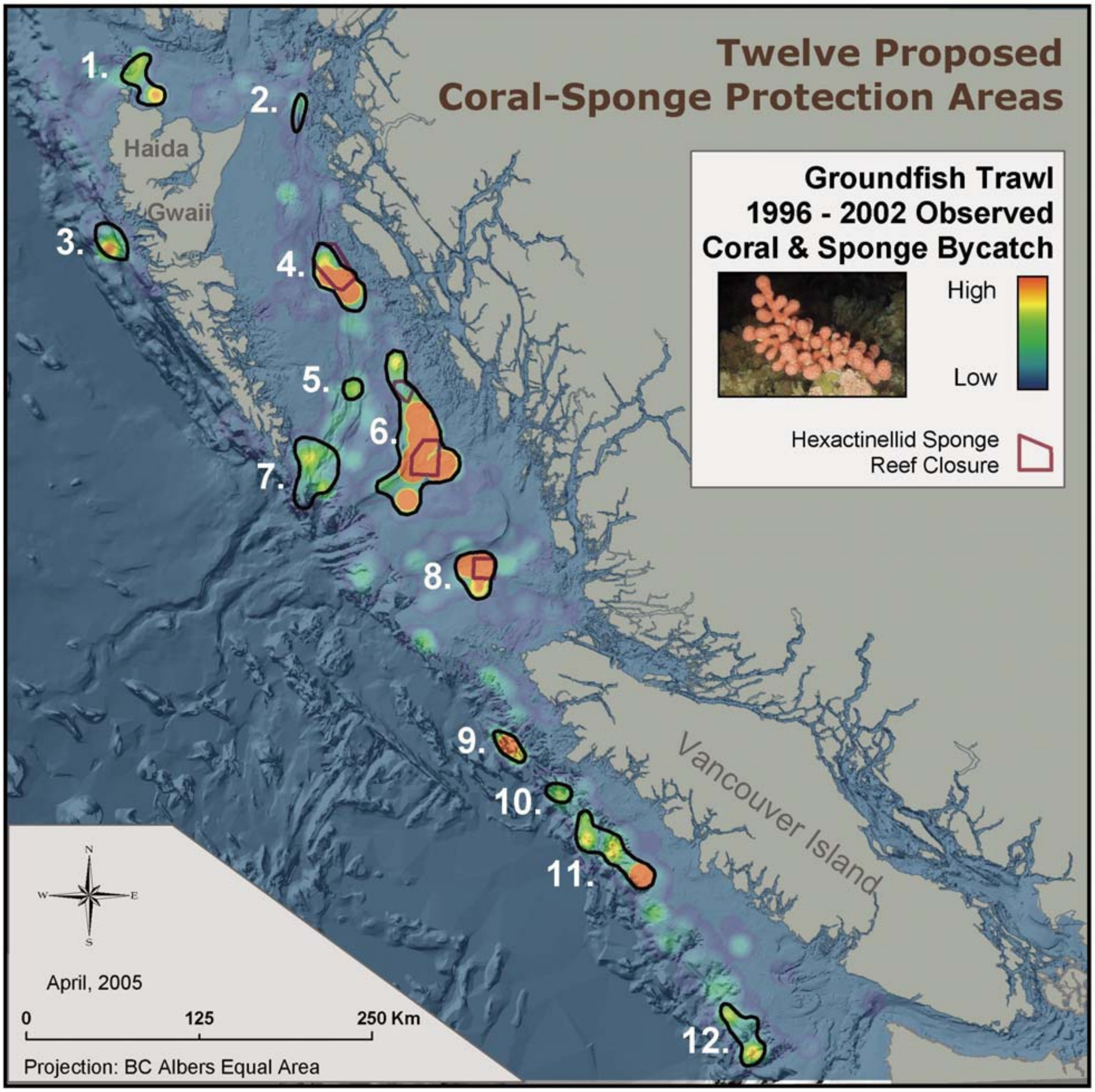

Figure 1: Proposed Coral-Sponge Protection Areas

1 **Learmonth Bank** (Gorgonian Corals)

2 **Bell Passage** (Sea Pens)

3 **Kindakun** (Sponges)

4 **McHarg Bank** (Sponges, Hex. Reef)

5 **Mid-Moresby Trough** (Gorgonian, Stony Corals)

6 **Mitchell's Trough** (Stony Corals, Soft Corals, Calcareous Corals, Sponges, Glass Sponges, 2 Hex. Reefs)

7 **S. Moresby Gully** (Gorgonian Corals, Sea Pens)

8 **Goose Trough** (Sponges, Hex. Reef)

9 **Kwakiutl Canyon** (Sponges, Sea Pens)

10 **Crowther Canyon** (Gorgonian Corals, Sponges, Sea Pens)

11 **Esperanza Canyon** (Sponges, Glass Sponges, Calcareous Corals)

12 **Barkley Canyon** (Sponges, Glass Sponges)

Note: The above-listed corals and sponges are categories used in the trawl observer program.

Introduction

Deep sea corals and sponges have only come to the attention of scientists, environmentalists, and the public within the last decade. In British Columbia, scientific attention has been focused on the globally unique Hexactinellid sponge reefs, but very little is known about BC corals.

Although deep sea corals are often mistaken for plants, they are actually composed of tiny fragile animals called polyps, typically joined together into colonies of hundreds or thousands, surrounding a calcareous skeleton. They reside much deeper than tropical reefs, and consequently do not rely on sunlight for their nourishment, instead filtering microscopic particles. Deep water corals are known to provide habitat for many species including rockfish, atka mackerel, shortspine thornyhead, juvenile Pacific halibut, rock sole, juvenile red king crab, and several species of shrimp.[2,3]

These forests are fragile, in some cases rare, and largely unstudied. For example, *Lophelia pertusa*, a hard coral from the *Scleractinia* Order and a known reef-builder, was discovered off the coast of Washington State in June 2004. Prior to this discovery, this coral was normally associated with the north Atlantic Ocean, and was not known to exist in north Pacific waters, indicating that deep sea exploration in this region is still in its infancy.[4]

Cold water sponges are amongst the simplest animals on earth, lacking internal organs and unable to move. They are filter feeders, channelling water through canals in their bodies. The sponges in BC contain spicules –silicon crystals– that serve as a skeleton. These "glass" sponges provide habitat for rockfish, spider and King crab, shrimp, prawns, euphasids, annelid worms, bryozoans, rare bivalves and gastropods, sea stars, and urchins.[5]

Deep sea corals and sponges exist in slow motion, only growing a few centimetres a year,[6,7] but living for a century or more.[8,9] In the case of BC's globally unique hexactinellid sponges, their colonies have been built up over thousands of years, sometimes as high as 19 metres,[10] the size of a small apartment building. Their fragility, age, and slow growth make deep sea corals and sponges extremely vulnerable to bottom trawling.

Taxonomy of Corals and Sponges

Corals (*Phylum Cnidaria*) and sponges (*Phylum Porifera*) are not at all closely related. They have been grouped together in this report for two reasons:

1) in BC they both can create habitat-forming structures that are damaged by bottom trawling; and,
2) they are difficult to identify and as a consequence the trawl observer data (used in our analyses) tended to mix them up, necessitating that they be treated together.

Most of the hard corals in BC are from the Class *Anthozoa,* Subclass *Octocorallia*, Order *Gorgonacea*. These "gorgonians" include three Families: Paragorgia (*Paragorgiidae*), Primnoa (*Primnoidae*), and Bamboo Corals (*Isididae*). They have a branching tree-like appearance, evoking comparisons to "gardens," "groves," or "forests."

Habitat forming sponges in BC are mostly Hexactinellid (Class *Hexactinellida*), also known as "glass" sponges.

Impacts of Bottom Trawling on Corals and Sponges

Coral forests and sponge reefs can be damaged by a variety of fishing gear including hook and line gear, traps, and bottom trawling; however, it is recognized worldwide that bottom trawling is by far the most damaging of all bottom fishing practices.[11] Trawling, also known as "dragging," involves towing tonnes of net, cable, and steel along the sea floor for several kilometres at a time, scooping up or crushing most organisms in its path.

In British Columbia, there are approximately 70 bottom and midwater trawl vessels. These relatively few vessels amount to the largest fishery by volume, which in 2004 had a catch of 104.7 thousand tonnes.[12, 13] However, most of this is from the midwater fishery for hake.[14] If this midwater fishery is removed, total landings amounted to 36.3 thousand tonnes, plus another 10.1 thousand tonnes that were discarded—over 1/4 of what was kept.[15] These discarded species, referred to as *bycatch*, generally have low survival rates. While most of the discards are fish, from 1996 to 2004, 322 tonnes of corals and sponges were also noted as bycatch.[16, 17]

Over the past few decades, international scientists have studied trawling with predominantly negative findings. In the fall of 2004, Britain's prestigious Royal Society, in a report for the British parliament, recommended that bottom trawling be banned in all British waters.[18]

The Scientific Consensus Against Bottom Trawling

The effects of bottom trawling have been widely studied, with overwhelmingly negative findings.[a] While the Pacific coast of North America has seen fewer studies than the Atlantic coast, these studies have documented a flattening of habitat complexity, destruction of long-lived structure-forming organisms such as sponges and corals, a reduction in abundance and diversity of invertebrates, and shifts in biological communities.[b,c,d] A study undertaken in South East Alaska recorded extensive damage to sponges and other invertebrates after a single trawl pass.[e]

In February 2004 1,136 scientists signed on to a document asking nations around the world to:

- ban bottom trawling to protect deep-sea ecosystems wherever coral forests and reefs are known to occur
- prohibit roller and rockhopper trawls and any similar technologies that allow fishermen to trawl on the rough bottoms where deep-sea coral and sponge communities are most likely to occur.
- support research and mapping of vulnerable deep-sea coral and sponge communities.
- establish effective, representative networks of marine protected areas that include deep-sea coral and sponge communities.

To read the whole statement, go to: http://www.mcbi.org/DSC_statement/sign.htm

Coral and Sponge Trawling Closures

Because of the growing recognition worldwide that bottom trawling causes damage to deep sea corals and sponges,[19, 20, 21, 22] year-round bottom trawling closures have been established in Australia, the European Union, New Zealand, Norway, Scotland, and the USA. In Norway, for example, it is estimated that 30% - 50% of *Lophelia* corals have been damaged or destroyed by bottom trawling.[23] In Florida, an area of 1043 km^2 (403 sq. mi.) is now completely closed to all activities, due to the destruction of habitat-forming *Oculina* corals.[24]

In Alaska, due to the cooperative work of scientists, environmentalists, and managers, the largest trawling closures in the world were recently passed. On Feb. 10, 2005, in a unanimous vote by the North Pacific Fishery Management Council, over 960,000 km^2 were closed to bottom trawling.[25] Within fishable depths, this was about 100,000 km^2, or 60% of the Aleutian shelf habitat. In addition, 21 dense coral garden sites totalling 7616 km^2 were closed to all bottom contact gear (six Aleutian sites, 380 km^2; ten Gulf of Alaska sites, 7156 km^2; and, five SE Alaska sites, 80 km^2).[26] These vast closures reflect a decision to value the long-term health of marine habitats over the short-term profits of a destructive fishing practice. In Alaska, coral areas are recognized as "habitat areas of particular concern" under the Magnuson-Stevens Act.

In British Columbia, it is a different situation: there are no closures to protect corals, and there is no formal designation to recognize their importance.

Images: Geological Survey of Canada

Figure 2: Hexactinellid Sponge (above) and trawled area previously with sponges (right)

There are presently four relatively small closures[27] to protect the globally unique hexactinellid sponge reefs. These came about after years of scientific and public pressure, beginning in 1987 – 1988, when the sponge reefs (*bioherms*) were discovered in the waters of Hecate Strait.[28] Despite being the only known examples in the world, they were given no protection at all by the DFO. Ten years later, trawl damage was detected by both multi-beam acoustic surveys and video transects conducted by the Geological Survey of Canada.[29] The scientists who had discovered them continued to argue for protection[30, 31], along with a recommendation from DFO in a Habitat Status Report.[32] However, the draggers downplayed the evidence, suggesting that these sponges damaged their nets and consequently they didn't fish near them. In response, DFO asked industry to comply with *voluntary* closures around the reefs, which began in 2000. Underwater video evidence showed that these voluntary closures were not working and that trawl damage was continuing.[33] Indeed, subsequent analysis by Living Oceans Society has found that observed bycatch of sponges and corals actually *increased* four to five-fold during these years, likely as a result of "fear fishing" (see sidebar). Mandatory fisheries closures were finally enacted in July 2002, fourteen years after the sponge reefs had been discovered,[34] and after considerable trawl damage had already occurred. The data indicate that these regulatory closures under the Fisheries Act have been effective in reducing sponge bycatch, though not completely.[35]

Fear Factor (why voluntary closures don't work)

Fear fishing occurs when fishermen fish an area more aggressively than normal because they are afraid it will soon be closed. It appears that during the time the voluntary closures were in place around the four sponge reefs, fishing intensity in those areas actually *increased*, as did the sponge bycatch. Consider Table 1, below: 2000 and 2001 were the years when voluntary closures were in place. Notice the four—fivefold increase in total bycatch during these years. Additionally, the proportion of large landings also jumped (Table 2), all in the vicinity of the sponges. Because of ongoing damage to the sponges, these areas were closed by regulation in 2002. Notice how the bycatch dropped back to pre-voluntary closure levels. Thus, the dragger's fears became a self-fulfilling prophecy whereby their increased fishing ensured that the areas were indeed closed.

Bycatch: A Serious Problem in British Columbia

In the spring of 2003, Living Oceans Society received groundfish trawl observer spatial data for the years 1996 (when the program began) to 2002.[36] In order to protect privacy, no vessel identifiers were given; and spatially, only midpoints of the trawls were provided (halfway between the start and end points). Subsequently, non-spatial data from 1996 to 2004 were also received.

From 1996 to 2004, coral and sponge bycatch of about 322 metric tonnes was reported by observers on bottom trawl vessels (Table 1). The actual number of animals destroyed is likely much higher, since many fragments are left behind on the ocean floor.[37] Because corals and sponges are non-commercial species, the observers had not received training in their identification, nor are they required to record them. The observers Living Oceans Society spoke to stated that not all coral-sponge bycatches were recorded, especially when they were still learning to identify the commercial fishes, and also in large sets with many other commercial species that needed tallying.[38]

From 1996 to 2002, 3915 catches of corals and sponges were recorded in 2.62% of all bottom trawls. The vast majority of these records were of small bycatches, usually just a few pounds (median = 5.0 lb[39]). However, in each year, there were also several very large bycatches observed. Overall, 9.4% of recorded coral-sponge bycatch was over 200 pounds (90.7 kg), and 3.9%, 154 records, were of landings over 1000 lbs (454 kg) (Table 2). The largest observed coral-sponge bycatches were staggering, with seven catches estimated to be over 10,000 lb (4536 kg), and three over 25,000 lb. (11340 kg). Regardless of whether the observers' estimates are accurate or not, the landings were clearly very large, representing massive habitat destruction.[40]

The low-weight bycatches were broadly distributed, and probably represented smaller animals, or fragments, perhaps of non-habitat-forming species. The heavier bycatches, however, were likely composed of the larger habitat forming species.

Independent Research Fills in Gaps

When LOS initially added up the numbers, it was surprising that given this massive ongoing bycatch, DFO had taken no actions. After discussing the matter with scientists and managers, it became apparent that no one at DFO had actually been monitoring the situation. With about 73 different commercial species being caught in trawl nets, the DFO was already too busy. (The health of over 60% of these stocks have not been assessed.[f]) Thus it took the independent efforts of Living Oceans Society to identify the issue of coral and sponge bycatch.

Table 1: Observed Bycatch o	
Year	**C-S Bycatch (Kg)**
1996	7,894
1997	39,444
1998	22,178
1999	21,813
2000	78,778 (voluntary sponge closures)
2001	101,332 (voluntary sponge closures)
2002	23,155 (legal sponge closures)
2003	17,216 (legal sponge closures)
2004	10,570 (legal sponge closures)
Total	**322,379**

Table 2: Observed Coral-Sponge Bycatch, 1996-2002

Year	All C-S	% Tows	>200 lb	%>200	>1000 lb	%>1000
1996	271	1.10%	18	6.6%	4	1.5%
1997	365	1.91%	28	7.7%	15	4.1%
1998	509	2.08%	26	5.1%	11	2.2%
1999	613	2.61%	34	5.5%	14	2.3%
2000	806	3.53%	128	15.9%	51	6.3%
2001	638	4.20%	86	13.5%	45	7.1%
2002	713	3.67%	47	6.6%	14	2.0%
Total	**3915**	**2.62%**	**367**	**9.4%**	**154**	**3.9%**

Identifying Areas of High Coral and Sponge Bycatch in BC

To identify areas where the largest bycatches were occurring, the heaviest quartile (25%) of records were mapped. These accounted for about 97% of the bycatch by weight (99% by CPUE[41]). In accordance with the published literature,[42, 43] much of the bycatch occurred along the shelf slope, the flanks of banks, and the troughs / gullies (Figure 3). However the spatial patterns were still difficult to discern, and interpretation could be biased by single large landings, rather than the overall abundance. Thus, it was recognized that instead of single large landings, of greatest interest was the *density* of all bycatch, with weight taken into account.

A density analysis moves through each cell on the map, taking into consideration all other points found within a specified "search radius" of that cell. Therefore, a region with many moderate landings will show up as denser in bycatch than an area with, for example, only one larger landing. Given enough records, this approach avoids results being skewed by single large landings or misreporting, as can happen if only largest values are considered. Also, this approach avoids the issue of larger management grid squares straddling areas of high bycatch, and thereby dividing the results, as can occur in systems that bin results into standardized management grids or statistical areas.

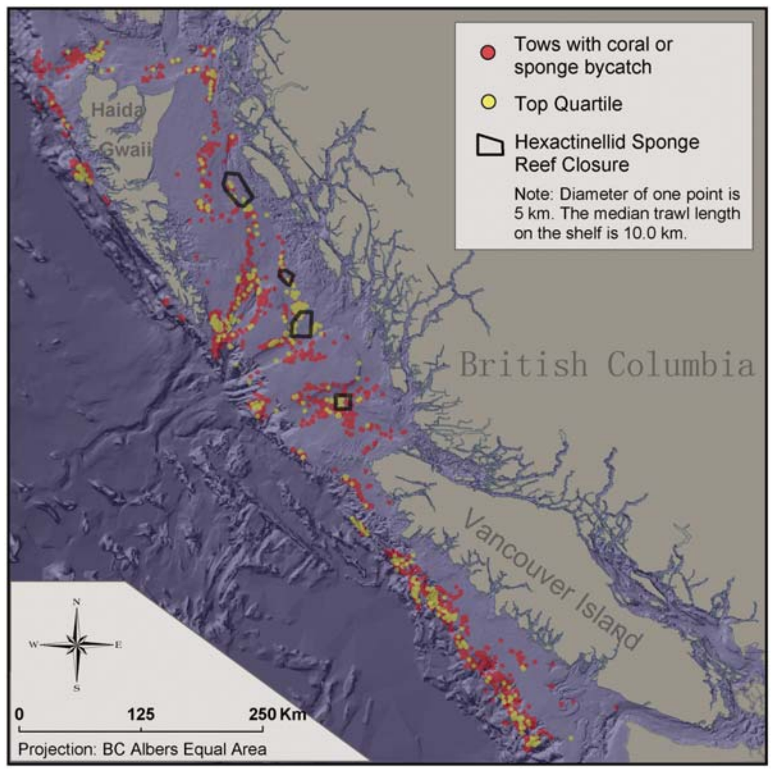

Figure 3: Top quartile of coral-sponge bycatch

The median length of a bottom trawl in waters less than 500 m depth was calculated to be 10.0 km, for the years of 2001 and 2002—the years when speed was recorded. (This compares favourably to the mean tow length of 9.6 km in the vicinity of the sponge reefs as calculated in a previous study by DFO scientists.[44]) Our density analyses used a search radius of 10 km, with a decay function whereby points nearby were weighted more than points further away (inverse distance weighted). This 10 km search radius allowed for the density measure to take into account neighbouring tows on average of about one tow length away, centre to centre. Longer search radii (e.g. 20 km) gave "fuzzier" more generalized results, whereas shorter radii (e.g. 5 km) appeared fragmented and somewhat more difficult to interpret. Density analyses are robust to minor variations in search radii, and the results grow or contract in a predictable and consistent fashion.

The results of the density analysis produced clear trends, allowing for the possibility that a few strategic closures could greatly reduce future bycatch. The map at the beginning of this document (Figure 1) depicts the results of the density analysis, and twelve areas that LOS has identified as being the best candidates for closures to protect corals and sponges.

Altogether, the twelve proposed *coral-sponge protection areas* (CSPAs) capture 97.1% of the observed trawl bycatch (98.8% by CPUE). They enclose 13 times more coral-sponge bycatch than would have been expected if the corals and sponges had been distributed randomly.

The above statistics should be interpreted with some caution, however, because they are influenced by large localized bycatches of what were very likely hexactinellid sponges.[45] The three proposed CSPAs in the vicinity of the hexactinellid sponges (#4, 6, 8) are characterized by the largest bycatches on the coast, alone accounting for 85.0% by weight and 92.3% by CPUE of all 1996-2002 coral-sponge bycatch. Because these very large landings overshadow other landings, which are likely of other species, these areas were removed from the analysis when determining the effectiveness of the other CSPAs. Considered on their own, these remaining nine CSPAs capture 80.9% of the remaining historical bycatch (84.5% by CPUE), indicating that these areas also provide a compelling spatial efficiency vis-à-vis protection.

Are Existing Closures Enough?

The first two years of observer data, when there were no closures, were examined to deduce how modern closures have affected the fishery (Figure 4). Overall, they appear to contain just 1.4% of historical trawl sets. In other words, they are where people didn't trawl much anyway. Had the sponge closures been enacted in 1996, 1/3 of overall coral-sponge bycatch would have been avoided; but, 2/3 would have remained. More protection, especially for corals, is required.

Dragging 6% of the Coast?

The trawl industry publicly states that they only trawl 6% of the coast (presumably the continental shelf & slope).[g] Figure 4 shows in orange the data-intense dragging areas, with the rest in purple, indicating much greater coverage than 6%.

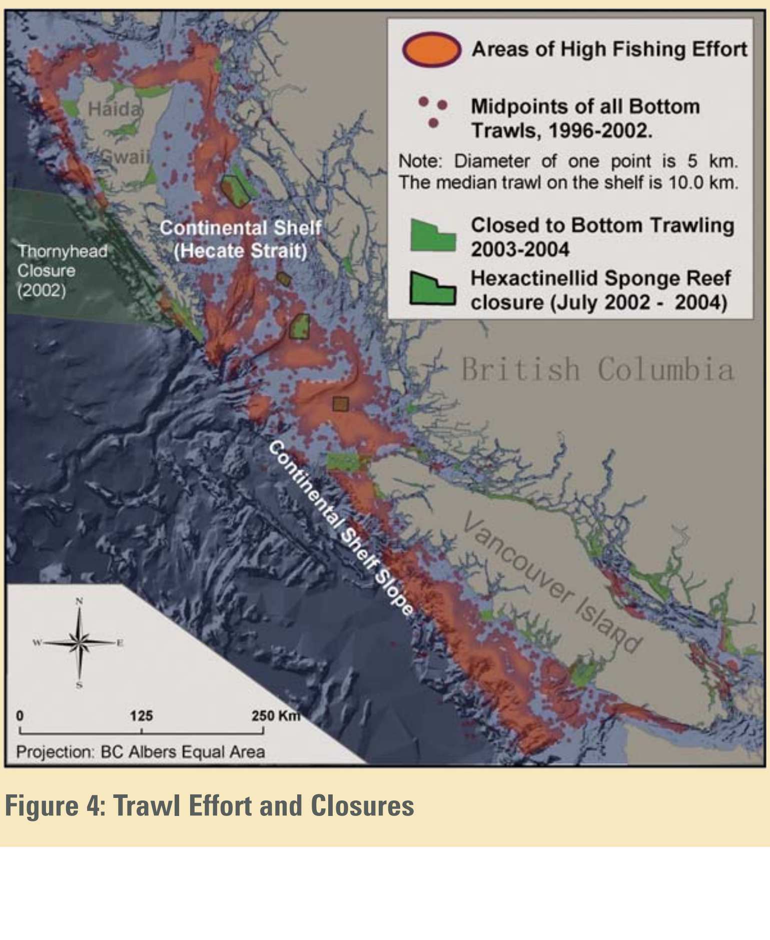

Figure 4: Trawl Effort and Closures

Using Midpoint Data vs. Start & End Points

To protect the privacy of trawlers, the data from DFO provided LOS with only the calculated midpoints of each tow. Although it would have been preferred to have the start and end points, this example illustrates how the density analysis addresses this issue.

The red lines represent what trawl tows could look like. A trawl set is not always a straight line; however, DFO receives only the start and end points of a set. Therefore the dashed lines connect the start to end points as a straight-line approximation of the trawl tow, as would be available to DFO and industry. The dots, representing the data given to LOS, are the midpoint of dashed lines. The blue shape represents an area that conceivably could have arisen after doing a density analysis of the midpoints. As can be seen, the blue shape still does a reasonable job of capturing the trawl activity. While start & end points would allow this shape to be fine-tuned, the shape is still a reasonable approximation. Thus, LOS is confident that these results, based on calculated midpoints, are meaningful.

Estimating the Biodiversity of the Coral Sponge Protection Areas

If there was a record of a coral or sponge coming up on deck, it is reasonable to assume that it was indeed a coral or a sponge. However, because these animals are difficult to identify, and because observers do not receive training in their identification, little confidence can be placed in the category to which it had been assigned.[46] Without reliable sampling or identification, it is difficult to determine how fully biodiversity is being represented. Certain categories of observer data were recorded more often in some places than others (Figure 1). This diversity of categories suggests the possibility of biodiversity; i.e., even if the categories are incorrect, the observers are still noting different corals and sponges in different areas. That the twelve CSPAs are distributed across a number of depths and locations also indicates they are plausibly capturing different species or species assemblages.

As explained previously, three of the CSPAs in Hecate Strait appear to do a good job of protecting the hexactinellid sponge reefs (which does not have a specific observer category). To estimate how well the given observer categories were represented, subsets from each category were chosen that were considered the most reliable observations.[47] Generally, these data were from the most recent years. However, for the more readily identifiable "Gorgonian" and "Sea Pen" categories, data from all years were included. Category years that contained notably suspect or anomalous data were removed. The 12 CSPAs were then examined to consider how well they would have protected these subsets. Overall, results were promising—about 80% or higher (Table 3). However, "Stony Corals" had 64% representivity, and "Sea Pens" 47%. The sea pens number is unsurprising as these species are fairly widespread. Given the absence of field surveys and expert identification, these results should be considered cautiously.

Table 3: Taxonomic representivity as estimated from observer data

Observer Category	Gorgonian Corals	Stony Corals	Soft Corals	Sea Pen	Sponges	Glass Sponges	Calcareous Sponges
Subsample Years	1996 - 2002	2002	2002	1996-2002	2000-2001	2001	1997 & 2002
Representivity	79.2%	63.5%	91.8%	47.1%	98.5%	98.3%	79.5%

Economic Effects of the Coral-Sponge Protection Areas

The groundfish trawl fishery is an individual quota fishery. Therefore, closing small parts of the coast should cause no economic harm, as the quotas can most likely be caught elsewhere.

To analyse the economics of the proposed closures, the value of every bottom trawl set, 1996-2002, was estimated (year 2002 dollars). A density analysis identified areas of higher and lower value per unit effort (Figure 5). While some of the potential CSPAs are in higher value areas, many were not. Overall, the CSPAs worked out almost exactly to be of average economic value (by weight), accounting for 30.3% of historic landings and 30.6% of historic earnings. Spatially, they occupy about 7.5% of the BC coast (shelf and slope to 2000 m), and contain 24.1% of historic 1996-2002 trawl sets.

Given their average economic value, and that this is an individual quota fishery, it is difficult to characterize that any potential economic loss would occur if the 12 areas were closed to trawling. Other modelling work in the region suggests that the mobility of commercial species may largely offset small spatial closures, such as suggested here.[48] On the other hand, as found in protected areas worldwide, protected areas might actually allow for increases in neighbouring fisheries through *spillover* effects of more sedentary species as their stocks rebuild.[49, 50, 51] The economic “hardship” of these coral and sponge protected areas could prove to be positive over time, if they allowed for certain stocks to rebuild.

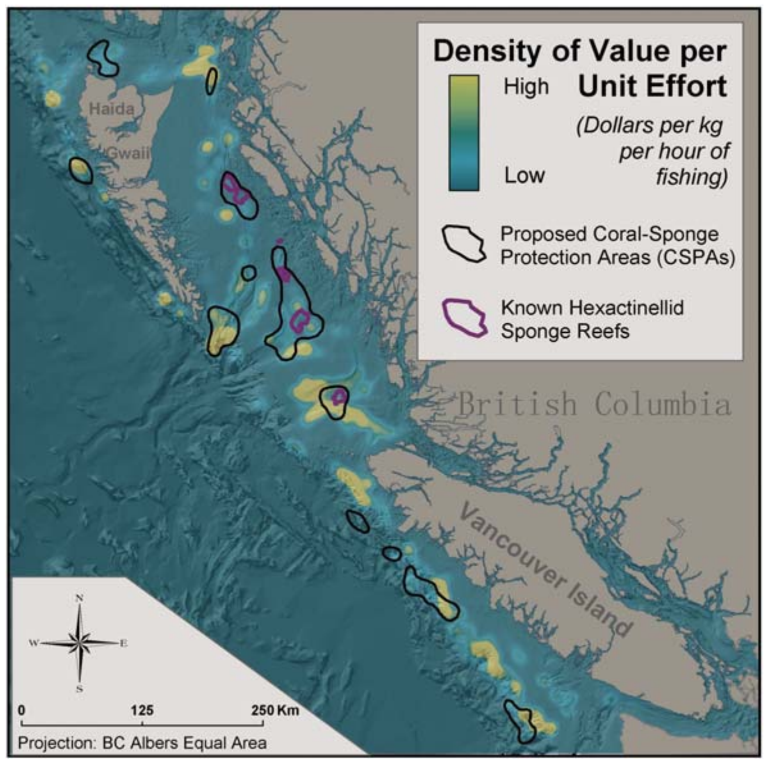

Figure 5: Areas of historically high economic value vs. the CSPAs

Discussion

While they remain poorly studied in BC, elsewhere it is widely accepted that the destruction of structural habitat-forming corals and sponges has a negative impact on ecosystems and on fisheries.[52, 53, 54, 55, 56, 57, 58] Most of the habitat-forming corals and sponges are long lived, slow to regenerate, and slow growing. Recovery from trawling is on the order of decades to centuries. In nine years, 322 tonnes of corals and sponges were observed as bycatch in BC's trawl fishery. This figure is likely many times smaller than the actual damage occurring. Given their slow growth rates, this destruction of corals and sponges is in no way sustainable.

Worldwide, the importance of deep sea corals is being recognized.[59] In BC, however, there is inadequate protection, with no closures in place to protect coral forests. While BC's sponge reefs have some protection, observer data suggests that the sponge reefs extend beyond the existing closures and continue to be damaged by bottom trawlers.

With fishing technology advancements such as GPS, fish finders (sonar), and "rock hopper" gear that allows trawling in previously inaccessible areas, the fisheries and habitats of the narrow continental shelf on the Pacific coast of Canada have come under increased pressure, with few natural refuges. Furthermore, trawls have recently begun to expand, fishing deeper along the slope in search of the long-lived, but poorly studied, thornyheads (*Sebastolobus spp*). These developments are cause for alarm. While healthy, large, habitat forming corals and sponges still exist, they will most assuredly be destroyed in a short time if trawling is allowed to continue and expand.

Due to the fragile nature of deep water corals and sponges, their importance in the marine ecosystem, and the significant threat from bottom trawling, DFO must take steps to protect these species on the Pacific Coast of Canada. Based on the information available and the results of this analysis, Living Oceans Society has determined that, if implemented, the following nine recommendations will contribute significantly to the protection of deep water corals and sponges. Living Oceans Society asserts that DFO must start implementing the first three recommendations immediately while the remaining 6 recommendations must be implemented by 2008.

Recommendations

To be implemented immediately:

1 That the twelve areas (CSPAs) identified in this report - known to be enduring significant and ongoing damage to coral and sponges - be closed immediately to all bottom trawling.

2 That as a precautionary measure, all other areas not currently trawled be closed until research can be conducted to determine their importance as coral/sponge (or other) habitat

3 That research be conducted to determine if other gear types are damaging coral and sponge habitat

To be implemented by 2008:

4 That these twelve identified areas be surveyed to gain a better understanding of the species and assemblages found there; and, to better refine the closure boundaries.

5 That the trawl observer program provide the necessary training and taxonomic keys to enhance rudimentary identification of corals and sponges

6 That the observer coral and sponge reporting categories be reviewed; and, that a separate category be created for Hexactinellid sponges.

7 That a sampling program be implemented whereby samples of landed corals and sponges along with their catch location, be sent to experts for full identification, so that a complete species inventory of BC can be developed.

8 That the preservation of habitat-forming corals and sponges become a priority of DFO scientists and managers working within groundfish and habitat sections.

9 That full-resolution spatial data for all relevant bottom fisheries, with start, mid, and end points, be provided to researchers interested in furthering this and related work.

Endnotes (to text boxes)

[a] For literature summaries on the harmful effects of bottom trawling, see:

Morgan, L.E. and Chuenpagdee, R. (2003) "Shifting Gears: Addressing the collateral impacts of fishing methods in US waters." *Pew Science Series* Island Press, Washington, DC, USA.

Watling, L. and Norse, E.A. (1998) "Disturbance of the seabed by mobile fishing gear: A comparison to forest clearcutting." *Conservation Biology* 12(6): 1180-1197.

Kaiser, M.J. (1998) "Significance of bottom-fishing disturbance." *Conservation Biology* 12(6): 1230-1235.

[b] Engel, J. and Kvitek, R. (1998) "Effects of otter trawling on a benthic community in Monterey Bay National Marine Sanctuary." *Conservation Biology* 12: 6 1004-1214.

[c] Heifetz, J. (1999) "Effects of Fishing Gear on Sea Floor Habitat." Progress Report for FY1999, Auke Bay Laboratory Alaska Fisheries Science Center NMFS.

[d] Krieger, K.J. (2001) Coral (*Primnoa*) impacted by fishing gear in the Gulf of Alaska. In Willison, J.H., Hall, J., Gass, S.E., Kenchington, E.L.R., Butler, M., and Doherty, P. Proceedings of the First International Symposium on Deep-Sea Corals, Ecology Action Center.

[e] Freese, L., Auster, P.J., Heifetz, J., Wing, B.L. (1999) "Effects of trawling on seafloor habitat and associated invertebrate taxa in the Gulf of Alaska." Marine Ecology Progress Series 182: 119-126.

[f] Glavin (2001) The conservation of marine biological diversity on species abundance on Canada's west coast: Institutional impediments. Groundfish: A case study. Report for the Sierra Club of BC. Last accessed June 15, 2003: http://www.sierraclub.ca/bc/Campaigns/Marine/Groundfish_2.pdf

[g] Canadian Groundfish Research and Conservation Society (2005) [web site]. Last accessed May 10, 2005: http://www.cgrcs.com/fishinfo.html

Endnotes (main text)

[1] Sylvia Earle (n.d.) Quoted in: Will the fish return? How gear and greed emptied Georges Bank. [web site] Last accessed May, 2005: http://sciencebulletins.amnh.org/biobulletin/biobulletin/story1249.html

[2] Heifetz, J. (2002) "Coral in Alaska: Distribution, abundance, and species associations." *Hydrobiologia* 471: 19-28.

[3] Malecha, P. W., R. P. Stone, and J. Heifetz. In press. Living substrate in Alaska: distribution, abundance and species associations. In P. Barnes and J. Thomas (Editors), *Benthic Habitats and Effects of Fishing*. American Fisheries Society, Bethesda, MD.

[4] Berton, H. (2004) "Atlantic coral detected off coast of Washington." *Seattle Times*, June 11. Last accessed June 2005: http://seattletimes.nwsource.com/html/localnews/2001953599_coral11m.html

[5] Krautter, Manfred, Conway, Barrie, Neuweiler, (2001) "Discovery of a 'Living Dinosaur': Globally Unique Modern Hexactinellid Sponge Reefs off British Columbia, Canada." *FACIES* 44: 265-282.

[6] While BC's corals have not been studied, Alaska *Primnoa* grow about 1 – 2 cm a year: Andrews, Allen H., Cordes, Mahoney, Munk, Coale, Cailliet & Heifetz, (2002). "Age, growth and radiometric age validation of a deep-sea, habitat-forming gorgonian (*Primnoa resedaeformis*) from the Gulf of Alaska." *Hydrobiologia* 471: 101-110.

[7] BC's Hexactinellid Sponges are estimated to grow 0 – 7 cm a year: Krautter, M., Conway, K.W., Barrie, J.V., Neuweiler, M. (2001) "Discovery of a 'Living Dinosaur': Globally unique modern hexactinellid sponge reefs off British Columbia, Canada." Erlangen *FACIES* 44: 265-282.

[8] Individual BC hexactinellid sponges are estimated to be at least 220 years old: *ibid*.

[9] Alaska primnoa have been aged to 160 years: "Age, growth and radiometric age validation of a deep-sea, habitat-forming gorgonian (*Primnoa resedaeformis*) from the Gulf of Alaska." *Hydrobiologia* 471: 101-110.

[10] These sponge reefs have been dated to be 9000 years old: Conway, K.W., Krautter, M., Barrie, J.V., Neuweiler, M. (2001) "Hexactinellid sponge reefs on the Canadian shelf: a unique 'living fossil'." *Geoscience Canada* 28:2 71-78.

[11] Morgan, L.E., and Chuenpagdee, R. (2003) "Shifting Gears: Addressing the collateral impacts of fishing methods in US waters." *Pew Science Series* Island Press, Washington, DC, USA.

[12] 10.5 thousand tonnes = 10,500,000 kg = 23,150,000 lb.

[13] Although this fishery has the largest landings, it has the lowest average value per pound in BC: Fisheries and Oceans Canada, 2004. Summary of Commercial Catch Statistics [web site]. Last accessed April 15, 2005: http://www-sci.pac.dfo-mpo.gc.ca/sa/Commercial/AnnSumm_e.htm

[14] Hake, a midwater fishery, in 2004 landed about 66 thousand tonnes of hake and another 2.5 thousand tonnes of other species, accounting for about 2/3 of all trawl landings.

[15] In 2004, excluding the midwater hake fishery, discards amounted to 28% of what was ultimately kept as catch. Or, to put it another way, 22% of all trawl catch, discards and landings, was bycatch.

[16] 322 tonnes of corals and sponges = 322,000 kg = 710,000 lb.

[17] Fisheries and Oceans Canada, Pacific Region, groundfish observer program [data set]. Analysis by the author.

[18] Royal Commission on Environmental Pollution (2004). Turning the tide: Addressing the impact of fisheries on the marine environment. Twenty-fifth report. Sir Tom Blundell, Chairman. Presented to

Parliament by command of Her Majesty, December, 2004. Last accessed Dec. 11, 2004: http://www.rcep.org.uk/fishreport.htm.

19 Freese, L., Auster, P.J., Heifetz, J., Wing, B.L. (1999) "Effects of trawling on seafloor habitat and associated invertebrate taxa in the Gulf of Alaska." *Marine Ecology Progress Series* 182: 119-126.

20 Hall-Spencer, J., Allain, V., and Fossa, J.H. (2002) "Trawling damage to Northeast Atlantic ancient coral reefs." *Proceedings of the Royal Society London B* (2002) 269: 507-511.

21 Heifetz, J. (1999) Effects of Fishing Gear on Sea Floor Habitat. Progress Report for FY1999, Auke Bay Laboratory Alaska Fisheries Science Center NMFS.

22 Witherall-Coon (2000) Protecting Gorgonian Corals off Alaska from Fishing Impacts. First International Symposium on Deep Sea Corals, Halifax, Nova Scotia.

23 Fossa, J.H.; Mortensen PB Furevik DM (2002) "The deep-water coral Lophelia pertusa in Norwegian waters: distribution and fishery impacts." *Hydrobiologia* 471: 1-12.

24 National Oceanographic and Atmospheric Administration (NOAA) (2005) Marine Protected Areas of the United States [web site]. Last accessed April 23, 2005: http://www3.mpa.gov/exploreinv/AlphaSearch.aspx.

25 North Pacific Fishery Management Council (2005). EFH Final Action, Council Motion [meeting minutes]. Last accessed April 16, 2005: http://www.fakr.noaa.gov/npfmc/current_issues/HAPC/HAPCmotion205.pdf. See also: Alsaka Marine Conservation Council (2005). North Pacific Fishery Managers Protect Globally Significant Corals from Destructive Effects of Bottom Trawl Fisheries [press release]. Last accessed April 16, 2005: http://www.akmarine.org/pressroom/release-021005.shtml.

26 Jonathon Warrenchuk, Marine Conservation Coordinator, Oceana, personal communication [email], Feb. 15, 2005.

27 700 km^2. Analysis by the author, based on DFO legal descriptions of the closures, as given in the 2005 Integrated Fisheries Management Plan, Groundfish Trawl. Last accessed April 16, 2005: http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/MPLANS/plans05/GFTrawl05.pdf.

28 Conway, K.W., Barrie, J.V., Austin, W.C., and Luternauer, J.L. (1991) "Holocene sponge bioherms on the western Canadian continental shelf." *Continental Shelf Research* 11(8-10): 771-790.

29 Conway, K.W. (1999) Hexactinellid Sponge Reefs on the British Columbia continental shelf: geological and biological structure with a perspective on their role in the shelf ecosystem. Canadian Stock Assessment Secretariat Research Document 99/192.

30 Conway, K.W., Krautter, M., Barrie, J.V., Neuweiler, M. (2001) "Hexactinellid sponge reefs on the Canadian shelf: a unique 'living fossil'." *Geoscience Canada* 28:2 71-78.

31 Krautter, M., Conway, K.W., Barrie, J.V., Neuweiler, M. (2001) "Discovery of a 'Living Dinosaur': Globally unique modern hexactinellid sponge reefs off British Columbia, Canada." *Erlangen FACIES* 44: 265-282.

32 "The sponge reefs are being impacted by mobile fishing gear [trawling]. The opportunity for study of the sponge reefs, both in terms of their modern ecology, and the linkages that these reefs have with extinct Mesozoic reefs may not exist in the future without protection." (p. 4) Fisheries and Oceans Canada, Pacific Region (2000). Hexactinellid sponge reefs on the British Columbia continental shelf: geological and biological structure. DFO Science Habitat Status Report 2000/02 E. Last accessed April 16, 2005: http://www.pac.dfo-mpo.gc.ca/sci/psarc/HSRs/hab-02.pdf.

33 Jamieson, J., and Chew, L. (2002) Hexactinellid Sponge Reefs: Areas of interest as Marine Protected Areas in the North and Central Coasts Areas. Canadian Science Advisory Secretariat Research document 2002/122.

34 It is interesting to note that contrary to DFO's own published literature, the 2005 DFO *Groundfish Trawl Management Plan* claims the sponge reefs were discovered only ten years ago, rather than the actual seventeen. C.f. page 9: http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/MPLANS/plans05/GFTrawl05.pdf vs. page 1: http://www.pac.dfo-mpo.gc.ca/sci/psarc/HSRs/hab-02.pdf.

35 After the closures, some large landings continued to be recorded in the vicinity. This would indicate that the closures are too small.

36 We did not receive spatial data for the months of Jan. – Mar. 2001. However, we do not believe these three missing months appreciably altered our spatial results.

37 Freese, L., Auster, P.J., Heifetz, J., Wing, B.L. (1999) "Effects of trawling on seafloor habitat and associated invertebrate taxa in the Gulf of Alaska." *Marine Ecology Progress Series* 182: 119-126.

38 Individuals provided information on the condition of anonymity.

39 But the mean is 166 lb (75 kg), indicating the distribution is extremely skewed towards some landings much heavier than would be expected in an even distribution. Because the observers estimate weight in pounds, these are the units we will use, which allows for whole numbers.

40 These enormous bycatches all occurred in the vicinity of the hexactinellid sponge reefs. Both inside and outside the areas now closed.

41 Catch per unit effort (CPUE): A measure sometimes used by fisheries scientists to indicate the abundance of a species; e.g. kg of fish caught per hour of fishing.

42 Etnoyer, P., and Morgan, L. (2003) Occurrences of habitat-forming cold water corals in the Northeast Pacific Ocean. A report to NOAA's Office of Habitat Protection Marine Conservation Biology Institute.

43 Freiwald, A., Fosså, J.H., Grehan, A., Koslow, T., Roberts, J.M. (2004) Cold-water Coral Reefs. UNEP-WCMC Cambridge UK.

44 Jamieson, J., and Chew, L. (2002) Hexactinellid Sponge Reefs: Areas of interest as Marine Protected Areas in the North and Central Coasts Areas. Canadian Science Advisory Secretariat Research document 2002/122.

45 Because there is currently no clear observer category for the hexactinellid sponges, the observers classed them under various categories, such as "stony corals," etc.

46 The exceptions to this rule were the categories of "gorgonian corals" and "sea pens," both of which are fairly easy to identify, and in which we therefore placed somewhat greater confidence.

47 Due to low numbers of observations, "Bath Sponges" were not included.

48 Walters, C.J., Bonfil, R. (1999) "Multispecies spatial assessment models for the British Columbia groundfish trawl fishery." *Canadian Journal of Fisheries and Aquatic Science* 56: 601-628.

49 Halpern, B. (2003) "The impact of marine reserves: Do reserves work and does size matter?" *Ecological Applications* 13:1 supplement 117-137.

50 Hastings A and Botsford L (1999) Equivalence in yield from marine reserves and traditional fisheries management. Science 284:1-2

51 Hastings A and Botsford L (2003) Comparing designs of marine reserves for fisheries and for biodiversity. Application of ecological criteria for evaluating candidate sites for marine reserves. Ecological Applications 13:1 supplement 215-228

52 Fossa, J.H.; Mortensen PB Furevik DM (2002) "The deep-water coral Lophelia pertusa in Norwegian waters: distribution and fishery impacts." *Hydrobiologia* 471: 1-12.

53 Heifetz, J. (2002) "Coral in Alaska: Distribution abundance and species associations." *Hydrobiologia* 471:19-28.

54 Husebo, A.L., Nottestad, J.H., Fossa, D.M., Furevik, and S.B. Jorgensen (2002) "Distribution and abundance of fish in deep-sea coral habitats." *Hydrobiologia* 471: 91-99.

55 Kaiser, M.J. (1998) "Significance of bottom-fishing disturbance." *Conservation Biology* 12(6): 1230-1235.

56 Krieger, K.J., and Wing, B. (2002) "Megafauna associations with deepwater corals (*Primnoa spp*) in the Gulf of Alaska." *Hydrobiologia* 471: 83-90.

57 Watling, L. and Norse, E.A. (1998) "Disturbance of the seabed by mobile fishing gear: A comparison to forest clearcutting." *Conservation Biology* 12(6): 1180-1197.

58 Croyer, M. Hartill, B., O'Shea, S. (2002) "Modification of marine benthos by trawling: Toward a generalization for the deep ocean?" *Ecological Applications*, 12(6): 1824-1839.

59 Freiwald, A., Fosså, J.H., Grehan, A., Koslow, T., and Roberts, J.M. (2004) Cold-water Coral Reefs. UNEP-WCMC Cambridge UK.

LIVING OCEANS SOCIETY