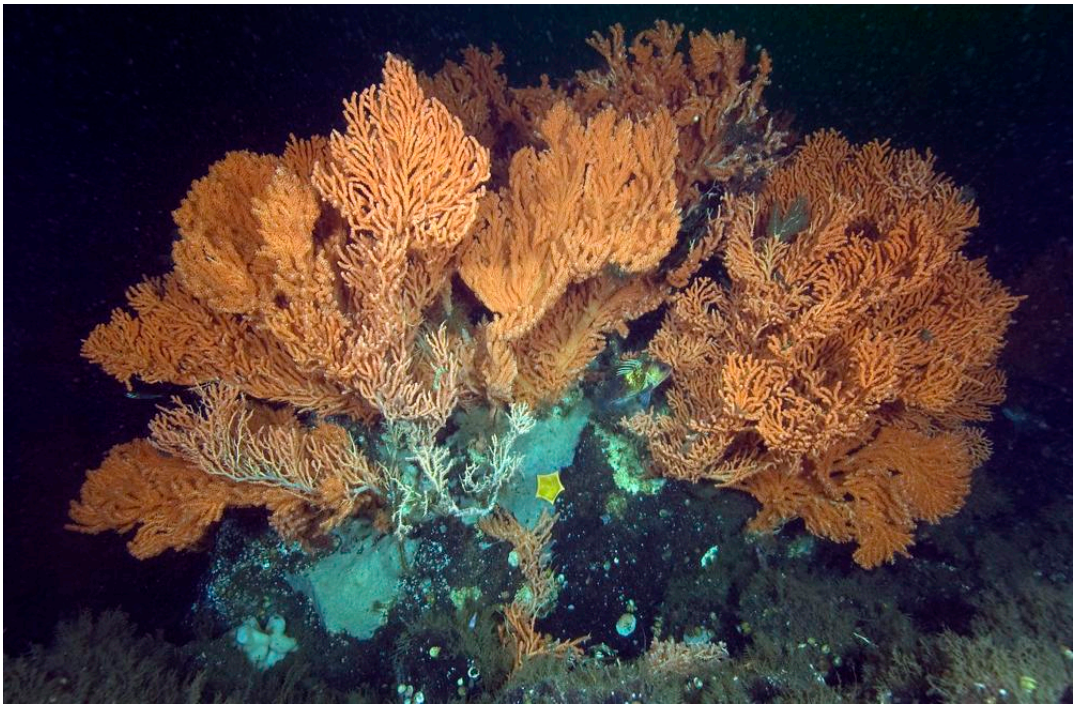
A Proposal to Create a Marine Refuge at the Knight Inlet Sill, British Columbia to Protect Unique Gorgonian Coral Habitat



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July 6, 2018

Knight Inlet is a long, narrow coastal fjord, extending 120 km inland from its entrance located 240 km northwest of Vancouver, near the north end of Vancouver Island. Despite a maximum depth of 540 m it features a relatively shallow sill lying between Hoeya Head and Prominent Point with a maximum depth of only 65 m. Due to the shallow depth of the sill, tidal currents in its vicinity frequently exceed 1 m/second.

The Knight Inlet sill has been of particular interest to oceanographers as it creates internal gravity waves and other hydraulic phenomena (Thompson, 1981). As a result, university and federal government scientists have undertaken several oceanographic surveys of these features. In the early 1980s Canadian researchers surveying Knight Inlet with the submersible *Pisces IV* encountered large fans of gorgonian coral on the flanks of the sill at depths of 65 to 200 m (Tunnicliffe and Syvitski, 1983). Boulders of various sizes were found scattered over the sill, many colonized by impressive coral fans, the largest three metres across. The fact that this gorgonian coral was present was itself noteworthy, but the scientists also observed that behind some of the boulders there were long drag marks, evidence that when the coral fan on a particular boulder became large enough it acted like a sail in the tidal currents. This was theorized to cause the boulder to be gradually transported until it was removed from the influence of the current or until the fan caused the boulder to tip over, thus spilling the "wind" from the sail created by the fan.

In April 1982, divers Ralph Delisle and Dave Wardell explored the sill and found some coral fans at -30 m. Delisle took underwater photos, but at the time did not realize the significance of their remarkable find; i.e. the shallowest sighting of this gorgonian ever in BC waters.

Since 2008, the proponent has made eight expeditions to the sill in order to document the density and distribution of gorgonian corals and sponges. In addition, a comprehensive species list of macro-invertebrates, fishes and marine mammals has been compiled (Table 1).

In order to confirm its identity, a sample of the gorgonian coral was sent to the Smithsonian Institution for examination. Dr. Stephen Cairns confirmed that the specimen was *Primnoa pacifica* Kinoshita, 1907. This species had been previously collected in BC from the Strait of Georgia at a depth of 350 m (Levings and McDaniel, 1974) and deposited in the USNM #57980 (Cairns and Bayer, 2005).

Biology of *Primnoa pacifica*

Primnoa pacifica is found from the Sea of Japan eastward across the Aleutian archipelago and south along the North American coast to La Jolla, California, generally at depths of 64 to 800 m. Off the BC coast, it appears to be widespread and attains considerable size, with the largest fans reaching more than three metres tall. The highest densities are found in areas of moderate to high currents (i.e. greater than 50 cm/sec) (Rooper et al, 2017).

In very large specimens the main stem can exceed six cm in diameter. Cross-sections reveal that the skeleton of *Primnoa pacifica* is densely calcified and exhibits growth rings much like a tree. These annuli can be counted and age has been verified using radiometric methods in *Primnoa resedaeformis* (Andrews et al, 2002). A dead branch of *Primnoa pacifica* from the Knight Inlet sill approximately 1 m tall and with a maximum diameter of 6 cm was examined by Allen Andrews who determined that it was approximately 80 years old (Andrews, pers. comm.) He estimated a basal radial growth rate of 0.33 mm/yr.

The 2009 *Finding Coral Expedition* by the Living Oceans Society searched for *Primnoa pacifica* off the BC coast utilizing Nuytco *DeepWorker* submersibles. They discovered extensive deep-water coral thickets near Dundas Island, in Portland Canal and in Juan Perez Sound.

The shallowest that *Primnoa* has been found at the Knight Inlet sill is 12 m below datum, however it has been found by divers as shallow as 9 m deep in Glacier Bay and Tracy Arm fjord, Alaska (Stone et al, 2005). Alaskan researchers suggest that low temperature, stable salinity and low ambient light levels encourage *Primnoa* to colonize the rocky drop-offs. Because there is an accurate record of the deglaciation of Glacier Bay, they estimated the growth rates for these corals at 2.4 cm per year.

Biophysical Description of the Knight Inlet Sill

The substrate on the crest of the sill within diving depths of 40 m is predominantly cobble trapped in coarse sands and gravel. However, in certain areas there are numerous erratic boulders, some reaching very large dimensions (greater than 5 m in diameter). These boulder fields provide stable attachment for a diversity of invertebrates in the significant tidal currents that upwell over the ridge. The largest *Primnoa* fans are attached to the sides and upper surfaces of the boulders.

Other conspicuous invertebrates include sponges such as the cloud sponge *Aphrocallistes vastus* (at the unusually shallow depth of 15 m), the soft goblet sponge *Amphilectus digitatus infundibulus*, the green sponge *Halichondria (Eumastia) sitiens* and many other encrusting demosponges; the zoanthid *Epizoanthus scotinus*; hydrocorals, especially *Stylaster verrillii*; hydroids (many species, including *Aglaophenia* spp., *Thuiaria* spp., *Thuiaria thuja*); anemones, including the plumose anemone *Metridium farcimen*, the crimson anemone *Cribrinopsis fernaldi* and the spotted swimming anemone *Stomphia coccinea*; echinoderms, including the basket star *Gorgonocephalus eucnemis*, spiny red star *Hippasteria phrygiana*, gunpowder star *Gephyreaster swifti*, white urchin *Strongylocentrotus pallidus*, an undescribed species of sun star *Solaster* sp. and feather star *Florometra serratissima*.

In addition to the population of *Primnoa* gorgonian coral, of particular interest was the finding of several rarely-seen soft goblet sponges, *Amphilectus digitatus infundibulus*, several more than 20 cm in diameter. This sighting proved to be a new shallow record in BC waters.

Another significant find was the bigmouth sculpin, *Hemitripterus bolini*, a species rarely seen in shallow water. The sighting represented a new southernmost record for this species in BC (previously Hakai Pass) and a shallow record (previously -122 m) of -10 m.

Additional sponges were collected for Drs. Bill Austin and Bruce Ott including one (*Hymetrochota* sp.) which may represent a new record for the NE Pacific. Several specimens of an undescribed sea star, *Solaster* sp. were collected for Dr. Roger Clark. Specimens of the soft coral *Thrombophyton trachydermum* were collected for the Royal BC Museum (Jim Boutillier, Pacific Biological Station).

Rationale for Protecting the Sill

1/ The Knight Inlet sill is the site of the shallowest known population of *Primnoa pacifica* on the coast of British Columbia and the only one accessible to study using scuba. The site offers a rare opportunity to study growth rates, distribution, predators and other aspects of its biology.

2/ The Knight Inlet sill represents a remarkable and unique habitat on the British Columbia coast. In addition to *Primnoa pacifica*, several other deepwater and/or rare species are found here:

- Soft goblet sponge *Amphilectus digitatus infundibulus* (shallow record for BC).
- Shrimp *Eualus townsendi* (shallow record for BC).
- Bigmouth sculpin *Hemitripterus bolini* (shallow and southern record for BC).
- Nudibranch *Tritonia* sp., possibly an undescribed species that preys on *Primnoa*.
- Dwarf white gorgonian coral *Anthothela pacifica*. Observed on the flanks of the sill at 150 m and deeper using ROVs (pers. comm., Jim Boutillier, PBS).

3/ *Primnoa pacifica* fans form dense thickets on the sill which provide important vertical relief and refuge for fishes, especially quillback (*Sebastes maliger*) and dark (*Sebastes ciliatus*) rockfishes. In deep water in the NE Pacific, especially in the Gulf of Alaska, these coral thickets are known to provide essential fish habitat (Stone et al, 2015).

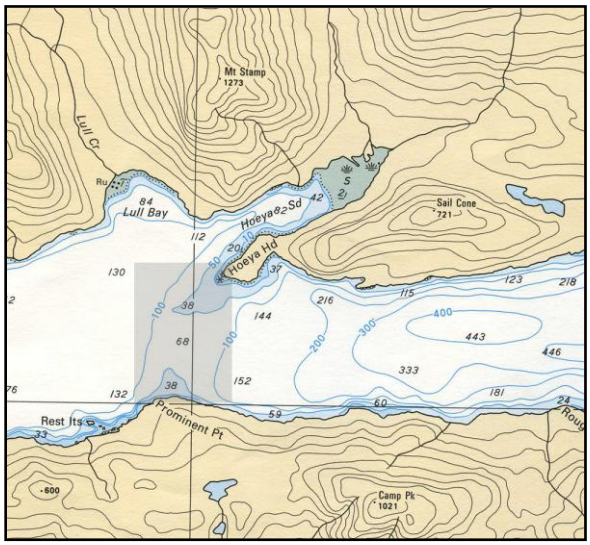
4/ Despite their strong holdfasts and wiry, somewhat flexible branches, *Primnoa* fans are often destroyed by bottom trawling and other bottom-contact fishing methods such as long-lining and trapping (Stone and Shotwell, 2007; Stone 2006).

At the Knight Inlet sill many broken and damaged coral fans have been observed on the sill. Some were entangled with monofilament fishing line and had been damaged by sport fishing tackle. Various flashers and downrigger weights were also found. Other broken fans were tangled with downrigger wire. Heavier rope, possibly remnants of commercial trap-lines, was also found.

Some large, nearly intact fans were observed that were not fouled with fishing gear and which may have broken free of their attachment naturally due to their large size and the force of the strong tidal currents. Detached fans lying on the substrate appeared unhealthy, with many dead and dying polyps.

This proposal to create the Knight Inlet Sill Marine Refuge meets the five DFO criteria that an area-based conservation management measure must comply with, namely:

1/ The Knight Inlet sill is a clearly defined geographic location encompassing the sill and adjacent areas. The area of the proposed Marine Refuge is shown at right.



2/ The Marine Refuge is intended to conserve and protect a unique, shallow-water population of the gorgonian coral *Primnoa pacifica*.

3/ The Marine Refuge includes the Knight Inlet sill, a glacial moraine habitat that is the site of exceptional diversity and the shallow-water emergence of several deep-water species, including *Primnoa pacifica*.

4/ The Marine Refuge is proposed as a long-term, in-perpetuity objective.

5/ The Marine Refuge will be effectively protected and conserved by the implementation of restrictions on all commercial and recreational bottom-contact fishing methods, log storage and dumping and anchoring. The collection of marine life for any purpose other than permitted scientific research will not be allowed.

Acknowledgements

The author acknowledges the valuable contributions of observations, photographs and video of many diving associates, including Ralph DeLisle, Andy Lamb, Doug Swanston, Lou Lehmann and Tom Sheldon. Bill Austin, Bruce Ott, Stephen Cairns, Sandra Millen, Jim Boutillier, Roger Clark, Greg Jensen and Catharine McFadden provided expert taxonomic advice. Allen Andrews provided expertise in the aging of gorgonian fans.

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Table 1: List of Conspicuous Invertebrates, Fishes and Marine Mammals from Knight Inlet Sill (as of July 2018 with additional data contributed by Andy Lamb)

TAXON	COMMON NAME	COMMENTS
ALGAE	**SEAWEEDS**	
Ulva sp.	sea lettuce	
Codium setchellii	spongy cushion	
Fucus distichus evanescens	rockweed	
Alaria marginata	broad winged-kelp	
Saccharina latissima	sugar wrack kelp	
Laminaria sinclairi	dense-clumped kelp	
Desmarestia sp.	thin acid kelp	
Nereocystis luetkeana	bull kelp	
Agarum fimbriatum	fringed sea colander klep	
Various spp.	filamentous red algae	
Clathromorphum spp.	crustose corallines	
Callophyllis sp.	beautiful leaf seaweed	
Opuntiella californica	prickly pear seaweed	
PORIFERA	**SPONGES**	
Sycandra cf. *utriculus*	leather bag sponge	
Rhabdocalyptus dawsoni	sharp-lipped boot sponge	
Aphrocallistes vastus	cloud sponge	
Isodictya rigida	orange finger sponge	
Amphilectus digitatus infundibulus	flabby bowl sponge	Shallow record for BC at -20 m
Lycopodina occidentalis	pipe cleaner sponge	
Iophon lamella	white reticulated sponge	
Halichondria (Eumastia) sitiens	green-tinged sponge	
Semisuberites cribrosa	funnel sponge	
Halsarca/*Oscarella* sp.	sponge	
Mycale (Aegogropila) adhaerens	sponge	
Suberites latus	hermit crab sponge	
Raspailiidae	sponges	
Hymetrochota sp.	sponge	New record for NE Pacific? (W. Austin)
Weberella sp.	sponge	
Lissodendoryx sp.	sponge	Possible undescribed species
Plakina atka	brain sponge	Possible new southern record for BC
CNIDARIA	**ANEMONES, CORALS**	
Metridium farcimen	giant plumose anemone	
Cribrinopsis fernaldi	snakelock anemone	
Urticina grebelnyi	painted anemone	
Stomphia didemon	swimming anemone	

Stomphia coccinea	spotted swimming anemone	
Epizoanthus scotinus	orange zoanthid	
Balanophyllia elegans	orange cup coral	
Thrombophyton trachydermum	pale soft coral	
Alcyonium sp. indeterminate	red soft coral	See Williams, 2013
Ptilosarcus gurneyi	orange sea pen	
Virgularia cf. *tuberculata*	white sea pen	
Halipteris willemoesi	sea whip	
Primnoa pacifica	gorgonian coral	Shallow record for BC at -12 m
Stylaster verrillii	branching pink hydrocoral	
Aglaophenia spp.	ostrich plume hydroids	
Thuiaria spp.	embedded sea fir hydroids	
Plumularia sp.	delicate plume hydroid	
Similiclava nivea	white hydroid	
Thuiaria thuja	bottlebrush hydroid	
Ectopleura marina	solitary pink-mouth hydroid	
Grammaria sp.	spindly embedded hydroid	
Lafoea dumosa	muff hydroid	
ANNELIDA	**SEGMENTED WORMS**	
Serpula columbiana	red trumpet calcareous tubeworm	
Eudistylia catharinae	roll-top feather duster worm	
Diopatra ornata	ornate tubeworm	
Halosydna brevisetosa	eighteen-scaled worm	
Protula pacifica	white-crowned calcareous tubeworm	
Chone aurantiacea	orange feather-duster	
Parasabella media	parasol feather-duster	
Megalomma sp.	twin-eyed feather-duster	
Myxicola infundibulum	slime-tube feather-duster	
Chaetopterus sp.	parchment tubeworm	
BRYOZOA	**MOSS ANIMALS**	
Schizoporella japonica	orange encrusting bryozoan	
Microporina borealis	stick bryozoan	
BRACHIOPODA	**LAMPSHELLS**	
Laqueus vancouveriensis	California lamp shell	
Terebratalia transversa	transverse lamp shell	
Terebratulina unguicula	snake's head lamp shell	
Hemithiris psittacea	black lamp shell	
MOLLUSCA	**CHITONS, BIVALVES, SNAILS...**	
Tonicella undocaerulea	blue-lined chiton	
Tonicella lineata	lined chiton	

Mopalia muscosa	mossy chiton	
Lepidozona mertensii	Merten's chiton	
Cryptochiton stelleri	giant Pacific chiton	
Placiphorella rufa	red veiled chiton	
Modiolus rectus	straight horsemussel	
Clinocardium nuttallii	Nuttall's cockle	
Saxidomus gigantea	Washington butter clam	
Hiatella sp.	nestler clam	
Mya truncata	truncated softshell clam	
Diadora aspera	rough keyhole limpet	
Bathybembix bairdi	Baird's margarite	
Ocinebrina interfossa	sculptured rocksnail	
Chlamys hastata	spiny pink scallop	
Ceratostoma foliatum	leafy hornmouth	
Nucella lamellosa	wrinkled dogwinkle	
Amphissa columbiana	wrinkled amphissa	
Nipponotrophon stuarti	winged trophon	
Calliostoma variegatum	variable topsnail	
Fusitriton oregonensis	Oregon triton	
Trichotropis cancellata	checkered hairysnail	
Tritonia festiva	diamondback nudibranch	
Onchidoris bilamellata	barnacle-eating nudibranch	
Triopha catalinae	clown nudibranch	
Tritonia sp.	pink tritonia	Possible new species
Tochuina gigantea	orange-peel nudibranch	
Enteroctopus dofleini	giant Pacific octopus	
ARTHROPODA	**SHRIMPS, CRABS**	
Erichthonius rubricornis	tube-dwelling sea flea	
Heptacarpus decorus	elegant coastal shrimp	
Eualus townsendi	Townsend's eualid	Shallow record for BC at -20 m
Spirontocaris lamellicornis	Dana's blade shrimp	
Heptacarpus kincaidi	Kincaid's shrimp	
Lebbeus grandimanus	candy stripe shrimp	
Pandalus eous	spiny pink shrimp	
Pandalus danae	coonstripe shrimp	
Cancer productus	red rock crab	
Metacarcinus magister	dungeness crab	
Pugettia gracilis	graceful decorator crab	
Hyas lyratus	Pacific lyre crab	
Chorilia longipes	longhorn decorator crab	

Acantholithodes hispidus	hairy-spined crab	
Cryptolithodes typicus	butterfly crab	
Rhinolithodes wosnessenskii	rhinoceros crab	
Phyllolithodes papillosus	heart crab	
Lopholithodes mandtii	Puget Sound king crab	
Lopholithodes foraminatus	brown box crab	
Placetron wosnessenskii	scaled crab	
Munida quadrispina	galatheid crab	
Pagurus beringanus	Bering hermit	
Pagurus armatus	backeyed hermit	
Elassochirus tenuimanus	widehand hermit	
Elassochirus gilli	orange hermit crab	
Balanus glandula	common acorn barnacle	
Balanus rostratus	rostrate barnacle	
Balanus nubilus	giant acorn barnacle	
ECHINODERMATA	**SEA STARS, URCHINS...**	
Evasterias troschelii	mottled star	
Mediaster aequalis	vermilion star	
Gephyreaster swifti	gunpowder star	
Ceramaster patagonicus	cookie star	
Hippasteria phrygiana	spiny red star	
Pteraster militaris	wrinkled star	
Pteraster tesselatus	slime star	
Henricia leviuscula	blood star	
Henricia sanguinolenta	fat blood star	
Pycnopodia helianthoides	sunflower star	
Crossaster papposus	rose star	
Solaster dawsoni	morning sun star	
Solaster stimpsoni	striped sun star	
Solaster endeca	northern sun star	
Solaster sp.	orange sun star	Undescribed (R. Clark, Pers. comm.)
Ophiopholis aculeata	daisy brittle star	
Gorgonocephalus eucnemis	basket star	
Florometra serratissima	feather star	
Strongylocentrotus droebachiensis	green sea urchin	
Strongylocentrotus pallidus	white sea urchin	
Parastichopus californicus	giant sea cucumber	
Cucumaria miniata	red sea cucumber	
Psolus chitonoides	creeping pedal sea cucumber	
Synallactes challengeri	long-spined sea cucumber	

CHORDATA	**TUNICATES**	
Corella willmeriana	transparent tunicate	
Ascidia paratropa	glassy tunicate	
Didemnum sp.	compound tunicate	
Cnemidocarpa finmarkiensis	broadbase tunicate	
Pyura haustor	warty tunicate	
Didemnum carnulentum	Pacific white crust	
Cystodytes sp.	compound tunicate	
	FISHES	
Aulorhynchus flavidus	tubesnout	
Microgadus proximus	Pacific tomcod	
Ronquilus jordani	northern ronquil	
Hexagrammus stelleri	whitespotted greenling	
Artedius harringtoni	scalyhead sculpin	
Triglops pingelii	ribbed sculpin	
Podothecus accipenserinus	sturgeon poacher	
Lepidopsetta bilineata	rock sole	
Parophrys vetulus	English sole	
Platichthys stellatus	starry flounder	
Chirolophis decoratus	decorated warbonnet	
Lumpenus sagitta	snake prickleback	
Sebastes caurinus	copper rockfish	
Sebastes maliger	quillback rockfish	
Sebastes melanops	black rockfish	
Sebastes ciliatus	dark rockfish	
Sebastes emphaeus	Puget Sound rockfish	
Hexagrammos decagrammus	kelp greenling	
Ophiodon elongatus	lingcod	
Jordania zonope	longfin sculpin	
Hemilepidotus hemilepidotus	red Irish lord	
Enophrys bison	buffalo sculpin	
Enophrys lucasi	leister sculpin	Southern record for BC?
Myoxocephalus polyacanthocephalus	great sculpin	
Hemitripterus bolini	bigmouth sculpin	Southern & shallow record at -10 m
Rhamphocottus richardsonii	grunt sculpin	
Nautichthys oculofasciatus	sailfin sculpin	
Liparis dennyi	marbled snailfish	
Agonopsis vulsa	northern spearnose poacher	
Pleuronichthys coenosus	C-O sole	
Ptilichthys goodei	quillfish	

	MAMMALS	
Phocoenoides dalli	Dall's porpoise	
Phocoena phocoena	Harbour porpoise	
Eumetopias jubatus	Steller sea lion	
Lagenorhynchus obliquidens	Pacific white-sided dolphin	
Megaptera novaeangliae	Humpback whale	
Phoca vitulina richardsi	Pacific harbour seal	