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# Re-evaluation of sponge reef complex occurrences and their protection in Pacific Canada

# Réévaluation des occurrences de complexes de récifs d'éponges et protection de ceux-ci dans le Pacifique canadien

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## Abstract

Evaluation of sponge bycatches in the vicinity of known sponge bioherms in Queen Charlotte Basin indicates that established groundfish trawl closures have reduced trawl impacts. Recent revision of the closure boundaries to better reflect the known spatial distribution of the bioherms will likely even further reduce direct trawl gear impacts. Impacts from other benthic gears could not be assessed because of the lack of relevant bycatch and fishing location data, but all benthic gear activity in the vicinity of all sponge bioherms should be terminated. Although direct incursions of trawls are now being minimized, there is still concern that fishing activity close to the sponge reefs may be impacting the sponges, either accidentally or through increasing suspended solids presence. No direct data on these potential impacts exist, but a precautionary management measure would be to establish larger closures, i.e. bioherm footprints plus a modest buffer zone, around the bioherm complexes. New smaller sponge bioherms have recently been found in both Queen Charlotte Strait and the Strait of Georgia, and it is recommended that effective closures for all benthic fishing gear impacts be also established around these sponge bioherm complexes as well.

## Résumé

L’évaluation des prises accessoires d’éponges dans le voisinage de biohermes d’éponges connus dans le bassin de la Reine-Charlotte indique que les fermetures de la pêche au chalut aux poissons de fond ont réduit l’impact associé aux chaluts. Une revue récente des limites de la zone fermée, visant à mieux refléter la répartition spatiale connue des biohermes, permettra probablement de réduire encore davantage les impacts directs associés aux chaluts. Les impacts associés à d’autres engins benthiques n’ont pu être évalués, faute de données pertinentes concernant les prises accessoires et les lieux de pêche, mais toute activité utilisant des engins benthiques au voisinage de tout bioherme d’éponges doit cesser. Bien que les incursions directes de chaluts soient maintenant réduites au minimum, on se préoccupe encore du fait que les activités de pêche qui ont lieu à proximité des récifs d’éponges puissent avoir un impact sur les éponges, soit accidentellement, soit par la présence croissante de solides en suspension. On ne dispose d’aucunes données directes sur ces impacts potentiels, mais une mesure de gestion prudente reposerait sur l’établissement de limites plus étendues aux zones fermées, c’est-à-dire la place occupée par les biohermes ajoutée à une zone tampon modeste entourant les complexes de biohermes. De nouveaux biohermes d’éponges plus petits ont été récemment découverts dans le détroit de la Reine-Charlotte et dans le détroit de Georgia, et l’on recommande que des fermetures effectives pour tous les engins de pêche benthiques soient également établies autour de ces complexes de biohermes d’éponges.

## Introduction

Much attention is currently being devoted in Canada to both the identification of sensitive marine habitats and species (e.g. identification of Ecologically and Biologically Significant Areas (EBSAs, DFO 2004) and Ecologically Significant Species and Community Properties (ESSCPs, DFO 2006b)) as part of pilot Integrated Management area ecosystem overview reports (EORs)) and the human impacts on such habitats and species (e.g. National Advisory Process (NAP) report of impact of trawl gears and scallop dredges on benthic habitats and communities, DFO 2006a). Globally unique biogenic habitats (Fig. 1), identified by Conway et al. (1991, 2001), have been previously described (Jamieson and Chew 2002) for the Pacific North Coast Integrated Management Area (PNCIMA), and management and research recommendations for their conservation were:

1. effective protection should be established as soon as possible,
2. for effective protection, there should be a protected buffer zone around the currently known areas of each actual reef complex,
3. development of research and monitoring programs to evaluate the nature and importance of the reefs to the overall shelf ecosystem is justified, and
4. other known sponge reefs in British Columbia (BC) should also be considered for protection.

Pacific Scientific Advice Review Committee (PSARC) Habitat Subcommittee recommendations (DFO 2002) were:

1) The four major sponge reef complexes in the Central Coast area are thought to be globally unique. The reefs need additional protection due to close proximity of existing groundfish trawl closure boundaries to the reef boundaries. As an immediate interim measure, fishery closures extending one mean trawl length (calculated to be 9 km) from the reef boundary are recommended to protect the sponge reefs from further physical damage. Research is recommended to determine scientifically defensible criteria for determining closure zone size and placement.
2) Serious consideration should be given to designating the reef complexes as Marine Protected Areas. This action would offer the most comprehensive level of protection.
3) Further research into the biology of these reef complexes and their ecological significance is required.

In response to DFO's scientific advice (Jamieson and Chew 2002, DFO 2002) and public pressure (Table 1), fisheries management established groundfish trawl closures in 2003 (Fig. 2) around known reef complex areas at that time. These replaced the voluntary groundfish trawl closures established in 2000 by the Groundfish Trawl Advisory Committee (GTAC). Science advice to establish buffer zones around the sponge reef complexes was not followed, and closure boundaries were straight lines located in close proximity to the estimated sponge reef complex borders. Groundfish trawl closure boundaries were subsequently modified on April 1, 2006, to reflect new spatial data on the locations of the reef complexes obtained by Natural Resources Canada (NRCan) scientists (Fig. 3).

These further seabed surveys by NRCan utilising multibeam mapping have greatly improved the areal georeferencing of the sponge reefs (Conway et al. 2005a, Krautter et al. 2006), and they show that the initial estimated locations of the sponge reefs provided by NRCan in Jamieson and Chew (2002) were only partially right. DFO Groundfish acted on this new mapping data to expand the existing closures in a timely manner after consultation with NRCan scientists, and the boundaries of the closures were redefined on April 1, 2006. Cook (2005) reviewed existing data with respect to determining the ecological function of the reefs.

Objectives of this working paper were to:

1) review the locations and sizes of the existing sponge reef closures established by Fisheries and Aquaculture Management (FAM) in 2002.
2) assess the extent to which the sponge reefs have been protected over time in relation to existing trawl closures
3) provide recommendations for improved protection of the sponge reef complexes.
4) present up-to-date data on the locations of sponge reefs in the Pacific Region, with advice and rationale concerning any further protection of the sponge reefs, particularly regarding those in the Strait of Georgia, and
5) determine if there are high priority areas for multibeam surveys to be undertaken based on excessive sponge bycatch levels. (e.g., area between reefs B and C).

Specific questions to be addressed in the working paper are to:

1) determine whether existing fishery closures are sufficient in area to protect known sponge reef bioherm complexes from the impacts of the groundfish trawl fishery.
2) advise whether a buffer zone of protection around the reefs is justified to protect the sponge reef bioherm complexes.
3) advise whether fisheries closures are sufficient to protect the sponge reef bioherm complexes in view of potential impacts from other types of ocean use.

## Methods

Sponge reef survey methodologies are described in Conway et al. (2005a,b) and Krautter et al. (2006) and maps provided here were produced by NRCan (Kim Conway, Sidney, BC, pers. comm.).

Centre locations of tows (determined from mid-points on a straight line between start and end locations) are mapped in relation to the sponge reefs and were provided by Jeff Fargo (Pacific Biological Station (PBS), Nanaimo, BC, pers. comm.). Only the spatial locations of 2005 glass sponge catches (kilograms summed for each square kilometre) where three or more vessels fished are shown in Fig. 6; black shaded areas indicate a catch range of 113-1361 kg but because only one or two vessels were involved, no finer spatial breakdown can be published.

Coral and sponge bycatch data summaries (Table 2A) were obtained from Alan Sinclair (Pacific Biological Station (PBS), Nanaimo, BC, pers. comm.).

## Results

1. Evaluation of Existing PNCIMA Trawl Closures for Sponge complex conservation

The detailed multibeam mapping of the four PNCIMA sponge reef complexes has provided a much improved understanding of their spatial distributions. Each reef complex actually consists of a large number of separate small reefs (Figure 1, from Conway et al. 2005b). The total area of reef complexes in PNCIMA was initially estimated to cover about 700 $km^2$ (Conway 1999, Jamieson and Chew 2002), but the actual footprint area of ground covered by reefs, i.e. excluding the area between the individual reefs, is now estimated to be about 386 $km^2$ (K. Iwanowska, Natural Resources Canada, Sidney, BC, March 2006, pers. comm.). However, because of the close proximity of the individual bioherms, the effective area that needs closure from benthic disturbance to protect the bioherm complexes needs to be larger than the actual footprint area of the bioherms, and in fact now exceeds the initially estimated 700 $km^2$ as the reef complexes have now been found to be larger in overall spatial area than initially estimated a few years ago, and exceed over 1000 $km^2$ (Cook 2005).

Known locations of sponge reefs and trawl closure boundaries up to April 1 2006, and potential trawl closure zones with the two buffer options considered in 2002 are shown in Figure 2. Rectangular closures are shown here to be consistent with the possible closures discussed in Jamieson and Chew (2002), and while these may not now be the most desirable shape (with state of the art GPS, any boundary shape can now easily be visualised), they do give scale to Fig. 2. Roughly, about 93% of sponge reef complexes A, C and D were enclosed within the initial groundfish closures, but only about 30% of reef complex B was within its 2002 closure zone. Boundaries of the revised closures established April 1, 2006 (Figure 3) only include the footprint of the revised reef complexes and have no specific buffer zone. Shrimp trawl closures for sponge reefs in 2006 have not had their boundaries revised to reflect the new understanding of bioherm spatial distribution (Figure 4).

Conway et al. (2005a) reported from data provided by Alan Sinclair (DFO, Nanamio, BC, pers. comm.) that about 95% of the sponge groundfish trawl bycatch caught between 1996-2002 came from close to the sponge reef complexes. Sinclair et al. (2005) analysed groundfish bottom trawl data from 1996-2004 and plotted estimated fishing effort (hr), aggregate catch per unit effort (CPUE kg $hr^{-1}$) for all fish species, and CPUE for individual species for PNCIMA on a 1 $km^2$ grid (tow lengths were much longer than one km, so effort and catches were prorated per unit area). They assumed that catchability was spatially constant and equal among species, and that maps of CPUE represented the spatial distribution of relative biomass within the fished area. Their analysis showed that 90% of fishing effort was distributed over 28% of the fished area, and that 50% of the effort was over only 6% of the fished area, with much effort in the Queen Charlotte Basin focused around the 200 m isobath. The sponge reefs are found at depths between 165 and 240 m (Krautter et al. 2001), indicating that they are in a depth range of high groundfish trawl activity. From 2003-2005, fishing effort close to the three more northerly sponge reef complexes (reefs A-C) was quite low, but was relatively high around the most southern PNCIMA reef complex (reef D) (Figure 5).

Since the trawl closures were established in July, 2002, there has apparently been little, if any, trawling in the closed areas. However, there was an area where sponge catch was significantly higher (Figure 6), which may in part be explained by the inadequacy of the 2002 closure around Reef B. However, it also suggests that concentrations of sponges may exist between reefs B and C and suggests that expanded multibeam coverage may be required to re-assess the mapped reef distribution in this boundary area.

All of the above is inferred from assumed straight line tows between start and end tow locations, which may not always, or even typically, be the case, as there are no data currently available to evaluate this. There is no reason to suggest that trawl fishing in British Columbia would not follow bottom bathymetry or other features and be nonlinear, particularly since trawl tows are relatively long, averaging about 9 km in length (Jamieson and Chew 2002).

Groundfish trawl landings of sponges and corals by year (Table 2A) indicate that sponges comprise the majority of sponge-coral landings, and that the total sponge landing continues to decline from the high values recorded in 2000-2001. Sponge landings from within 9 km of the groundfish trawl sponge closures (Table 2B, 6054 kg) represented 72% of the sponge landings from the entire trawl fishery (8444 kg) in 2005. Much of this landing (57%, 3454 kg, 22 sets) came from around reef B which we now know was inadequately covered by the trawl closures established in 2002 (Fig. 2). 41 % (2482 kg, 20 sets) of the sponge landing came from around reef C, which was more effectively covered by the closures (Fig. 2). Most trawling was around reef D (Fig. 6; J. Fargo, pers. comm.), but the 36 sets there caught only 93 kg of sponges (Table 2B). An insignificant sponge catch (6 kg, 5 sets) occurred around reef A. Table 2C summarizes landed species and finfish bycatch species reported in 2005 from tows with a midpoint within a 9 km rectangular zone (see Fig. 2) around the 2002-established sponge reef closures (J. Fargo, pers. comm.), i.e., data on benthic finfish community structure around each of the four reef complexes.

In summary:
1) There were 419 tows with sponge in them from the total of 16,247 bottom trawls made in the 2005 groundfish trawl fishery,
2) 86 of these tows were within the 9 km zone described here; these tow’s midpoints were outside of the closed areas,
3) 74% of the sponge catch within the 9 km zones came from nine tows in the black area in Figure 6, and
4) Sponge bycatch in 2005 was 14% of the maximum sponge landing (2001) between 1996-2004. Annual sponge bycatch has steadily decreased since 2002 (Table 2A).

2. New Sponge Reef Locations

A number of additional, although much smaller, sponge reef complexes have been found in Queen Charlotte Strait near Malcolm Island (Dixie Sullivan (via Kim Conway), Environment Canada, N50° 41.8104', W127° 05.628', depth: 89m) and in the Strait of Georgia (Fig. 7). The former one was multibeam surveyed in July, 2006, and was found to cover 0.86 $km^2$ (Fig. 8). It also is largely located in a now-closed logging debris dump site, which may have impacted it detrimentally. Conway et al (2005b) describe bioherms in the Strait of Georgia from McCall Bank and the Fraser Ridge, but additional ones have recently been found off the Englishman River mouth (Parksville), off Gabriola Island and in the Active Pass area off the southern Gulf Islands (Figure 7, K. Conway, pers. comm.). Evidence suggests that the sponge reefs in the central Strait of Georgia at Halibut and McCall Banks and south of Active Pass (Fig. 7) have been impacted heavily by trawl activity in the past. The evidence for this includes sidescan sonograms showing abundant trawl marks at Halibut and McCall Bank (Conway et al., 2005a and unpublished data – Pacific Geoscience Centre) and seabed video transects from the south Active Pass reef that indicate mechanical impacts to the reef forming glass sponges. Proximity of these locations to trawl sets documented between 1996 and 2001 (Alan Sinclair, written communication) would also suggest that trawling has impacted these reefs. In the case of the Active Pass area reefs, that occurs in more shallow water, it is possible that other mobile gear such as shrimp trawl may have impacted the reefs (Figure 7 - Inset B at location 9).

An additional reef at 20 m depth, about 50 by 80 m in area, has been described by SCUBA divers on the sill off Squamish in Howe Sound (Douglas Swanston, Seacology, North Vancouver, BC, pers. comm.: N49º 34.675’, W123º 16.410’, just east of the Defence Islets). There are presently no benthic gear fishing closures around any of these inshore sponge reefs, although in 2006 there was a shrimp trawl voluntary advisory for one reef (Site 1 in Fig. 7): “Fishers are advised that concern has been expressed for the impact of commercial fishing gear on sponge reefs in the lower Gulf at a location 12 km. offshore of Sturgeon Bank at approximately $49^{o}9.5'$ North and $123^{o}23'$ West in 160 to 220 meters of water” (http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/MPLANS/plans06/Shrimp_trawl_2006-07_IFMP.pdf).

## Discussion

1. Queen Charlotte Basin sponge reef complexes:
Complete multibeam assessment of the four primary sponge reef complexes has provided accurate positioning and sizes of these globally unique features. Initial groundfish trawl closures helped to minimise impacts from trawl gear damage, and while new closure boundaries were only established about six months ago, they presumably will be even more effective at reducing sponge reef damage, as estimated from sponge bycatch decreases in recent years. However, unlike in the Maritimes where since Jan 1, 2006, Vessel [Spatial] Monitoring System (VMS) data is now required from every vessel with mobile gear (initial data obtained is still being analysed (S. Gavaris, DFO, St. Andrews,

NB, pers. comm.)), there are no such requirement from Pacific vessels fishing mobile gear, including the groundfish trawl fleet, and the only routine information being provided to researchers and managers at present are start and end tow locations. The primary role of groundfish observers present on all groundfish trawl vessels since 1996 is to observe, record and report. While enforcement is not a requirement of them, if they see an infraction, then they are required to report it, and indeed, have a special form to fill out which documents the observations they made. With respect to cruise tracks, they routinely report start and end locations, and while they can, and even may regularly, observe the GPS cruise tracks, this would not necessarily show infractions (e.g. having a portion of the tow within a closed area) as the closed areas are not required to be shown on the vessel's GPS relative to the cruise track, i.e., on the same display (Greg Workman, DFO, Nanaimo, BC, pers. comm.). Some fishers may enter these data on their GPS displays, while others may not. Thus, except for a high sponge bycatch recording, there is presently no routine, reliable way to assess how close to the sponge reef closure boundaries groundfish trawl vessels are fishing and whether trawl incursions into the closed areas occasionally occur.

For these reasons, DFO's current databases do not allow accurate trawl path determinations, particularly where trawl tows are relatively long (average length is about 9 km) and occur in a bathymetrically complex environment. It would be useful to have accurate trawl paths routinely and impartially provided to DFO in electronic form.

While many species of fish and invertebrates have been documented as occurring on the sponge bioherms (Jamieson and Chew 2002), the full ecosystem role of the sponge reefs has yet to be determined. By providing structural habitat and presumably having a higher abundance of species than might otherwise be present in the area, recruitment rates of at least some species are likely enhanced. This becomes even more likely if fishing closures maximise both the abundances and the sizes of individuals of species on the reefs, thereby allowing for improved population fecundity to be achieved. Fisheries in adjacent open areas may be benefiting from a spillover of recruits from this protected habitat, but whether this potential benefit is real or could be enhanced if the closure areas were slightly larger has yet to be determined.

Gear types other than groundfish trawls can potentially damage structural species such as corals and sponges, notably long line (hook and line rockfish – inside and outside, and halibut), trap and shrimp trawls in BC. In raising hook and line gear and traps, the gear may be dragged over the bottom, which could damage structural species extending up from the bottom. At present, shrimp trawl closures exist around the sponge reefs, but these closure boundaries have not been modified to reflect the new refined locations of the reefs (Figure 4). Other gear types are not presently prohibited from being utilised in the sponge reef areas, with the exception that shrimp and prawn trap fishermen are advised to avoid cloud sponge areas in selected areas in Saanich Inlet in waters less than 40 m depth, and on sponge reefs in the lower Gulf of Georgia at a location 12 km offshore of Sturgeon Bank at approximately 49-09.5 north and 123-23.0 west in 160 to 220 m of water ((http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/MPLANS/plans06/Prawn06pl.pdf).

It should also be noted that there has been no comprehensive and systematic drop camera or video assessment of the condition of the reef complexes to assess whether damage has in fact recently occurred. DFO has a ROV that is capable of assessing reef conditions, and NRCan has recently acquired a drop camera that could be borrowed and used if appropriate ship time could be provided (K. Conway, pers. comm.).

There is also concern that even if trawl activity does not extend onto the reefs directly, trawling in close proximity to the reefs may introduce sediment into the water column that drifts over the reefs at levels that might be harmful to sponges. Concerning the sedimentary regime around the sponge reefs, in the Queen Charlotte Basin (QCB), winter downwelling and the summertime relaxation of downwelling, or weak upwelling, in combination with the focused moderate currents of the semi-diurnal tidal regime are important mechanisms for the development of large sponge reef complexes (Whitney et al., 2005). In the QCB, the sponge reefs occur in areas that are rich in dissolved silicate (>40 µM) and have relatively high fluxes of opal, i.e., biogenic detritus (~2 mol Si m-2 y-1) mainly derived from diatom tests. Bottom currents, constrained and focused by bathymetry, are moderate (35 to 50 cm s-1) which helps transport both dissolved and particulate materials to sponges and at the same time prevent smothering of living sponges by sedimentation. The sponge reef complexes are located on the mid to inner shelf in the thalweg of the troughs and this location ensures that enriched bottom waters are funneled to the reefs. Detrital material, suspended in a bottom nepheloid layer, is derived from both onshore coastal sources and the resuspension of offshore particles, and is effectively trapped by the dense populations of sponges (Whitney et. al, 2005). Trapping of these materials results in the observed enrichment of organic carbon, nitrogen and opal as measured in cores, relative to surrounding and underlying sediments (Conway et al., 2001). The sponges thus exist in relatively enriched zones where several oceanographic processes ensure an optimal delivery of dissolved nutrients and potential food particles. Tidal currents repeatedly cycle bottom waters across the reefs. Because of the tidal regime and current field, particulate material has a residence time of six days in contact with the largest reef complex (Whitney et al., 2005). The large obstructing mounds on the seabed appear to deflect tidal currents, creating flow conditions that are more locally complex than outside of the reef areas (Whitney et al., 2005). These factors indicate that the sponge reefs effectively trap materials at the reef sites. The processes of construction of the reefs suggests that introduction of suspended sediments into the water column by a mechanism such as trawling would possibly result in the trapping and retention of this material on the reefs, though this would depend on the characteristics of these sediments. The sediments normally trapped by sponges on the reefs tend to very fine grained (Conway et al., 2001) and organically rich (Conway et al., 2005b) and the affects of the introduction of more sediments of different textures or composition is unknown.

Given the above, the earlier PSARC recommendations (DFO 2002) for a buffer zone around the actual footprint of the reefs are still suggested as desirable. Both the initial and current modified groundfish trawl closures which closely follow the estimated footprints of the reef complexes were established by groundfish managers following discussion with NRCan researchers. Their initiative is lauded, but prior consultation with DFO oceans managers and science conservation researchers in the design of the closure boundaries in the future might help to ensure that both effective protection of the reefs and maximisation of the ecosystem benefits they provide are best achieved. The presumption is that with their sophisticated navigational equipment, fishers are not impacting the sponges, but since there presently is no way to easily confirm just how close the trawls are passing to the mapped bioherms, the concern and suggested need for even a modest buffer zone is both because of possible accidental incursion of trawls onto a reef and that possible increased suspended solids from nearby trawling is having an impact.

A buffer zone around the immediate footprint of the bioherms, previously recommended by PSARC (DFO 2002) for groundfish trawls, was one average trawl tow length, i.e. 9 km. In Figure 2, rectangular reef complex footprint closures are illustrated, and potential buffer zones of 5 and 9 km, about 1/2 and one average groundfish trawl tow length, respectively, are mapped to show the potential sizes of closure options. If buffer zones are established, they do not necessarily need be rectangular and could follow the current closure outlines of the bioherm footprints. As mentioned above, the limited fishing effort around reef complexes A-C suggests that inclusion of buffer zones there as part of the trawl closures would have relatively little overall economic impact on the groundfish industry. A larger closure zone around reef complex D would likely displace some fishing effort to other areas, but given that the mobilities of the exploited species, while unknown, may be substantial for some species at least, and potential spillover of adult fish from such a refugia may be extensive, the implications and extent of displacement even there may not be economically significant. However, it is recognised that generally, benthic species like rockfish and flatfish are not believed to move great distances once they become adults, and many may not travel more than five km (R. Haigh, DFO, Nanaimo, pers. comm.). Their pelagic offspring (larvae and juveniles), on the other hand, could potentially disperse over large distances and settle away from the adult habitat.

In short, with available data, neither positive nor negative impacts on groundfish fishing can be easily estimated. Establishing an effective sponge reef closure (i.e., with buffer zones) would then be an adaptive management exercise, as only by doing it can both the biological and economic consequences be assessed and if necessary, mitigated. Given that the sponge reef complexes are globally unique, their conservation is suggested to override possible economic concerns that have not been substantiated at this time. This point also argues that closure establishment should be expanded to all benthic fishing activity around the footprint of the reefs.

While the sponge reef complexes are recognised as globally unique, the question has still been raised as to whether all four reef complexes should be equally protected? Would protection of only a few be adequate conservation, and given that their may be some negative economic consequences to protection, particularly around reef complex D, could some potential damage of this latter reef, for example, be tolerated and still achieve acceptable overall sponge reef conservation if conservation of the other three major bioherm areas was fully achieved. The main arguments for full conservation of all four reefs centre around two issues: what is the ecosystem role or function of the sponge reefs in the larger ecosystem, and are the biological communities around each of the four reef complexes similar?

The overall ecosystem role or function of the sponge reefs in the larger ecosystem remains largely unknown, and is unlikely to be determined in the near future for the following reasons:
1) to assess community structure without damaging the reefs, non-destructive survey methodologies will have to be utilised. These will largely require deployment of cameras and video equipment that while available, will be expensive to utilise. The remoteness of the location, its exposure to potentially rough sea conditions, and the size of the equipment being used to reach the depths of the sponges requires the use of large survey vessels, which are both expensive and difficult to acquire because of other competitive demands for their time;
2) such camera equipment can only survey a relatively small geographic area per unit of survey time, and while effective for benthic low mobility species, is less effective at surveying higher mobility species such as fish. This means that effective assessment is likely to be slow, time consuming, and therefore costly.

Nevertheless, Cook (2005) has done some analysis based on the video and grab data collected in both Queen Charlotte Basin and on the Fraser Ridge. Her analyses indicated the following:
1) live sponge habitat has increased species richness when all fauna are combined and increased abundance of individuals when boot sponges and demosponges are removed from the analyses;
2) live reefs are nursery habitats for juvenile rockfish,
3) live reef and off-reef habitats have significantly different community structures,
4) trends in abundance between habitats for specific taxonomic groups depend on which group is being considered,
5) high complexity areas have increased richness and abundance of individuals and a significantly different community structure compared to the other complexity values, and
6) off-reef, high complexity areas have the highest richness and abundance of individuals of all the shelf communities.

Other more specific conclusions were:
1) dead sponge supports a larger population of megafauna in terms of abundance, richness and diversity than does live sponge and that there are substrate preferences within taxonomic families,
2) polychaete richness and diversity are significantly higher in reef versus off-reef habitat at the family level but not the species level,
3) reef and off-reef habitats are different in terms of polychaete community structure, and
4) tubiculous deposit feeders are the dominant taxa at both reef and off-reef sites.

With respect to macro-fauna community differences around the sponge reefs in Queen Charlotte Basin, this has already been generally documented by Jamieson and Chew (2002). They stated that the vast majority of catch was flatfish at Reef A, followed by rockfish / thornyheads, and others. There, the bycatch comprised only a small percentage (<5%) of the total catch, with no major differences between species groups on or adjacent to the reef. In comparison, the majority of the catch at Reefs C and D was rockfish / thornyheads, with an increased percentage when including the surrounding area adjacent to the reef. The bycatch percentage for other species declined in tows adjacent to Reefs C and D. The fish communities around the more northern and southern reef complexes thus differs, meaning while the sponge species in the reef complexes are similar, the roles of the reefs in the larger ecosystem are likely different.

It can therefore be argued strongly that all potential ecological roles of all reefs should be conserved.

2. Sponge reefs in other areas
With increasingly more and more of the coast being surveyed with multibeam sonar, additional sponge bioherms are being discovered, and their recent rate of discovery suggests that more likely exist and await discovery. However, newly discovered reefs to date are all nearshore and are relatively small in comparison to the known four major Queen Charlotte Basin reef complexes, suggesting that it is unlikely that new large reefs on the scale of those found in Queen Charlotte Basin will be found in either other offshore areas or in inshore waters. The fact that inshore sponge reefs may be more common than previously realised and may be widely distributed should not infer that they do not all need protection, as biogenic habitat in the relatively homogenous deep-water environment is relatively rare. This was recognised in the recent national workshop on Ecologically Significant Species and Community Properties, with recognition that all structure-providing species merit enhanced management and conservation. Like eelgrass and macrophyte beds in shallow water, concentrations of structural species in deep water should all be protected from all human disturbances to the greatest extent possible, as their roles or function in the overall ecosystem are likely substantial, or at least this should be assumed until proven otherwise.

It should also be noted that because of their relatively small sizes (typically much less than 1 $km^2$), these smaller isolated inshore bioherms are much more vulnerable to destruction by mobile benthic activities, particularly if they occur in areas of generally smoother bottom. Some reefs just discovered in the Strait of Georgia appear to have had the sponges on them mostly destroyed by trawling activity (see above), so immediate regulations to prevent future damage are needed if the sponges on them are to be preserved.

Finally, the finding that a significant sponge reef occurs at a location that was a past logging debris dump site (now closed) demonstrates why locating future benthic dump and dredge impact sites without prior survey of the area's benthic communities should not be acceptable if a precautionary approach to biogenic habitat conservation is being practiced. When the logging debris dump site was established, there was no understanding of the nature of sponge reefs, and likely no need for an analysis of potential ecosystem impact. This is not the case today, though, justifying the requirement for rigorous benthic evaluation methods before such designations are made.

## Recommendations

1. A suitable buffer area needs to be established around existing sponge reef trawl closures. The width of the buffer zone should take into consideration potential trawl track variability where the trawl does not precisely follow the vessel and also accommodate any potential suspended sediment increase generated by trawl activity. As these parameters are not well know it is recommended that determination of appropriate buffer zone dimensions be the subject of future research.

2. It is recommended that all mobile benthic gear vessels be required to utilise VMS equipment and that these data be provided to DFO to allow documentation of possible benthic gear impacts.

3. While trawling has the potential greatest impact on sponge reefs, other gear types such as long lines and traps can also have impacts. All BC sponge reef complexes, i.e. including those in the Strait of Georgia and other locations, should be closed to all bottom impacting fishing activities, and indeed all human disturbances, to the greatest extent possible.

4. The presence of large concentrations of structural species such as sponges likely indicates areas of high ocean productivity, or at least food availability, at depth, and as such, help identify ecologically and biologically significant areas. The significance of these areas to the overall ecosystem should be studied to help ensure that appropriate ecological objectives are defined and appropriate subsequent monitoring effected.

**5**. Multibeam surveying should be undertaken in the area of high sponge bycatch between Reefs B and C to determine if reefs exist in this area. This will allow managers to determine if the recent high sponge bycatch is related to the presence of sponge reefs or not.

## Acknowledgements

We thank Douglas Swanston for providing information about the Howe Sound sponge reefs described, and J. Fargo and A. Sinclair for providing groundfish trawl data and analyses.

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Table 1: Chronology of actions re the establishment of closures around the sponge reefs.

| Date | Action | Reference/Action |
|---|---|---|
| 1991 | NRCan first documents presence of sponge reefs | Conway et al. 1991 |
| 1999 | Impacts of bottom trawling activity on the reefs by Pacific fisheries documented; PSARC recommendation for a moratorium on all mobile fishing gear activity on the reefs | Conway 1999 |
| 1999 | PSARC recommendation for immediate protection from potentially damaging fishing methodologies, and long-term protection through designation of an MPA; recommendation for searches for other bioherms by requesting observers to document all species, and to analyse fishing vessel observer logs | Stocker and Pringle 1999 |
| 1999 | Resource Management Executive Committee (RMEC) did not support the MPA recommendation "... because criteria for MPAs had not yet been established…", but recommended that the industry be encouraged to implement voluntary closures so as to provide immediate protection. | Email from John Pringle, pers. comm. |
| 2000 | Voluntary closure around bioherms by shrimp trawl initiated; Voluntary groundfish trawl closures implemented by Groundfish Trawl Advisory Committee (GTAC) | http://ops.info.pac.dfo.ca/ fishman/Mgmt_plans/archive/2 000/Shrimp00pl.PDF |
| 2001 | March 9 - CONSERVATION GROUP CALLS FOR MARINE PROTECTED AREA TO SAFEGUARD HECATE STRAIT SPONGE REEF COMMUNITIES | Canadian Parks and Wilderness Society (CPAWS) press release |
| 2002 | Visual evidence that trawling impacts were still occurring | K. Conway, Natural Resources Canada (NRC), Sidney, BC, pers. comm. |
| 2002 | July 2 - CONSERVATION GROUP SLAMS DFO FOR FAILING TO PROTECT UNIQUE HECATE STRAIT SPONGE REEFS - NEW DAMAGE REPORTED BY SCIENTISTS; FRAGILE SPONGE REEFS OFF THE B.C. COAST ARE MADE MOSTLY OF GLASS AND DATE BACK TO THE JURASSIC ERA | CPAWS press release; Toronto Star article |
| 2002 | July 9 - ACTION ALERT: Fragile, globally unique sponge reefs being trashed - Fisheries and Oceans Canada must act now to stop further trawl damage; 1. NATIONAL POST, "PROVINCE TO PROTECT GLASS-LIKE SPONGE REEFS" 2. VICTORIA TIMES COLONIST, "RARE SPONGE REEFS PROTECTED" | CPAWS press release; two newspaper articles |
| 2002 | July 19 – Regulation groundfish trawl closures established around bioherms; FIRST STEP IN PROTECTING RARE SPONGE REEFS LAUDED BY CONSERVATION GROUP, LONG TERM PROTECTION THROUGH MARINE PROTECTED AREAS STILL NEEDED | http://ops.info.pac.dfo.ca/ fishman/Mgmt_plans/archive/2 003/Trawl03pl.PDF; CPAWS press release |
| 2002 | November 5-7 – PSARC recommendations that: 1) protection should be quickly established, and that because of the fragmented nature and irregular boundaries of each reef necessitate that for effective protection, there should be a buffer zone around the currently known area for each reef to minimise the potential for future reef damage. 2) both the Strait of Georgia bioherm and sponge mats be recommended for Marine Protected Area status. | Jamieson and Chew 2002 |
| 2002 | PSARC recommendation for additional protection due to close proximity of existing groundfish trawl closure boundaries to the reef boundaries, and as an interim measure, fishery closures extending one mean trawl length (9 km) from the reef boundaries are recommended; serious considerations should be given to designating the reef complexes as MPAs. | Antcliffe 2002 (http://www.dfo-mpo.gc.ca/csas/Csas/ proceedings/2002/PRO2002_0 29e.pdf) |
| 2003 | April 12 - A MARINE JURASSIC PARK NEEDS SAVING: THE HUGE, DELICATE SPONGE REEFS BENEATH QUEEN CHARLOTTE SOUND FORM A ONE-OF-A-KIND NATIONAL TREASURE | Vancouver Sun article |
| 2003 | Regulation shrimp trawl closures established around bioherms for 2003/04 season | http://ops.info.pac.dfo.ca/ fishman/Mgmt_plans/archive/2 003/ShmpTrwl03pl.pdf |

| | | |
|---|---|---|
| 2003-2005 | NRCan multibeam survey revises footprint of bioherms; Small reefs discovered in Georgia Basin during multibeam surveys (Fraser Ridge, McCall and Halibut Banks etc.). | Four main reef complexes multibeam surveyed in the PNCIMA specifically to determine reef distribution. All deep water Georgia Basin areas multibeam surveyed (K. Conway) |
| 2004 | Mar 18 - Living Oceans Society (LOC) met with Al Macdonald, and presented results of “DFO bycatch” analysis re sponges/corals | LOC/DFO meeting |
| 2004 | Apr 2 – LOC met with Bruce Turris (Can. Groundfish Research and Conservation Society (CGRCS)) and presented results of “DFO bycatch” analysis re sponges/corals | LOC/CGRCS meeting |
| 2004 | April 30 - CONSERVATION GROUP PLEASED THAT WORLD HERITAGE LIST RELEASED - EXPRESSES DISAPPOINTMENT THAT UNIQUE BC SPONGE REEFS OMITTED | CPAWS press release |
| 2004 | June 4 ‘ LOC presented results of “DFO bycatch data” analysis re sponges/corals to Groundfish Trawl Advisory Committee | LOC/GTAC meeting |
| 2005 | Feb 24 - B.C.’S REEFS AMONG SCIENCE’S GREAT FINDS | Georgia Strait article |
| 2005 | July 19 - "REEFS IN DANGER, STUDY WARNS"; ENVIRONMENTALISTS DEMAND MORE PROTECTION FOR REEFS | Globe and Mail articles |
| 2005 | July-August - LOC mail campaign to DFO’s minister and Pacific RDG to have coral/sponges protected | LOC press release |
| 2005 | Sept - RDG directs staff to “articulate a plan for moving forward on the development of a regional conservation strategy for corals and sponges” | DFO action |
| 2005 | Oct 19-21- OTTAWA TRAWL NET DISPLAY OF A DRAG NET ON PARLIAMENT HILL. Presented to the Standing Committee on Fisheries, as well as many M.P.’s. ENGOs met with senior DFO NHQ staff to present the case for sponge/coral conservation. | LOC and Ecology Action Centre (Halifax) press release |
| 2006 | May 30 – LOC invites world renowned oceanographer and deep sea explorer Dr. Sylvia Earle to Canada, to meet with fisheries Minister Loyola Hearn and to individually meet with several members of the Standing Committee on Fisheries. Deep sea corals and sponges are discussed. | LOC Press release |
| 2006 | April 1 – Following consultation between NRCan and DFO Groundfish, boundaries of regulation groundfish trawl closures established around bioherms revised, without a buffer zone | groundfish 2006 management Plan.pdf |
| 2006 | April 18 - DFO TAKES ACTION TO PROTECT SPONGES | Vancouver Sun and Prince Rupert Daily News articles |
| 2006 | May 12 – CPAWS Sponge Brochure release to media | CPAWS press release |
| 2006 | Oct 30 – Regional Coral/Sponge Workshop with DFO, ENGOs and sectors, which resulted in a Briefing Note being prepared for the RDG | DFO and CPAWS |
| 2006 | November 21 – PSARC paper documents overall reduction in sponge bycatch landing over previous 3 y, but continued sponge bycatch round Reefs B and C. | This paper |
| 2006 | Nov 23 - SENATE FISHERIES COMMITTEE HEARS URGENT PLEA TO PROTECT UNIQUE BC MARINE LEGACY: THE PLANET’S ONLY KNOWN LIVING GLASS SPONGE REEFS | CPAWS presentation |

Table 2: Recorded observer catches (kg) of: A. sponges and corals in the entire BC groundfish trawl fishery, 1996-2005 (from A. Sinclair, pers. comm.); and B. sponges and C. finfish in 2005 from tows with a midpoint within a 9 km rectangular zone (see Fig. 2) around the 2003-established sponge reef closures (from J. Fargo, pers. comm.) Shaded cells = landed catch.

A.

| Species Description | Sponges | Calcareous sponges | Glass sponges | Stony corals | Soft corals | Gorgonian corals | |
|---|---|---|---|---|---|---|---|
| **Species Code** | **2A0** | **2A1** | **2I0** | **3J2** | **3R0** | **3S0** | **Total** |
| **Year** | | | | | | | |
| 1996 | 4408 | | 943 | 1671 | | | 7023 |
| 1997 | 19,303 | 11,403 | 1247 | 6036 | 6 | 6 | 38,003 |
| 1998 | 7640 | | | 12,446 | 18 | 1828 | 21,933 |
| 1999 | 4711 | | | 13,728 | 1250 | 1744 | 21,434 |
| 2000 | 52,349 | | | 14,279 | 11,164 | 441 | 78,234 |
| 2001 | 56,464 | | 3485 | 13,801 | 26,116 | 307 | 100,175 |
| 2002 | 18,296 | 333 | 1078 | 485 | 2119 | 513 | 22,827 |
| 2003 | 12,765 | 676 | 2711 | 56 | 148 | 270 | 16,629 |
| 2004 | 8000 | 30 | 555 | | 1093 | 547 | 10,227 |
| 2005 | 6361 | | 2083 | 35 | 86 | 286 | 8852 |

B.

| Species Description | Sponges | Calcareous sponges | Glass sponges | Bath Sponges | |
|---|---|---|---|---|---|
| **Species Code** | **2A0** | **2A1** | **2I0** | **2Q0** | **Total** |
| **Reef** | | | | | |
| A | 0.5 | | 2.3 | 3.6 | **6.4** |
| B | 1944.1 | | 1510.5 | | **3454.6** |
| C | 2477.5 | | 4.5 | 18.1 | **2482.1** |
| D | 41.2 | | 5.9 | 46.7 | **119.0** |
| Total | **4463.3** | | **1523.2** | **68.4** | **6062.1** |

C.

| Reef Code | A | B | C | D | Total Discards |
|---|---|---|---|---|---|
| **Species** | | | | | |
| Dogfish | 22244 | 10 | 288 | 583 | 23125 |
| Big skate | 1352 | 31 | 25 | 92 | |
| Sandpaper skate | | | | 19 | 19 |
| Longnose skate | 14 | 22 | 11 | 169 | 14 |
| Spotted ratfish | 660 | 45 | 3517 | 1441 | 5663 |

| | | | | | |
|---|---|---|---|---|---|
| American shad | | | 5 | 10 | 15 |
| Pacific herring | | | | 35 | 35 |
| Chum salmon | | | 10 | | 10 |
| Coho salmon | | | | 4 | 4 |
| Sockeye salmon | 3 | | | | 3 |
| Pacific cod | 639 | 9 | 91 | 1546 | |
| Pacific hake | 675 | 9 | 58 | 1875 | 2617 |
| Walleye pollock | 11 | 8 | 125 | 136 | 280 |
| Eelpouts | | | | 9 | 9 |
| Bigfin eelpout | | | | 25 | 25 |
| Jack mackeral | | | | 7 | 7 |
| Wolf eel | 26 | | | | 26 |
| Pacific ocean perch | | 100 | 6479 | 4793 | |
| Redbanded rockfish | | 31 | 190 | 1038 | |
| Shortraker rockfish | | | 8 | 3 | |
| Silvergray rockfish | 5086 | 9 | 263 | 2926 | |
| Green-striped rockfish | | 40 | 19 | 56 | |
| Darkblotched rockfish | | | 9 | | 9 |
| Splitnose rockfish | | | 75 | 9 | 84 |
| Widow rockfish | | 20 | 145 | 253 | 20 |
| Yellowtail rockfish | 4605 | 1751 | 679 | 4505 | |
| Rosethorn rockfish | | 30 | 27 | 55 | 82 |
| Canary rockfish | | | 20 | 168 | |
| Quillback rockfish | 3 | | | | 3 |
| Bocaccio | 30 | 11 | | 121 | |
| Redstripe rockfish | | 327 | 124 | 158 | 282 |
| Yellowmouth rockfish | | 5 | 3842 | 262 | 267 |
| Yelloweye rockfish | | | 7 | | 7 |
| Sharpchin rockfish | | 5 | 493 | 91 | 96 |
| Shortspine thornyhead | | 5 | 12 | 86 | 17 |

| | | | | | |
|---|---|---|---|---|---|
| Sablefish | 5 | 2 | 44 | 193 | 244 |
| Lingcod | 62 | 50 | 80 | 3690 | |
| Spinyhead sculpin | | | 9 | | 9 |
| Sculpins | | | | 5 | 5 |
| Cabezon | | 5 | | | 5 |
| Pacific sanddab | | | | 43 | 43 |
| Arrowtooth flounder | 1711 | 36 | 772 | 14,082 | 772 |
| Petrale sole | 225 | | | 823 | |
| Rex sole | 86 | 5 | 9 | 664 | 95 |
| Flathead sole | | | | 295 | |
| Pacific halibut | 604 | 17 | 315 | 1046 | 1982 |
| Rock sole | 2732 | | | 349 | |
| Slender sole | | | | 25 | 25 |
| Dover sole | | | | 2245 | |
| Yellowfin sole | 22 | | | | 22 |
| English sole | 451 | | 62 | 611 | 62 |
| Curlfin sole | 72 | | | 10 | 10 |
| Sand sole | | | | 23 | 23 |
| Total | 41,319 | 2586 | 17,817 | 44,619 | |
| Total Discarded | 23,678 | 142 | 5459 | 6063 | 35,342 |

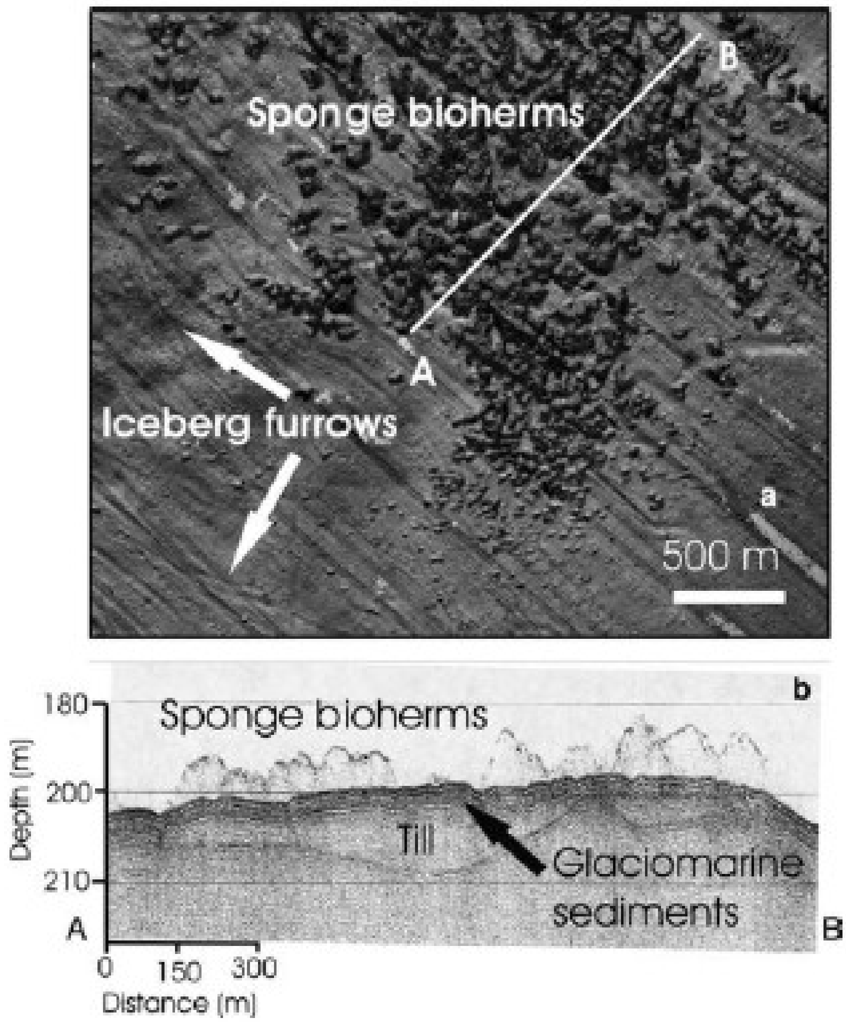


Figure 1: Sponge bioherms in Hecate Strait, to show a typical spatial distribution of bioherms in part of a sponge reef complex  (Fig. 3 from Conway et al. 2005b).

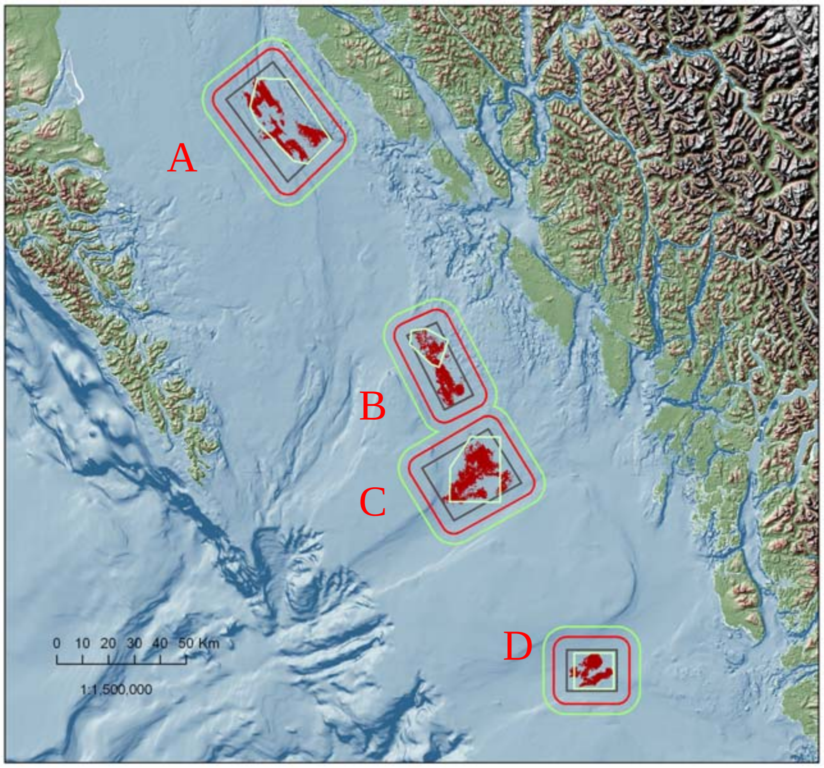


Figure 2: Known locations of the four PNCIMA sponge reef complexes (A, B, C and D; red polygons), trawl closure boundaries from 2003 to April, 2006 (lightest colour, inner lines), and potential trawl closure zones with two buffer options, at 5 (red lines) and 9 km (outer light colour lines) distance from a proposed basic closure (black line, not adopted).

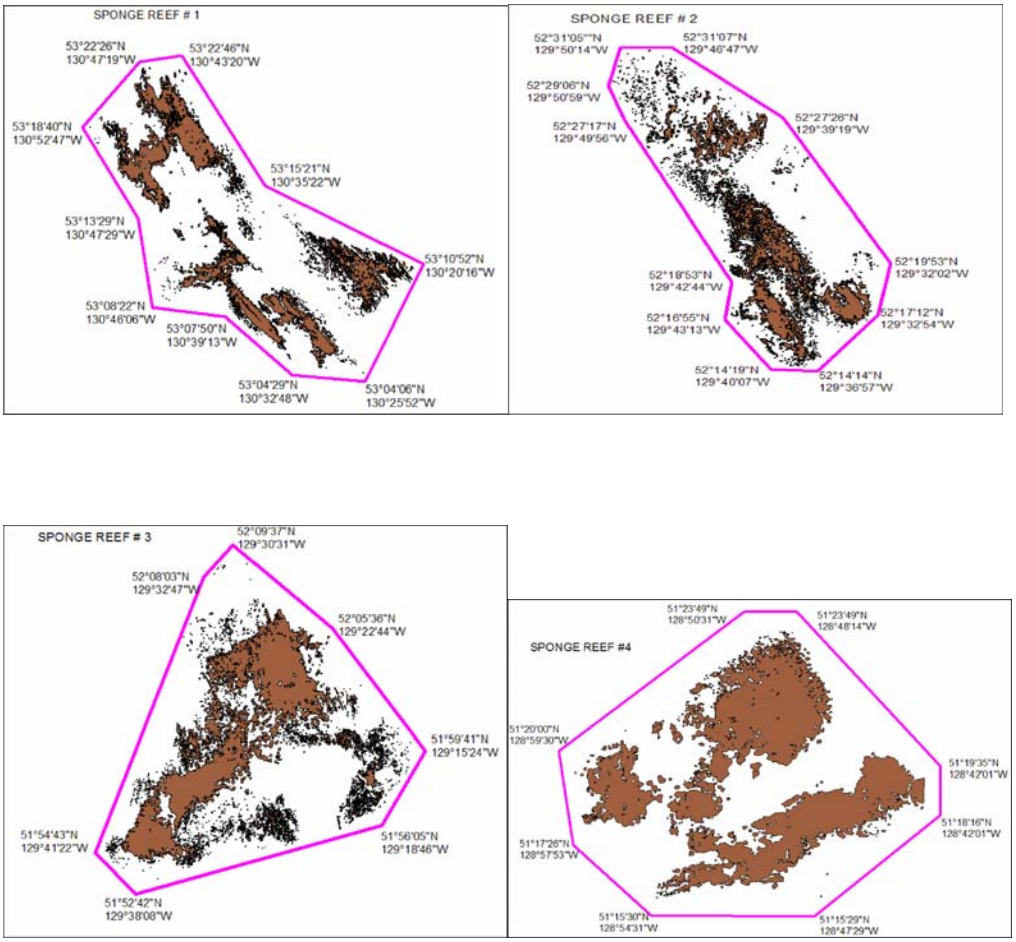


Figure 3: Maps of groundfish trawl closure boundaries adopted as of April 1, 2006 (http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/mplans/plans06/Groundfish06-07/Appendix%208%20Trwl%20Har%20Plan.pdf). Sponge reefs 1, 2, 3 and 4 correspond to reef designations A, B, C and D used in this paper and Jamieson and Chew (2002).

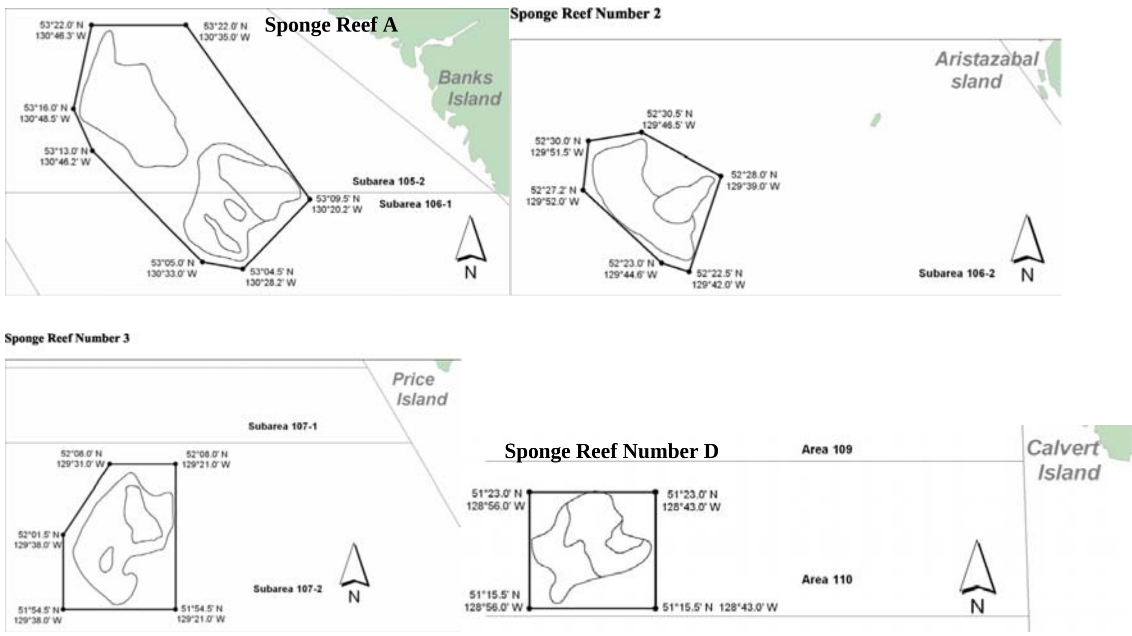


Figure 4: Maps of shrimp trawl closure boundaries in Queen Charlotte Sound in effect from April 1, 2006 – March 31, 2007. (http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/MPLANS/plans06/Shrimp_trawl_2006-07_IFMP.pdf). Sponge reefs 2 and 3 correspond to reef designations B and C used in this paper and Jamieson and Chew (2002).

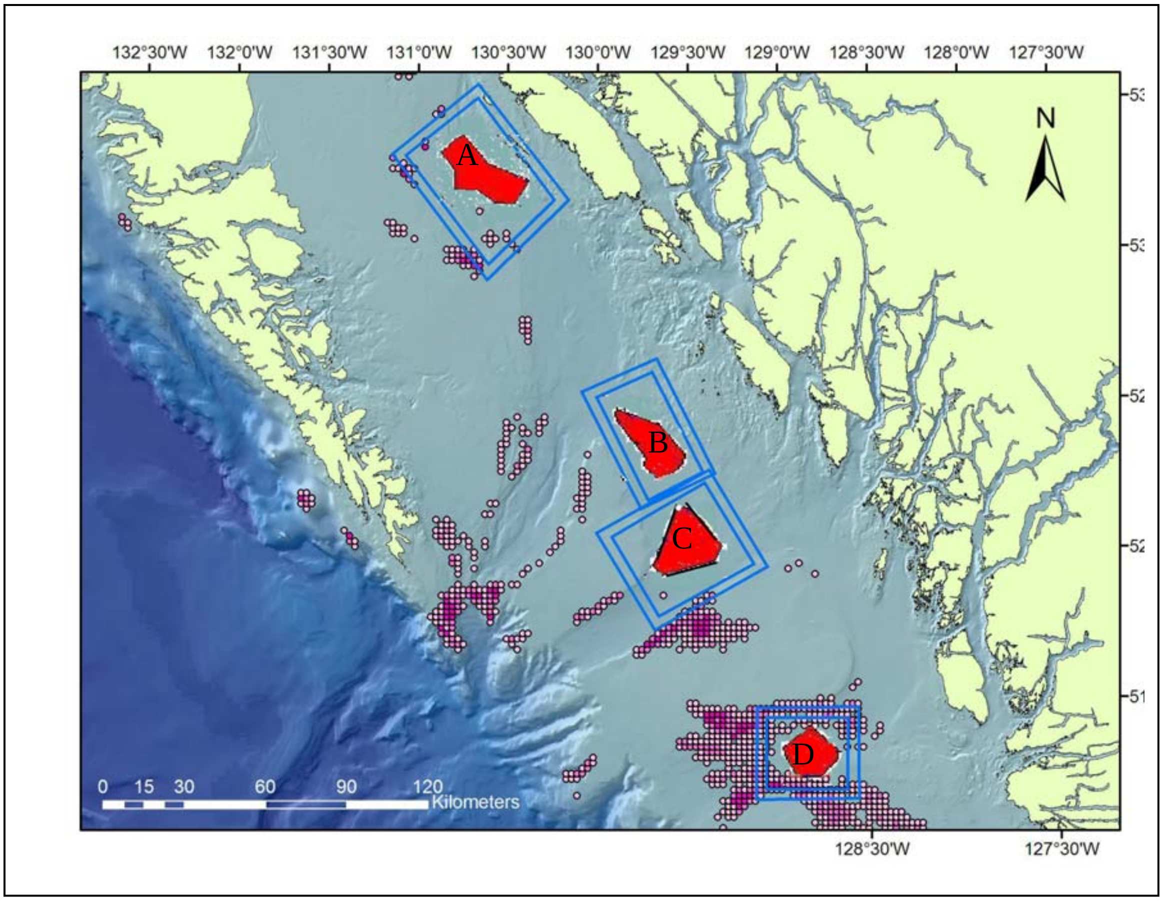


Figure 5: Distribution of tows in the 2003-2005 B.C. bottom trawl fishery. The shaded squares indicate tows made by 3 or more vessels, gridded on a 2 sq. km. cell size using the mid locations for the tow. A total of 16235 tows are summarized here, with 2739 tows excluded because of the minimum three vessel rule. (J. Fargo, pers. comm.).

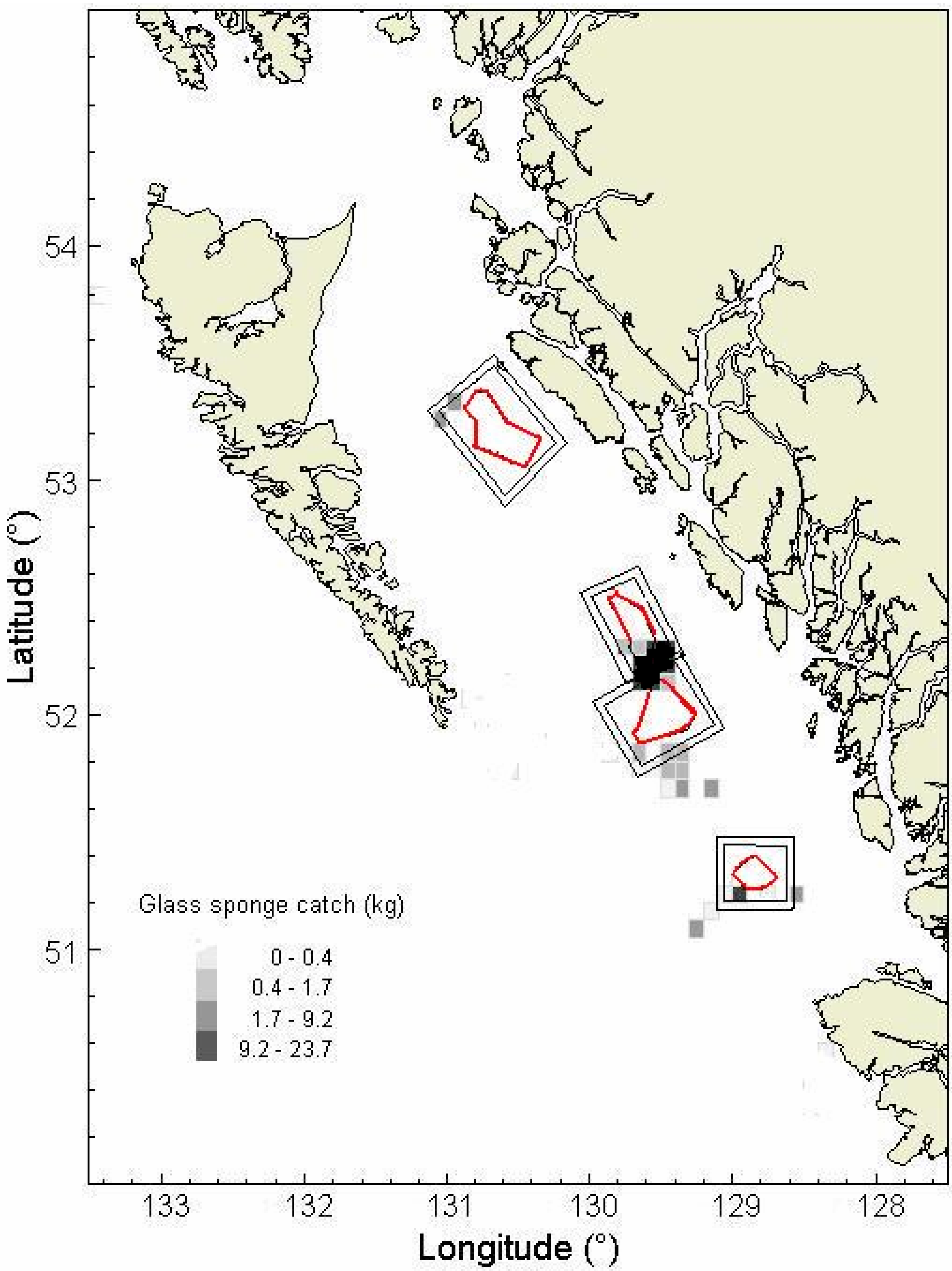


Figure 6: 2005 glass sponge catches in kilograms summed for each square kilometre where three or more vessels fished; the black shaded area indicates a catch range of a 113 to 1361 kg that involved only two vessels. The legend break points of 0-0.4, 0.4-1.7, 1.7-9.2 and 9.2-23.7 correspond to the 1st to the 30th percentiles, 31st to the 60th percentiles, 61st to 90th percentiles and the 91st to 100th percentiles of the data distribution. New closures around sponge reefs identified from multibeam hydroacoustic data are outlined in red. Five and nine km rectangle areas around the reefs are outlined in black. (J. Fargo, pers. comm.).

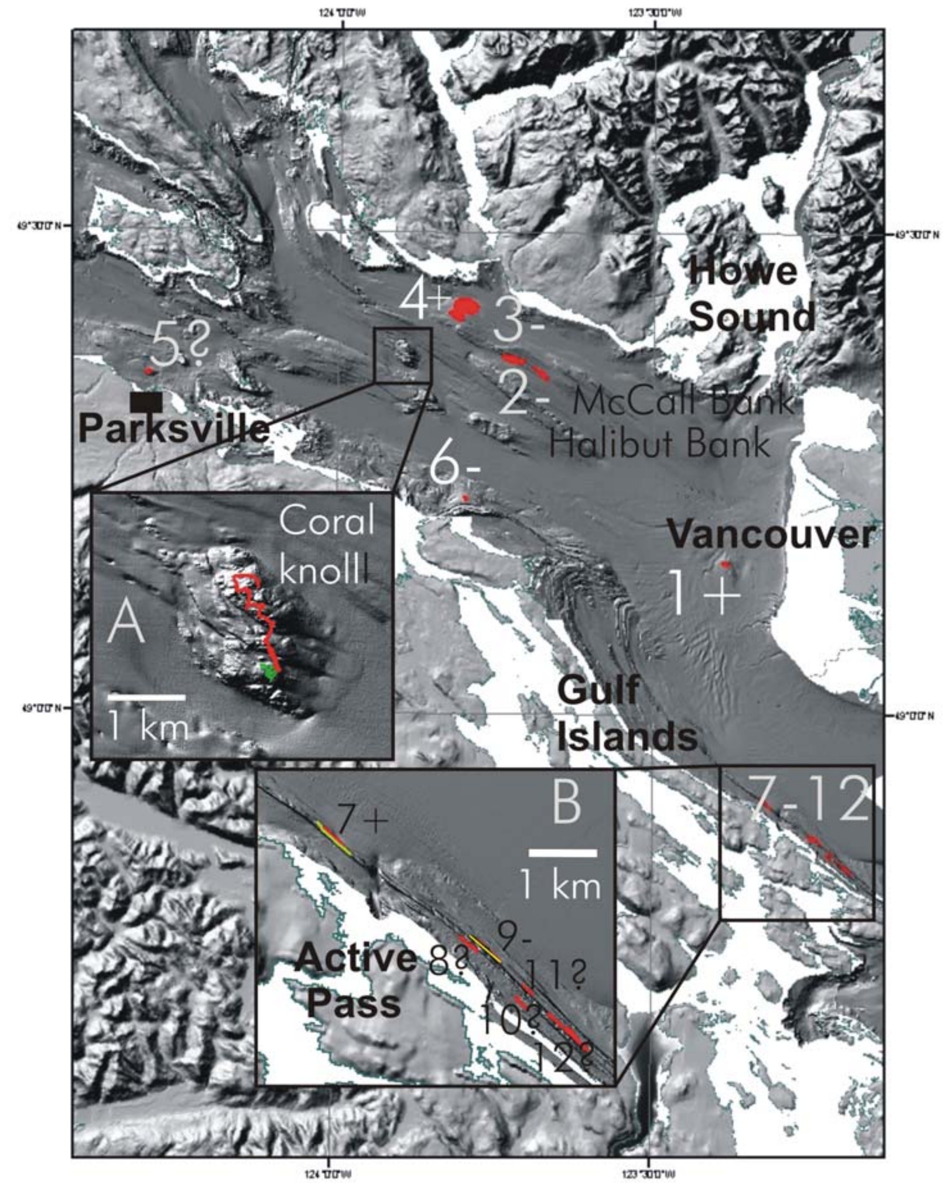


Figure 7. Location of known sponge reefs (numbers) and location of *Lophelia pertusa* coral occurrence in Georgia Basin (Inset A). Status of sponge reefs is indicated by a + symbol when the reef is known to be healthy; a - symbol where largely or completely dead and a ? symbol where the status of the reef is unknown. For further information on site 1 - (Fraser Ridge) see Conway et al., 2004; for sites 2- 4, including McCall and Halibut Bank reefs see Conway et al., 2005b. Sites 5-12 are reported in ?. Inset "A" shows ROPOS transects over the coral knoll site. Inset "B" shows reefs adjacent to Active Pass where ROPOS diving revealed a healthy reef (7) and a largely dead reef (9).

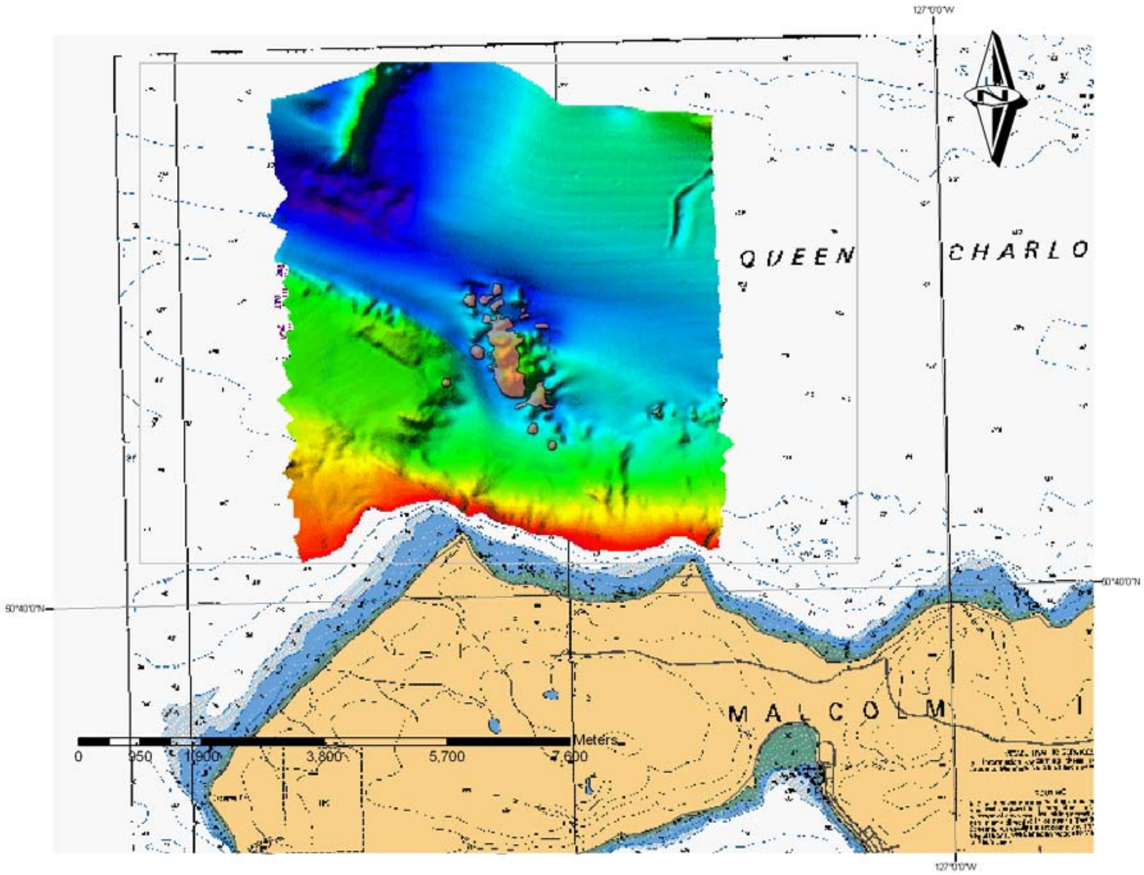


Figure 8: Newly found sponge reef locations (red) near Malcolm Island, Queen Charlotte Strait (K. Conway, pers. comm.).