# Taxonomy and zoogeography of cold-water corals in coastal British Columbia

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**Abstract**

The current state of knowledge of cold-water corals in British Columbia is summarized. Pacific Canada has a more diverse coral community than does Atlantic Canada, as is the case for most taxonomic groups. A list of Pacific Canada's known coral species and potential species based on records from adjacent jurisdictions is presented, along with maps derived from existing records showing all currently known locations of corals in British Columbia. To date, five orders, 24 families, and 59 species of corals are documented from British Columbian waters, but an additional three families and 36 species may also occur in British Columbia, as these species have been documented from adjacent areas, i.e., southeast Alaska, Gulf of Alaska seamounts, and Washington/Oregon.

Cold-water corals occur throughout the world's oceans, from the Antarctic to the Arctic and within the Mediterranean Sea. Diversity is greater in the northern hemisphere than in the southern, and the age of the fauna is a key factor in determining its latitudinal distribution (Keller and Pasternak, 2001). Depth, currents, productivity, and sedimentation all influence large-scale distributional patterns (Roberts et al., 2006), and the depth distribution of a species may vary across an ocean basin, e.g., eastern vs western Atlantic (Cairns and Chapman, 2001).

Typically, these corals are found in relatively shallow continental shelf and slope waters (Roberts et al., 2006), 50–1000 m depth, including shelf-edge canyons, deep channels between fishing banks (MacIsaac et al., 2001) and on fjord walls. However, cold-water corals, mostly gorgonians and hydrocorals, in the eastern North Pacific are most abundant in a much narrower depth zone. The most extensive coral surveys in the eastern North Pacific have been conducted in the Aleutian Islands. Limited submersible data to 367 m there found that corals were most abundant between 100–200 m, with mean coral abundance (3.85 colonies $m^{-2}$ over 25 transects) far exceeding that reported for other high-latitude ecosystems (Stone, 2006).

We use the term "coral" for members of the class Anthozoa, subclasses Octocorallia (soft corals, black corals, and sea fans) and Hexacorallia (stony and cup corals); and class Hydrozoa, order Filifera (fire and lace corals). Although we include the octocoral orders Alcyonacea, Antipatharia, and Pennatulacea as corals, only the hexacoral order Scleractinia is included, because other hexacoral orders (e.g., Actiniaria, Zoanthidea) are not skeletonized. Our octocoral classification follows Williams and Cairns (last revised January 2006), which uses a system of higher taxa after Bayer (1981) for Helioporacea and Alcyonacea, and Kükenthal (1915) and Williams (1995) for Pennatulacea. Because it is quite recent, this classification does not always agree with current Integrated Taxonomic Information System (ITIS) data on the web; e.g., species in the order Gorgonacea

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have been included in the order Alcyonacea by Williams and Cairns (2006), though the order is still shown as separate in ITIS. Octocorals, scleractinians and hydrozoan corals can be either zooxanthellate or azooxanthellate, while antipatharians are strictly azooxanthellate. Cold-water corals that exist below the photic zone do not form symbiotic associations and are thus azooxanthellate.

The majority of cold-water corals are solitary as well as azooxanthellate. However, a few colonial forms are hermatypic, e.g., *Lophelia pertusa* (Linnaeus, 1758) and *Dendrophyllia* sp., that is, their skeletons accumulate as biogenic build-ups. Deep- and cold-water coral accumulations have been called reefs, banks, mounds, and bioherms. The term reef, while widely used, traditionally implies a navigational hazard. Tropical coral reefs are biogenic structures built by both reef-building scleractinians and coralline algae, each having a key "cementing" function in reef development. In contrast, cold-, and usually deep-water scleractinian reefs (e.g., *Lophelia* reefs) are built mainly by the corals themselves without any input from algae. However, shallow cold-water coral reefs have been poorly studied, so this generalization may not be true for all cold-water corals. Bioherm is a more general term for any biogenic build-up of skeletal remains on the site where the organisms lived. They may consist of coral, sponge, or other skeletonised invertebrate fragments that have been built on and added to by successive generations. We also distinguish between true scleractinian coral reefs and octocoral "forests", i.e., concentrations of octocorals, which seem to be more common in British Columbian waters than are true scleractinian reefs.

Cold-water corals can form an extensive structural habitat, but their spatial occurrence, biology, and ecological significance are relatively poorly known due to their predominance in deep waters. However, Roberts at al. (2006) suggest that cold-water corals are arguably the most three-dimensionally complex habitats in the deep ocean, noting that over 1300 species have been found living on *L. pertusa* reefs in the NE Atlantic. While their role in the marine benthic ecosystem has yet to be fully defined, cold-water corals are often found in association with numerous other species (Cimberg et al., 1981; Koslow et al., 2001; Witherell and Coon, 2001; Etnoyer and Morgan, 2003; Gass, 2003; Hyland et al., 2005; and Stone, 2006), leading to the precautionary concern that coral concentrations in particular may have an important ecosystem role and thus should be particularly conserved.

Cold-water coral structures range from small, solitary individuals to massive reef habitats, often in relatively barren surroundings. Habitat-forming cold-water corals include octocorals, hexacorals (hermatypic scleractinian corals), and hydrocorals (Roberts et al., 2006). Live and dead portions of a coral's matrix or lattice framework can create substratum and shelter for other corals, sponges, brachiopods, bivalves, crustaceans, bryozoans, crinoids and tunicates (Koslow et al., 2001; Hall-Spencer et al., 2002). The complex branching morphology of many cold-water corals creates structures of sufficient size to provide substrate or refuge for other species (Etnoyer and Morgan, 2003; Roberts et al., 2006; Stone, 2006).

The majority of cold-water corals exhibit preference for rocky substrate or hard surfaces with moderate to strong currents, although pennatulaceans generally prefer unconsolidated substrates. Preferred coral substrate thus ranges from fine, well-sorted sand, gravel areas, and shell deposits, to slump deposits with rock outcrops, boulders, crevices, rock pinnacles, over hangs, living habitat, sheer cliffs, and iceberg furrows (MacIsaac et al., 2001).

In Canada, cold-water corals have been reported from both Atlantic (Breeze et al., 1997) and Pacific waters (McAllister and Alfonso, 2001; Lamb and Handby, 2005). In Nova Scotia, distributions are limited by both geography and bathymetry (Breeze and Davis, 1998). Off Nova Scotia, highest coral diversity has so far been observed at the "Gully" and the "Stone Fence" (Breeze et al., 1997; MacIsaac et al., 2001). Reyes-Bonilla (2002) suggested that there were about 79 species of azooxanthellate corals along the western coast of the Americas, representing ten families, with 29 species from six families having an average depth distribution greater than 200 m. Gass (2003) reported that the northeastern Pacific coral fauna was dominated by large gorgonian octocorals. In the Northeast Pacific, the most extensive regional surveys have been conducted in Alaskan waters (Heifetz, 2002; Etnoyer and Morgan, 2003; Stone, 2006).

Increased awareness of concentrations of cold-water corals and their high vulnerability to damage from human activities such as benthic fishing gear, coupled with new legislation (e.g., Canada's Oceans Act) requiring ecosystem-based approaches to management, are providing a new impetus for describing coral occurrence and distribution off British Columbia. Better conservation of biogenic marine habitats is high on the agenda of environmental non-governmental organisations (e.g., Ardron, 2005), including the minimization of impacts from fishing gear on benthic habitats (MacIssac et al., 2001).

Little published data exist on cold-water corals in British Columbia. Levings and McDaniel (1974) noted corals were one of many benthic organisms on an underwater cable in the Strait of Georgia, Austin (1985) provided an extensive list of marine invertebrates (60 corals) for the north-eastern Pacific, and McAllister and Alfonso (2001) listed 21 species in a preliminary assessment of the cold-water corals of British Columbia. Most recently, Canessa et al. (2003) reported corals in the ecosystem overview report of Bowie Seamount, Ardron et al. (2007) summarized and mapped coral occurrences in bycatch analyses of groundfish trawl data, and Conway et al. (2005) reported corals from their ROV surveys in the 100–300 m depth range.

Seamounts, i.e., extinct underwater volcanoes rising over 1000 m from the seafloor, provide opportunity for patchy, wide-scale occurrence of benthic species in a primarily homogeneous environment. Canada's Pacific Bowie Seamount has been recently surveyed, with research efforts targeted on a limited number of species (primarily rockfish and sablefish), but alcyonacean and scleractinian corals were observed there (Canessa et al., 2003). In 2002, seven seamounts (Patton, Murray, Chirikof, Marchand, Campbell, Scott, and Warwick) from the Cobb Hotspot in the Gulf of Alaska were explored using submersibles and multibeam bathymetric surveys (Etnoyer and Morgan, 2003).

Conway et al. (2007) documented the remains of a large dead coral reef in the Strait of Georgia at 255 m, identified as *L. pertusa* (S. Cairns, Smithsonian National Museum of Natural History, pers. comm.) (Jamieson et al., 2006). While this particular reef did not contain live corals, its presence in British Columbian waters strongly suggests that other as-of-yet undiscovered *Lophelia* reefs likely exist in British Columbian waters. Austin (1985) reported this species, initially misidentified as *Solenosmilia variabilis* Duncan, 1873, from Alberni Inlet, Vancouver Island. Rogers (1999) and Hyland et al. (2005) listed other *Lophelia* records for the North Pacific, including Cobb Seamount and the American side of Juan de Fuca Canyon, but there are no other records from Canadian waters.

To date, no summary exists of available data on cold-water corals of British Columbia, Canada, similar to that for Nova Scotia (Breeze et al., 1997). Here, we list both observed

corals from Pacific Canadian waters and potential corals based on records from adjacent areas, and identify and map locations of corals from existing records and anecdotal information. Most data presented here are from deeper waters and specifically from either commercial fishing data or research surveys. Scuba diving observations are inadequately represented. Modern sport divers can dive within the depth ranges of some cold-water coral species in coastal regions, and valuable information is likely available from interested citizens.

## Field taxonomic identification challenges

Generally, coral genera and species are distinguished by skeletal morphology. However, many features, such as septal arrangements in scleractinians and sclerite form and distribution in octocorals require tissue preparation and a microscope, an approach that takes time and cannot be implemented at sea by observers reporting commercial fishing bycatches. Observers, if present, can retain some reference specimens for later identification, but they, like fishers, have time and space constraints. Thus, precise taxonomic identification in the field is unlikely to occur except for the most common species. To date, observers in British Columbia have not had convenient field identification guides for even common species, so observer-reported data have not been usable taxonomically. Efforts are now underway to produce such coral identification information. The following references have been used to determine taxa groupings: Orders Alcyonacea and Pennatulacea (Williams and Cairns, 2002), Order Antipatharia (Opresko, 2005, ITIS Taxonomic Report, November 2005), Order Scleractinia (Cairns, 1994), and order Filiferа (ITIS Taxonomic Report, November 2005). Cairns et al. (2002) was also utilized.

## Methods

Data were obtained from surveys, by-catch information, and personal and museum collections. For reporting consistency, corals were mapped only to orders due to identification inconsistencies. Mapped data points included areas where identified corals were collected during research surveys and/or fishing activities. As mentioned above, published literature on cold-water corals in British Columbia is limited. Bibliographic databases included those of Fisheries and Oceans (called WAVES), museum libraries, and scientific journals. Literature requests from cold-water coral researchers were also made, and on-line resources were utilized when available from reliable sources.

Cold-water coral records from museums (Table 1) were included in the maps. These data, along with species listed in the published literature or from private collections where specimens were identified by recognized experts, were the only data used to determine taxa present at the species level, as taxonomic identification in other databases were not at the species level. Records unidentifiable to species, either from British Columbian waters or as potential species from adjacent areas, were included in the list as "sp." only if no other species of that genus was listed in any of the shaded columns in Table 2B; if other species were present, these records, identified in Table 2B, were assumed to be from existing species. The exceptions were for unidentified species records if either they appeared different from known species by the person reporting them (typically listed as sp. A, B, etc.) or they were geographically distant from other known species records from that genus. These latter records, also identified (Table 2B), were assumed here to represent other species, but this will only be confirmed when proper identifications are completed.

The Fisheries and Oceans Canada (DFO) trawl observer database is a major source of British Columbian fisheries data that includes by-catch records. Beginning in 1954 and prior to the establishment of complete observer coverage in 1996, fishers logged only two occurrences of coral.

Table 1. Number of cold-water coral records mapped for British Columbia, their source and years. DFO = Fisheries and Oceans Canada, Pacific Region.

| Data source | Data years | No. Records mapped |
|---|---|---|
| Royal British Columbia Museum | 1965–2001 | 19 |
| Canadian Museum of Nature | 1900–1991 | 7 |
| National Museum of Natural History–Smithsonian Institution | 1888–2001 | 9 |
| Centre for Marine Biodiversity and Parks Canada–Gwaii Haanas | 1888–2000 | 262 |
| GFBio Database–DFO Groundfish research data | 1966–2002 | 152 |
| Tanner Crab Database–DFO | 1999–2003 | 29 |
| Shrimp Database–DFO | 1966–2003 | 114 |
| International Pacific Halibut Commission–Stock Assessment Data | 1995–2003 | 15 |
| DFO PacHarv Observer Trawl Database | 1996–2003 | 860 |

Recording of data has since greatly improved, although by-catch species identification remains an issue. All records of corals in DFO's "PacHarvTrawl" (groundfish trawl) and "PacHarvSable" (sablefish trap) databases represent species (or groups of organisms) observed during fishing events, combined here as PacHarv, between the first quarter of 1996 and the fourth quarter of 2003. International Pacific Halibut Commission (IPHC) annual stock assessment surveys provided an additional 15 records (Tracee Geernaert, IPHC, pers. comm.). Spatial data from the available fishery databases contained "rolled-up" records representing information from three or more vessels within a defined spatial area (to protect the privacy of an individual's records). To optimize the number of records within the smallest data area, records were rolled-up into 16-km$^2$ bins by year. The centers of each spatially referenced bin (latitude and longitude) containing coral records identifiable to order were plotted and represented as point records.

Only a few DFO scientific research surveys contain records of cold-water corals. Groundfish, shrimp, and tanner crab surveys prior to 2004 contained 295 records of observed corals as incidental catch. The latitude and longitude of these locations were mapped and represent the midpoint of each set line. To date, there have been no directed research initiatives on cold-water corals in British Columbia.

The limited literature on British Columbian cold-water corals includes a taxonomic list by Austin (1985) and a report by McAllister and Alfonso (2001). Since cold-water marine environments are generally similar in adjacent waters, species presence and distribution can, to some extent, be inferred from literature on corals from nearby northeast Pacific regions, notably Washington and southeastern Alaska, and to some extent from global observations. Maps were produced to complement the earlier maps produced by McAllister and Alfonso (2001) and more recently produced maps by Ardron et al. (2007) for coral bycatch in British Columbia. All available coral data within the Canadian Exclusive Economic Zone (EEZ) were mapped. This encompasses all of British Columbia's territorial waters. Maps were produced in ArcGIS (9.0) with base map bathymetric intervals of 500 m.

## Results and Discussion

Cold-water corals found to date in British Columbian waters include representatives of five orders, 24 families, and 59 species (Table 2). Inclusion of potential species from southeastern Alaska, Gulf of Alaska seamounts, and Washington/Oregon brings the total to a likely 27 families and 95 species. Additional likely families are Scleroptilidae, Chrysogorgiidae, and Coralliidae**.**

To date, 55 species of corals have been reported from south-eastern Alaskan waters and Gulf of Alaska seamounts (Table 2; B. Stone, NOAA, pers. comm.) and 30 species from Washington/Oregon (C. E. Whitmire and M. E. Clarke, NOAA, pers. comm.). Only two taxa are known from both Southeast Alaska/Gulf of Alaska seamounts and

Table 2. Geographical distributions of (A) family and (B) species coral records in north-eastern Pacific waters. Families and species known to occur in British Columbia are in the darkly shaded column, and those likely to occur in British Columbia include those reported from Washington and Oregon, southeastern Alaska and the Alaska seamounts (lightly shaded columns). BS = Bering Sea, AI = Aleutian Islands, WG = western Gulf of Alaska, EG = eastern Gulf of Alaska, SM = seamounts, BC = British Columbia, WO = Washington and Oregon, Loc = total estimated number to date of local (EG to WO) species, Reg = total estimated number to date of regional species. ● = present. Alaskan records from R. Stone, NOAA, pers. comm., adapted by him from Heifetz et al. (in press); Washington and Oregon records from C. E. Whitmire and M. E. Clarke, NOAA, pers. comm. and Rogers (1999); British Columbian records include those from Kosloff (1974), Austin (1985), Sloan et al. (2001), and Etnoyer and Morgan (2003). ♦ = unidentified species records assumed to be a known listed species from the same general area. ♣ = unidentified species records assumed to be a non-listed species, because either they appeared to be different from known listed species by the person reporting them or they were geographically distant from other known listed species records from that genus.

| A. Taxa | BS | AI | WG | EG | SM | BC | WO | Loc | Reg |
|---|---|---|---|---|---|---|---|---|---|
| Order Alcyonacea (gorgonians and true soft corals) | 8 | 46 | 14 | 14 | 7 | 21 | 13 | 37 | 66 |
| Acanthogorgiidae | | 4 | 1 | 2 | | 2 | 2 | 5 | 7 |
| Alcyoniidae | 1 | 4 | 1 | 1 | | 4 | 2 | 4 | 7 |
| Chrysogorgiidae | | 2 | | | | | 1 | 1 | 2 |
| Clavulariidae | 1 | 2 | 1 | 1 | | 1 | | 1 | 2 |
| Coralliidae | | | | | 1 | | | 1 | 1 |
| Isididae | | 2 | 3 | 3 | 4 | 3 | 2 | 6 | 6 |
| Nephtheidae | 1 | 3 | 1 | 1 | | 2 | 1 | 2 | 3 |
| Paragorgiidae | | 1 | 1 | 1 | 1 | 3 | 1 | 3 | 4 |
| Paramuriceidae | | 1 | | | | | | | 1 |
| Plexauridae | | 8 | 1 | 1 | 1 | 5 | 2 | 7 | 12 |
| Primnoidae | 5 | 19 | 5 | 4 | | 1 | 2 | 7 | 21 |
| Order Pennatulacea (sea pens) | 4 | 3 | 4 | 7 | | 17 | 10 | 23 | 24 |
| Anthoptilidae | 2 | | | | | 2 | 1 | 2 | 3 |
| Funiculinidae | | | | | | 1 | 1 | 1 | 1 |
| Halipteridae | 1 | 1 | 1 | 2 | | 1 | | 3 | 3 |
| Kophobelemnidae | | | | | | 2 | 2 | 3 | 3 |
| Pennatulidae | | 1 | 1 | 2 | | 2 | 1 | 2 | 2 |
| Protoptilidae | | | 1 | 1 | | 2 | 1 | 3 | 3 |
| Scleroptilidae | | | | | | | 1 | 1 | 1 |
| Stachyptilidae | | | | | | 1 | | 1 | 1 |
| Umbellulidae | 1 | 1 | 1 | 1 | | 1 | 1 | 1 | 1 |
| Virgulariidae | | | | 1 | | 5 | 3 | 6 | 6 |
| Order Antipatharia (black corals) | | 2 | 1 | 9 | 2 | 6 | 3 | 13 | 14 |
| Antipathidae | | 1 | | 1 | | 1 | 2 | 2 | 2 |
| Cladopathidae | | | 1 | 2 | 1 | 1 | | 3 | 4 |
| Schizopathidae | | 1 | | 5 | 1 | 4 | 1 | 8 | 8 |
| Order Scleractinia (stony and cup corals) | 2 | 9 | 6 | 6 | 2 | 9 | 1 | 11 | 14 |
| Caryophylliidae | | 4 | 3 | 4 | 1 | 7 | 1 | 8 | 9 |
| Dendrophylliidae | | 1 | 1 | 1 | | 1 | | 1 | 1 |
| Flabellidae | 1 | 2 | 1 | | | | | | 2 |
| Fungiacyathidae | 1 | 2 | 1 | 1 | 1 | 1 | | 2 | 2 |
| Order Filifera (hydrocorals) | 3 | 25 | 2 | 8 | | 6 | 3 | 11 | 31 |
| Stylasteridae | 3 | 25 | 2 | 8 | | 6 | 3 | 11 | 31 |
| Total | 17 | 85 | 27 | 44 | 11 | 59 | 30 | 95 | 149 |

Table 2. Continued.

| B. Taxa | BS | AI | WG | EG | SM | BC | WO |
|---|---|---|---|---|---|---|---|
| Order Alcyonacea (gorgonians and true soft corals) | | | | | | | |
| Acanthogorgiidae | | | | | | | |
| cf. *Acanthogorgia* | | ● | | | | | |
| *Calcigorgia beringi* | | ● | | ● | | | |
| *Calcigorgia spiculifera* | | ● | ● | ● | | ● | ● |
| *Calcigorgia* sp. A | | ● | | | | | |
| *Calcigorgia* sp. | | | | | | | ● |
| *Calcigorgia kinoshitae* | | | | | | ● | |
| Alcyoniidae | | | | | | | |
| *Alcyonium* sp. | | | | | | ● | |
| *Anthomastus* cf. *grandiflora* | | | | | | ● | |
| *Anthomastus japonicus* | ● | ● | | | | | |
| *Anthomastus* cf. *japonicus* | | ● | | | | | |
| *Anthomastus ritteri* | | ● | ● | ● | | ● | ● |
| *Anthomastus* sp. A (red) | | ● | | | | | |
| *Anthomastus* sp. B (gray) | | | | | | ● | ● |
| Chrysogorgiidae | | | | | | | |
| cf. *Chrysogorgia* | | ● | | | | | ● |
| *Radicipes* sp. A | | ● | | | | | |
| Clavulariidae | | | | | | | |
| *Clavularia moresbii* | | ● | ● | ● | | ♦ | |
| *Sarcodictyon incrustans* | ● | ● | | | | | |
| Coralliidae | | | | | | | |
| *Corallium* sp. A | | | | | ● | | |
| Isididae | | | | | | | |
| *Acanella* sp. A | | | | | ● | | |
| *Isidella paucispinosa* | | ● | ● | ● | | | |
| *Isidella* sp. A | | | | | ● | | |
| *Isidella* sp. | | | | | | ● | ● |
| *Keratoisis profunda* | | ● | ● | ● | ♦ | ♦ | ♦ |
| *Lepidisis* sp. | | | ♦ | ♦ | ♦ | ● | |
| Nephtheidae | | | | | | | |
| cf. *Eunephthya*[?] (*Gersemia*) | | ● | | | | | |
| *Eunephthea rubiformis* | ● | ● | ● | ● | | ● | |
| *Eunephthea* sp. | | ● | | | | ♦ | ♦ |
| Paragorgiidae | | | | | | | |
| *Paragorgia arborea* (=*P. pacifica*) | | ● | ● | ● | ♦ | ● | ♦ |
| *Paragorgia yutlinux* | | | | | | ● | |
| *Paragorgia stephencairnsi* | | | | | | ● | |
| Paramuriceidae | | | | | | | |
| *Paramuricea* sp. A | | ● | | | | | |
| Plexauridae | | | | | | | |
| *Alaskagorgia aleutiana* | | ● | | | | | |
| *Euplexaura marki* | | ● | ● | ● | | | ● |
| *Muriceides cylindrica* | | ● | | | | | |
| *Muriceides* cf. *cylindrica* | | ● | | | | | |
| *Muriceides nigra* | | ● | | | | | |

Table 2. Continued.

| B. Taxa | BS | AI | WG | EG | SM | BC | WO |
|---|---|---|---|---|---|---|---|
| *Swiftia* (*Psammogorgia*) *spauldingi* | | | | | | ● | |
| *Swiftia beringi* | | ● | | | | | |
| *Swiftia kofoidi* | | | | | | | ● |
| *Swiftia pacifica* | | ● | | | | ● | |
| *Swiftia simplex* | | ● | | | ● | ● | |
| *Swiftia torreyi* | | | | | | ● | |
| Primnoidae | | | | | | | |
| *Amphilaphis* sp. A | | ♣ | | | | | |
| *Amphilaphis* sp. B | | ♣ | | | | | |
| *Amphilaphis* sp. C | | ♣ | | | | | |
| *Arthrogorgia kinoshitai* | ● | ● | ● | ● | | | |
| *Arthrogorgia otsukai* | ● | ● | | | | | |
| *Arthrogorgia utinomii* | | ● | | | | | |
| *Callogorgia* sp. | | | | | | | ● |
| *Fanellia compressa* | ● | ● | | | | | |
| *Fanellia fraseri* | | ● | ● | | | | |
| *Narella* sp. A | | ● | | | | | |
| *Parastenella* sp. A | | ♣ | | | | | |
| *Parastenella* cf. *doederleini* | | | | | | | ● |
| *Plumarella flabellata* | | ● | | | | | |
| *Plumarella longispina* | ● | ● | ● | ● | | | |
| *Plumarella spicata* | | ● | | | | | |
| *Plumarella spinosa* | | ● | | | | | |
| *Primnoa pacifica* | ● | ● | ● | ● | | | |
| *Primnoa pacifica* var. *willeyi* | | | | | | ● | |
| *Primnoa wingi* | | ● | ● | ● | | | |
| *Thouarella hilgendorfi* | | ● | | | | | |
| *Thouarella striata* | | ● | | | | | |
| *Thouarella superba* | | ● | | | | | |
| *Thouarella* sp. | | | | | | | ♣ |
| Order Pennatulacea (sea pens) | | | | | | | |
| Anthoptilidae | | | | | | | |
| *Anthoptilum grandiflorum* | ● | | | | | ● | ● |
| *Anthoptilum murrayi* | ● | | | | | | |
| *Anthoptilum cf murrayi* | | | | | | ● | |
| Funiculinidae | | | | | | | |
| *Funiculina parkeri* | | | | | | ● | ● |
| Halipteridae | | | | | | | |
| *Halipteris californica* | | | | ● | | | |
| *Halipteris* cf. *californica* | | | | | | ● | |
| *Halipteris willemoesi* | ● | ● | ● | ● | | | |
| Kophobelemnidae | | | | | | | |
| *Kophobelemnon hispidum* | | | | | | ● | |
| *Kophobelemnon affine* | | | | | | ● | ● |
| *Kophobelemnon biflorum* | | | | | | | ● |

Table 2. Continued.

| B. Taxa | BS | AI | WG | EG | SM | BC | WO |
|---|---|---|---|---|---|---|---|
| Pennatulidae | | | | | | | |
| *Pennatula phosphorea* | | | | ● | | ● | |
| *Ptilosarcus gurneyi* | | ● | ● | ● | | ● | ● |
| Protoptilidae | | | | | | | |
| *Distichoptilum rigidum* | | | | | | | ● |
| *Distichoptilum* cf *rigidum* | | | | | | ● | |
| *Protoptilum* sp. A | | | ● | ● | | ● | |
| Scleroptilidae | | | | | | | |
| *Scleroptilum* sp. | | | | | | | ● |
| Stachyptilidae | | | | | | | |
| *Stachyptilum superbum* | | | | | | ● | |
| Umbellulidae | | | | | | | |
| *Umbellula lindahli* | ● | ● | ● | ● | | ● | ♦ |
| Virgulariidae | | | | | | | |
| *Acanthoptilum gracile* | | | | | | ● | |
| *Balticina californica* | | | | | | ● | |
| *Balticina septentrionalis* | | | | | | ● | |
| *Stylaulta elongate* | | | | | | ● | |
| *Stylatula gracile* | | | | | | | ● |
| *Virgularia cystiferum* | | | | ♦ | | ● | ♦ |
| Order Antipatharia (black corals) | | | | | | | |
| Antipathidae | | | | | | | |
| *Antipathe*s sp. | | | | | | ● | ● |
| *Parantipathes* sp. | | ● | | ● | | | ● |
| Cladopathidae | | | | | | | |
| *Chrysopathes formosa* | | | | ● | | | |
| *Chrysopathes speciosa* | | | | ● | | ● | |
| *Heliopathes pacifica* | | | | | ● | | |
| *Trissopathes pseudotristicha* | | | ● | | | | |
| Schizopathidae | | | | | | | |
| *Bathypathes alternata* | | | | ● | | | |
| *Bathypathes patula* | | | | ● | | ● | ♦ |
| *Dendrobathypathes boutillieri* | | | | | | ● | |
| *Dendrobathypathes* n. sp. A | | ● | | ● | | | |
| *Lillipathes lilliei* | | | | ● | | | |
| *Lillipathes wingi* | | | | | | ● | |
| *Lillipathes* n. sp. A | | | | ● | | | |
| *Umbellapathes helioanthes* | | | | | ● | ♦ | |
| Order Scleractinia (stony and cup corals) | | | | | | | |
| Caryophylliidae | | | | | | | |
| *Caryophyllia alaskensis* | | ● | ● | ● | | ● | |
| *Caryophyllia arnoldi* | | ● | ● | ● | | ● | |
| *Crispatotrochus foxi* | | ● | ● | ● | | | |
| *Labyrinthocyathus quaylei* | | | | | | ● | |
| *Desmophyllum dianthus* (=*D. cristagalli*) | | | | | | ● | |
| *Leptopenus discus* | | ● | | | | | |
| *Lophelia pertusa* | | | | | ● | ● | ● |

Table 2. Continued.

| B. Taxa | BS | AI | WG | EG | SM | BC | WO |
|---|---|---|---|---|---|---|---|
| *Paracyathus caltha* | | | | | | ● | |
| *Paracyathus stearnsi* | | | | ● | | ● | |
| Dendrophylliidae | | | | | | | |
| *Balanophyllia elegans* | | ● | ● | ● | | ● | |
| Flabellidae | | | | | | | |
| *Flabellum* sp. | | ● | | | | | |
| *Javania borealis* | ● | ● | ● | | | | |
| *Javania cailleti* | ● | ● | ● | ● | | ● | |
| Fungiacyathidae | | | | | | | |
| *Fungiacyathus marenzelleri* | | ● | | | ♦ | | |
| Order Filifera (hydrocorals) | | | | | | | |
| Stylasteridae | | | | | | | |
| *Crypthelia trophostega* | ● | ● | | | | | |
| *Cyclohelia lamellata* | ● | ● | | | | | |
| *Cyclohelia* sp. A | | ♣ | | | | | |
| *Distichopora borealis* | | ● | | | | | |
| *Distichopora* sp. A | | ♣ | | | | | |
| *Errinopora nanneca* | | ● | | | | | |
| *Errinopora pourtalesii* | | ● | ● | ● | | ● | |
| *Errinopora stylifera* | | ● | | | | | |
| *Errinopora zarhyncha* | | ● | | | | | |
| *Errinopora* sp. A | | ♣ | | | | | |
| cf. *Stenohelia* sp. [?] | | ● | | | | | |
| *Stylantheca papillosa* | | ● | | | | | |
| *Stylantheca porphyra* | | | | ● | | ● | |
| *Stylantheca pterograpta* | | ● | | ● | | ● | ● |
| *Stylaster alaskana* | | ● | | | | | |
| *Stylaster brochi* | | ● | | | | | |
| *Stylaster californicus* | | | | | | | ● |
| *Stylaster campylecus campylecus* | | ● | ● | ● | | | |
| *Stylaster campylecus parageus* | | | | ● | | | |
| *Stylaster campylecus trachystomus* | | ● | | | | | |
| *Stylaster campylecus tylotus* | | ● | | | | | |
| *Stylaster cancellatus* | | ● | | ● | | | |
| *Stylaster elassotomus* | | ● | | | | | |
| *Stylaster moseleyanus* | | ● | | | | | |
| *Stylaster norvegicus* [?] | | | | | | ● | |
| *Stylaster polyorchis* | | ● | | | | | |
| *Stylaster porphyra* | | | | | | ● | |
| *Stylaster stejnegeri* | ● | ● | | | | | |
| *Stylaster venustus* | | | | ● | | ● | ● |
| *Stylaster verrillii* | | ● | | ● | | | |
| *Stylaster* sp. A | | ♣ | | | | | |

continental US waters (but not British Columbia), which constitutes a more conservative number of potential species for British Columbia than those known only from either Southeast Alaska/Gulf of Alaska seamounts or Washington/Oregon. In total, 149 taxa are now reported in the northeast Pacific north of California. The disparities in regional numbers of taxa likely largely reflects differing levels of survey effort conducted in the different jurisdictions, with significant changes in numbers of taxa present south of Alaska likely to occur when future survey effort is directed towards corals. Apart from Alaska, most coral records to date have been obtained incidentally during the course of surveys targeted on other taxa, which were mostly commercial species.

Among the 149 regional taxa listed here, 66 (44%) were Alcyonaceans (gorgonians or true soft corals), 24 (16%) were Pennatulaceans (sea pens and sea whips), 14 (9%) each were Antipatharians (black corals) and Scleractinians (stony and cup corals), and 31 (21%) were filiferans (hydrocorals). These relative proportions may largely reflect proportions from the locations, depth ranges (50–250 m), and gear types (e.g., groundfish trawls, traps) where commercial fishing has occurred to date. For example, taxa such as the scleractinians are likely less efficiently captured by commercial gears than the generally larger octocorals. In British Columbia, proportions of known occurrences of species to date of the different orders above were 36, 29, 15, 10, and 10%, respectively. These proportions are lower in the alcyonaceans and higher in the pennatalaceans than regionally, which probably reflects the greater reporting emphasis in British Columbia from groundfish trawl bycatch records, and the focusing by fishers on relatively smooth substrate areas that have been fished for decades. Accurate commercial bycatch reporting has mostly been since 1996, and in many areas, large structural species such as gorgonians that might have occurred in previously undisturbed habitat would likely have been destroyed by trawl activity decades ago.

Within coral orders in British Columbia, in the Alcyonacea, the families Plexauridae and Alcyoniidae had the most genera, but no family had more than five species listed. In the Pennatulacea, the Virgularidae had five species listed, and four other families each had two species. The Caryophylliidae dominated the Scleractinia at seven species, the Achizopathidae dominated the Antipatharia with four species, and all six filiferan species were in the family Stylasteridae.

In total, 1826 British Columbia cold-water coral records were mapped. Table 1 presents their data source, years of data collection, and the number of records with geospatial information. These maps identify areas where corals have been encountered and expand on those of McAllister and Alfonso (2001). Figure 1 illustrates the distribution of all cold-water coral documented in British Columbian waters. The concentration of filiferans around the Queen Charlotte Islands in northern British Columbia (Fig. 1E) likely reflects the extensive marine biodiversity surveys conducted recently off Gwai Haanas National Park Reserve, i.e., sampling effort distribution, while the spatial concentration of pennatalaceans just east of the Queen Charlotte Islands (Fig. 1C) can be explained by the extensive occurrence of soft substrate (sand and gravel) in this relatively heavily fished area, i.e., substrate type. The clustering of many coral records along the continental shelf break and slope reflects the presumed relative abundance of suitable coral habitat at the greater depths that occurs there, i.e., both the presence of more exposed rock and stronger currents that occur at depth in the canyons that transverse this region. These bathymetric and oceanographic features create habitat particularly suitable for many corals, i.e., hard substrates devoid of sediment and readily available suspended food particles. Finally, because effort distribution to date has been biased and methods

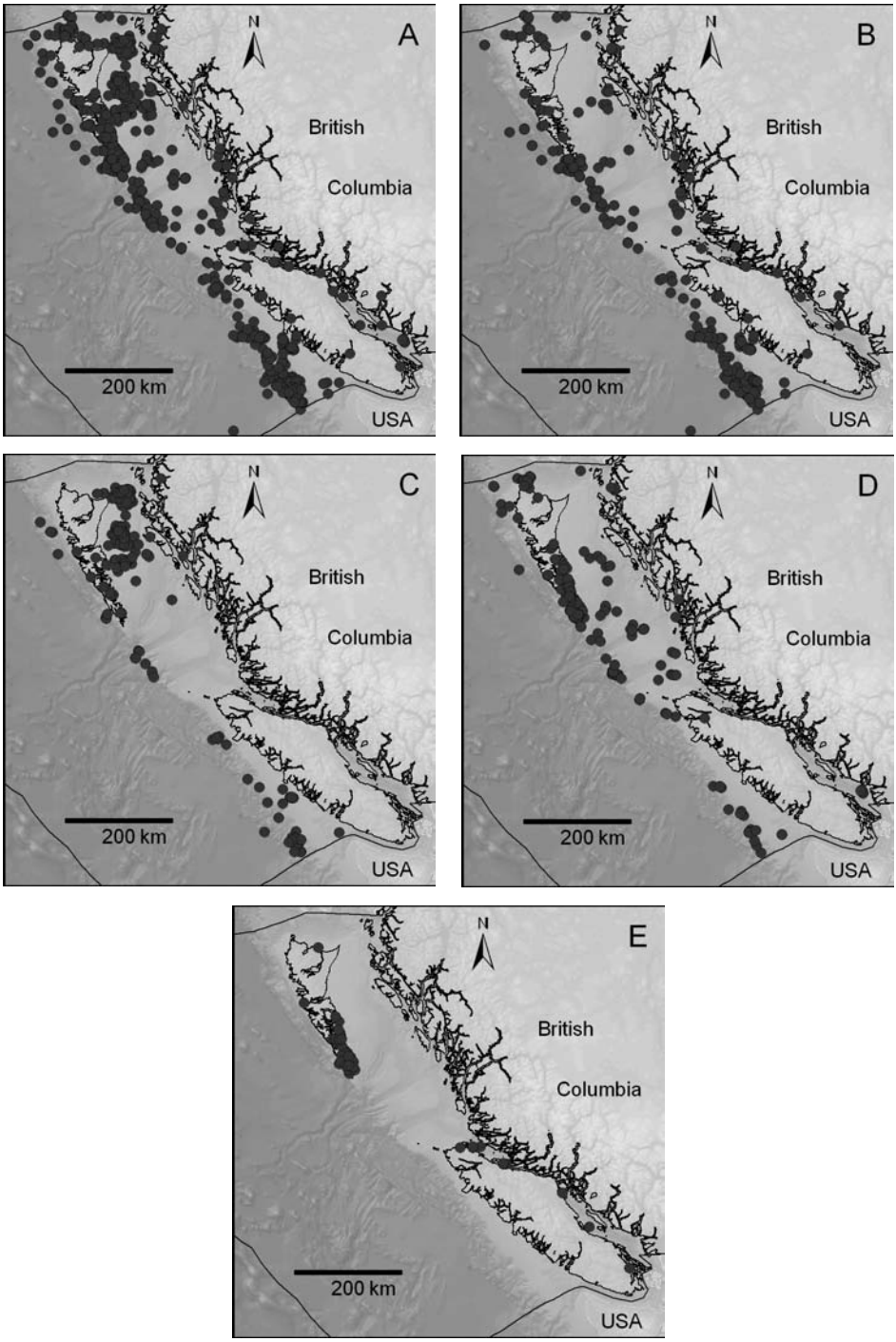


Figure 1. Locations of corals reported from British Columbia, Canada. (A) All, (B) Alcyonacea, (C) Pennatulacea, (D) Scleractinia, (E) Filifera.

of data collection have been limited, documented existing coral order distributions may only partially reflect actual spatial distributions, which will no doubt become more apparent as additional data are acquired from areas not extensively fished to date.

The distributional scale of much existing data is currently too large to define discrete locations of corals (e.g., groundfish trawl tows average ~10 km; tow midpoints were mapped, as it is not known where along the tow paths corals landed were actually caught by the gear), although Ardron (2005) and Ardron et al. (2007) suggest where coral concentrations are based on groundfish trawl by-catch data. Surveys utilizing video equipment are needed for ground-truthing and identifying coral species and other vulnerable benthic organisms at an acceptable resolution. Such surveys would also allow coral abundance assessments in areas with relatively low fishing disturbance or in areas not well suited for current fishing methods (e.g., rough ground) due to potential gear damage or loss.

Given the relative lack of dedicated surveys for corals in the north-eastern Pacific and the relatively large number of species that exist in adjacent areas to British Columbia but which are as yet undocumented in British Columbia, it is expected that many new coral species will be found in Pacific Canada. Cold-water corals are now recognised as important and worth conserving by the general public, and future research and management efforts to survey their presence and abundance and to minimize human impacts on them are being developed.

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