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The intentional scuttling of surplus and derelict vessels: Some effects on marine biota and their habitats in British Columbia waters, 2002

Sabordage intentionnel de navires en surplus et épaves : quelques effets sur le biote marin et sur les habitats dans les eaux de la Colombie-Britannique, 2002

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1.0 ABSTRACT/RESUMÉ

Abstract

Artificial reefs have been created in most world seas for a range of reasons including attempts to enhance marine productivity, and to attract recreational and commercial fish species and recreational divers. Many nations' navies have a surplus of vessels requiring disposal. One cost-effective disposal method is to scuttle them in locations appropriate for the recreational use of scuba-equipped divers. Once in place the "vessel-reef" becomes colonized by epibenthic organisms, and attracts pelagic and demersal fishes, making it even more interesting to human divers. Habitat managers and ocean planners ask if the ecological benefits of scuttled vessels outweigh the ecological losses? This report reviews the Canadian and British Columbia regulatory information on the scuttling of vessels, the scientific information on artificial reefs, and collates the scattered information on the use of scuttled vessels as artificial reefs with emphasis on those in Canadian Pacific coast waters. A list of the 18 scuttled vessels-as-reefs in BC waters is provided along with the area of smothered sea floor per vessel (range from ~14-m^2 to ~2 330-m^2); the estimated total for all scuttled vessels is ~10 500-m^2 (~1.1 ha). Where available, lists of macro-flora and -fauna (range from 25 to 96 species) either attached or closely associated (small to large epifaunal fishes and invertebrates) with each BC vessel-reef is provided along with descriptive narratives. Frequently observed fish include copper (*Sebastes caurinus*) and quillback (*S. maliger*) rockfish, lingcod (*Ophiodun elongatus*), kelp greenling (*Hexogrammus decagrammus*), shiner (*Cymatogaster aggregata*) and pile (*Rhacochilus vacca*) perch, and padded (*Artedius fenestralis*), grunt (*Rhamphocottus richardsoni*) and scalyhead (*Artedius harringtoni*) sculpins. Species richness becomes maximal in about two years. Detailed scientific studies surrounding scuttled vessels have not been carried out in BC waters, though workers elsewhere have shown that infaunal densities under a scuttled vessel hull were from 3 – 15 times less than one meter beyond the hull. Tagging studies show that artificial reefs both attract motile adult species from adjacent natural reefs, and add to the overall production of an area through the recruitment of juveniles that feed and grow in and around the reef. Other studies have shown that the production from an artificial reef far exceeds the production of the previous sand/mud ecosystem. A range of recommendations are provided including the discouragement of pyrotechnical shows during ship scuttlings, and that the location of vessel-reefs should be carefully selected with the site being >2 km from natural reefs.

RESUMÉ

Des récifs artificiels ont été créés dans la plupart des mers du globe pour une diversité de raisons, notamment pour améliorer la productivité marine, pour attirer des espèces de poissons pour la pêche sportive et commerciale et pour offrir des lieux de plongée sous-marine. Les marines de bon nombre de nations possèdent des navires en surplus qu'il faut éliminer. Une méthode d'élimination rentable consiste à les saborder dans des lieux appropriés pour la pratique de la plongée autonome. Une fois en place, le « navire-récif » est colonisé par des organismes épibenthiques et attire des poissons pélagiques et démersaux, ce qui les rend encore plus intéressants pour les plongeurs. Les gestionnaires de l'habitat et les personnes qui s'occupent de la planification des océans se demandent si les avantages écologiques des navires sabordés dépassent les pertes écologiques. Le présent rapport examine l'information sur les règlements mis en vigueur par le Canada et la Colombie-Britannique sur le sabordage des navires, l'information scientifique sur les récifs artificiels et réunit de l'information éparse sur l'utilisation de navires sabordés comme récifs artificiels, en mettant l'accent sur ceux présents dans les eaux côtières du Pacifique canadien. Une liste des 18 navires sabordés servant de récifs dans les eaux de la Colombie-Britannique est fournie, accompagnée de la superficie du plancher océanique occupée par ces navires (allant de ~14 m^2 à ~2 330 m^2); la superficie totale estimée pour tous les navires sabordés est ~10 500 m^2 (~1,1 ha). Lorsque disponible, des listes des espèces de macroflore et de macrofaune (allant de 25 à 96 espèces), soit rattachées, soit étroitement associées (petits à grands poissons et invertébrés épifauniques) à chaque navire-récif de la C.-B. est fournie, accompagnée de descriptions. Parmi les poissons fréquemment observés figurent les sébastes cuivrés (*Sebastes caurinus*) et les sébastes à dos épineux (*S. maliger),* les morues-lingue (*Ophiodun elongatus),* les sourcils de varech (*Hexogrammus decagrammus),* les ménés émeraude (*Cymatogaster aggregata),* les perches de pilotis (*Rhacochilus vacca)* et les chabots rembourrés *(Artedius fenestralis),* grogneurs (*Rhamphocottus richardsoni)* et à tête écailleuse (*Artedius harringtoni).* La richesse en espèces atteint son maximum en environ deux ans. On n'a pas mené d'études scientifiques détaillées sur les navires sabordés dans les eaux de la Colombie-Britannique, bien que des travailleurs d'ailleurs aient montré que les densités d'espèces benthiques sous la coque d'un navire sabordé étaient de 3 à 15 fois moindre qu'à un mètre au-delà de la coque. Les études de marquage montrent que les récifs artificiels attirent les espèces d'adultes vagiles des récifs naturels adjacents et ajoutent à la production globale d'une zone par le recrutement de juvéniles qui se nourrissent et croissent dans le récif et autour de celui-ci. D'autres études ont montré que la production dans un récif artificiel dépassait de loin la production dans l'écosystème antérieur de sable et de boue. Une série de recommandations est formulée, notamment sur l'effet néfaste des spectacles pyrotechniques organisés au moment du sabordage des navires et le choix minutieux de l'emplacement des navires-récifs, lesquels doivent se situer à plus de 2 km de récifs naturels.

2.0 INTRODUCTION AND OBJECTIVES

Artificial structures are not new as habitat features of the aquatic environment. Ancient peoples placed rocks and logs to attract fishes for improved harvesting. In more recent times, largely over the past 50 years, governments, industries, academia and even the public around the world have promoted and/or constructed artificial structures as hard substrate or reef habitat. They have used a wide array of natural and manufactured materials from relatively small items such as rubber tires, white goods (e.g. refrigerators), concrete blocks, marine cable, plastic pipe and quarry rock -- to larger items including army tanks, military aircraft, oil rigs and vessels.

The purposes of these artificial reef placements are just as varied: to enhance or increase the production and harvest of artisanal and commercial fisheries; to establish aquaculture production sites; to enhance recreational fishing by hook-and-line and spear; to control fishing mortality using gear interference; to manipulate the life history of organisms; to protect sensitive or threatened habitats; to mitigate offsite habitat damage and loss; to conserve biodiversity; to restore or enhance on-site water and habitat quality; to enable scientific research and experimentation; to promote volunteer citizen monitoring and public awareness; and to provide attractions for recreation and tourism largely for scuba divers (Seaman 2000). This report focuses largely on the latter, that is artificial reefs constructed by intentionally sinking boats and ships for recreational and tourist diving attractions.

In 1997, leading up to this review and report, the Environmental Protection Branch of Environment Canada, North Vancouver, requested scientific and technical advice from the Water Quality Unit of the Department of Fisheries & Oceans' (DFO) Habitat and Enhancement Branch (HEB), Vancouver about the effects of scuttling ships on fish and fish habitat. At that time, it was expected that applications pursuant to Ocean Disposal provisions of the Canadian Environmental Protection Act would be received over the coming decade for sinking numerous surplus naval ships and various derelict vessels as artificial reefs largely for recreational divers. In turn HEB requested DFO's Marine Environment and Habitat Science Division (MEHSD), Sidney to offer a scientific perspective on whether or not vessels scuttled on this scale and for this purpose would harmfully alter, disrupt or destroy fish habitat pursuant to the Fisheries Act.

In summer 1997, a review of the published reports and unpublished information was undertaken by MEHSD staff. This served as background for an informal, one-day regional workshop organized at Nanaimo, BC in November 1997, and attended by nine Science and HEB staff (See Acknowledgements). The objective was to advise on whether or not reefed vessels resulted in habitat loss or habitat gain. Professional judgements only were made by the participants, as summarized here from the unpublished minutes of the workshop:

- There is considerable conflicting evidence in the world's literature on whether or not artificial reefs such as scuttled ships increase the diversity, abundance and/or production of fish and fish habitats;
- Ships sunk as artificial reefs add habitat structure and complexity in locales of low relief such as sand/mud plains that are typically chosen as sites; a community of pelagic species is now possible, largely from attraction and aggregation from elsewhere;

- Benthic organisms that seed the colonization of the reef will not settle at the expense of other natural sites;
- The ships' steel, iron and/or aluminium provide hard substrate for colonization of benthic species, but these materials are not preferable to inert natural substrates such as rock;
- The local biodiversity and biological productivity increase on ship reefs, but their contribution to the region is likely to be immeasurably small;
- Ship reefs may increase the juvenile survival rates and biomass of some reef fishes, with the exception of most rockfishes. Ship reefs will probably not sustain all life stages of rockfish, but may create a slight but immeasurable net gain in feeding habitat for adult rockfish preying on smaller fishes;
- Local benthic habitat and associated biota such as polychaetes are destroyed by direct smothering beneath the ships' hulls, and altered by small physical changes such as sediment grain size caused by increased currents and turbulence;
- Ship reefs may support a different type of pelagic fish community than that of the adjacent natural reefs, largely because of the differing dominance of seaweeds as habitat for smaller fishes;
- The local biomass will likely increase on ship reefs, but not always with a corresponding increase in local production – as evidenced by proliferation of anemones and other coelenterates that are not common prey. Any gain in fish production would be small and difficult to measure; and
- The effects of ship reefs will be limited, and likely not measurable, on adjacent natural rocky reefs and their biota, regardless of closeness in proximity.

Some of the workshop's recommendations included:

- Ship reefs should be sited in moderate current areas to avoid siltation and anoxic build-up and to increase turbulence and mixing that enhances production;
- Ship reefs should best be located in the photic zone to better foster primary production;
- The proponents should conduct site surveys with regulators and the diving public, to facilitate before-and-after research. The performance of ships as artificial reefs could be studied and monitored by recreational divers and diving clubs, given the proper training and co-ordination; and
- Evaluations of the benefits and disadvantages of ship reefs should clearly separate ecological function from those of cultural, recreational and economic values. In spring 2001, Science Branch decided to look more closely at the published literature, regional reports and unpublished information, and to submit the findings as a working paper to the Habitat Subcommittee of the Pacific Science Advisory Review Committee (PSARC)(See Appendix 1 for the PSARC Request for a Working Paper).

At about the same time (March 2001), DFO's Habitat Management and Oceans Policy (Ottawa) organized a national workshop on the assessment and research of artificial reef technologies. Approximately fourteen DFO scientists and biologists from five Canadian Regions met together in St. Catherines, Ontario, together with six others from other governments, academia and industry. Their tasks included the defining of generic criteria, guidelines and standards for establishing a consistent national approach to evaluate and assess proposals for installing artificial reefs in fresh and marine waters. The issues ranged from site selection and reef design to performance monitoring and research funding. One practical matter that was raised, but not resolved by the participants, was whether or not an artificial reef structure compensates, or more than compensates, for its footprint beneath which habitat is altered or destroyed (proceedings unpublished).

Purposes of this report were: first, to simply compile and catalogue the scattered information on existing artificial reefs created by sinking derelict and surplus vessels; Secondly, to review the known and possible environmental effects of artificial reefs and summarize the BC evidence and the published literature from around the world; And thirdly, to focus on the physical and biological effects of artificial reefs on marine fish and their habitats. The issues associated with possible chemical effects from introduced contaminants were deemed to be outside the scope of this report.

The general background and technical information and scientific advice provided here are intended to help reef developers, marine regulators, habitat managers, coastal planners, environmental groups and the public in gaining a common understanding of historic vessel reef development in BC coastal waters. Further, the report should allow more ready evaluation of the environmental consequences and implementation of mitigative measures as governments and stakeholders together deliberate on the numbers, types and locations of future reef construction.

3.0 REGULATORY APPROACH IN BRITISH COLUMBIA

3.1 Canadian Environmental Protection Act and Canadian Environmental Assessment Act

To date in British Columbia, provincial and federal authorities have considered the purposeful scuttling of derelict and surplus vessels as a regulatory matter largely involving solid waste disposal in the ocean in accordance with Canadian Environmental Protection Act (CEPA).

Section 70 of Part VI of CEPA states that “no person shall dispose of any ship...in any area of the sea except in accordance with an (Ocean Disposal) Permit….”. Since 1975, the Minister of the Environment has authorized disposal by issuing such Permits, following multi-agency technical reviews by the Regional Ocean Disposal Advisory Committee (on which several DFO Branches are represented), and environmental impact assessments and public reviews of the proposed vessel sinkings in accordance with the Canadian Environmental Assessment Act (CEAA). All relevant materials received and generated by the Minister are made available to the public at Environment Canada’s Public Registry. The Minister also takes into account comments from the public and other stakeholders, as well as the advice from other agencies.

These application procedures are now outlined for British Columbia and Yukon waters in the Disposal of Vessel Guidelines for applying for an Ocean Disposal Permit (Environment Canada 1998c; Environment Canada 1998d).

Every Permit Application must contain the following:

- A description of the proposed vessel disposal project, including the anticipated schedule and purpose of sinking;
- Detailed drawings and/or photographs of the vessel;

- A complete written description of the vessel, including its size and weight;
- Hull and superstructure materials and coatings;
- Materials to be left on board after proposed vessel preparation;
- Detail plans of the removal, prior to sinking, of all materials posing threats to the marine environment and to other legitimate uses of the sea including, but not limited to fuels, lubricating oils, greases, hydraulic fluids, PCBs in electrical equipment, and floatables;
- The co-ordinates of the proposed vessel disposal, shown on a hydrographic chart;
- A description of the site in relation to local communities and landforms;
- The proposed orientation of the vessel on the ocean bottom;
- The physical nature of the ocean bottom and the associated biological resources information including videotape records; and
- Evidence showing bottom capability to support and secure the vessel in place.

In the case of large and complex vessels, Environment Canada may require the applicants to hire and pay for registered professional engineers to evaluate the cleanup.

Applicants must provide detailed descriptions of other legitimate uses of the sea such as commercial and sport fishing, aquaculture, boating and shipping in the general area of the proposed vessel disposal site. Written proof must be provided by the applicants that direct notification and consultation with other users of the area regarding the proposed vessel disposal have been considered and assessed.

Before the Minister of the Environment issues a Permit, a final inspection of the vessel is conducted by Environment Canada inspectors. They ensure that all materials which pose a threat to the marine environment and to other legitimate uses of the sea have been removed, and that any potentially adverse environmental impacts have been mitigated. The Permit does not authorize the establishment or operation of a recreational diving facility or any future use of the vessel by the applicant.

To further assist applicants, Environment Canada's Pacific and Yukon Region, has produced two useful documents. The first, "Clean-up Standard for Ocean Disposal of Vessels" defines the minimum cleanliness requirements before permitting under CEPA (Environment Canada 1998a). The clean-up criteria based on post-sinking observations, site monitoring data and published literature. In the absence of complete data and information, however, the stricter criteria are maybe employed. The second document, "Clean-up Guideline for Ocean Disposal of Vessels" (Environment Canada 1998b), offers practical guidance based on observation and experience on how to perform tasks or meet a requirement.

It is this regulatory approach in BC that has prompted some stakeholders to be critical of reef development, suggesting that ship scuttling appears more than a solid waste disposal program (Hellerman 1995; Georgia Strait Alliance 1996; Georgia Strait Alliance 1997).

3.2 Navigable Waters Protection Act (NWPA)

The depth of water over a scuttled vessel must be adequate, typically greater than 14 m, to avoid posing a hazard to navigation, and to be in compliance with the NWPA. Consequently, any application must include an estimate of the depth of water that will cover the sunken vessel at lowest tides, for the regulatory approval of the Canadian Coast Guard. Within months of sinking, if possible, the ship reef is charted by the Canadian Hydrographic Service, and its minimum depth and marker buoys are announced to the boating community and then eventually depicted on future charts.

3.3 Fisheries Act

Using the applicants' information in the Ocean Disposal Permit process, DFO technical and management staff must assess the risk of or potential damage to fish and marine mammals and/or fish habitat. With respect to Section 35 of the Fisheries Act, they must determine whether or not a HADD (Harmful Alteration, Disruption or Destruction) of fish habitat is expected and if so, the proposed compensation for the net loss of productive capacity of fish habitat. DFO must also determine the probable success of proposed mitigation and/or compensation measures and, as appropriate the acceptability of any residual impacts. This report provides technical and scientific information for this regulatory requirement.

4.0 SOURCES OF INFORMATION

For over fifty years, researchers have studied artificial reefs constructed in the warm Caribbean Sea and South Pacific to the temperate North-Pacific and Atlantic waters. Findings have been published in journals such as the Journal of Experimental Marine Biology and Ecology, Fisheries Research, Italian Journal of Zoology, Australian Journal of Ecology, Marine Biology, Bulletin of Marine Science, and the Journal of the Fisheries Research Board of Canada.

Topics varying from the management and economics of artificial reefs to their technology and performance have been dealt with at regular international gatherings such the International Reef Conference, International Conference on Ecological System Enhancement Technology for Aquatic Environment, International Conference on Aquatic Habitat Enhancement, Japan-U.S. Symposium on Artificial Habitats for Fisheries, International Conference on Artificial Reefs and Associated Habitats, European Marine Biology Symposium and the International Coral Reef Congress.

Conferences Proceedings from artificial reefs are sometimes published in special issues of journals such as the *Bulletin of Marine Science* Volumes 35 (1985), 44 (1989) and 55 (1994). Major reviews are also available such as *Artificial Reef Research: A Review with Recommendations for Future Priorities* (Bohnsack and Sutherland 1985), *Artificial Habitats for Marine and Freshwater Fisheries* (Seaman and Sprague 1991), *Encyclopedia of Environmental Biology* (Seaman 1995), *Artificial Reefs in European Seas* (Jensen *et al.*, eds. 1999), and *Artificial Reef Evaluation: With Application to Natural Marine Habitats* (Seaman, ed. 2000). These reviews and proceedings were of particular value in preparing this report.

Specific to artificial habitats in BC marine waters, there are three recent reviews. First, an unpublished report by Jones and Welsford (1997) about artificial reefs in BC prepared for by the Artificial Reef Society of British Columbia. Secondly, under contract to DFO, G3 Consulting (2000) conducted an audit of environmental management practices at coastal log-handling facilities. With a goal of achieving No-Net-Loss of fish habitat, log handling practices have included the building of subtidal rocky reef habitat to compensate for natural habitat losses at 24 sites within DFO's (Pacific Region) South Coast Area.

More relevant is a manuscript report by Naito (2001) that provides an overview of artificial reefs for southern BC. He summarized the physical and biological information available, mostly from various letters, memoranda and consultant's reports, for 15 known artificial reefs constructed prior to 1994. Only three of the reefs inventoried were built using vessels for recreational purposes. The majority were constructed of rock riprap, cinder blocks or broken concrete for habitat compensation and/or research experiments.

The most common information source for BC ship reefs are unpublished data recorded in the personal logs and data sheets held by individual recreational SCUBA divers, and provided as a courtesy to the author. Recently some of these data are also reported and archived on the Internet as part of REEF (Reef Environmental Education Foundation) initiatives in the US and Canada. (www.reef.org).

5.0 PAST AND FUTURE OF SHIP REEF DEVELOPMENT

5.1 In British Columbia

Recreational diving and nature viewing has been one goal of artificial reef installations since first attempted in the early 1970s. Of course, wreck diving has been popular for much longer, but many ships were wrecked in waters unsafe and too deep, or the wreck was in poor condition. Over the years, irresponsible divers have also stripped wrecks of objects having heritage value (pers. com. Tex Enemark, Underwater Archaeological Society). Since many divers are challenged by penetration dives, structures of their preference are ship reefs sunk in waters of about 30 metres. This allows adequate exploration time before running low on air. Other divers value the history and heritage of ship wrecks (Walden 2001), thus promoting the scuttling of decommissioned, surplus vessels that have served with recognition in the Canadian military.

There are limited, scattered descriptions of vessels intentionally scuttled as artificial reefs for recreational divers in British Columbia's marine waters. Tables 1 and 2 summarize the basic information available about these vessels including names, displacement, size, sinking dates, locations and water depths. A key source of information was Environment Canada's Ocean Disposal applications on file and derived computer database shown in Table 3. The WebPages of the Artificial Reef Society of British Columbia, other regional and international artificial reef societies, and commercial dive charter companies are useful.

Details are not included here about other known scuttled vessels – such as eight boats that form a protective breakwater at the Pacifica Paper mill in Powell River, a BC ferry in Quathiaski Cove near Campbell River, and the 70 ton wooden fish boat BCP #44 at the Gabriola Ocean Dump Site #113. These vessels were not sunk for recreational diving and fall outside the scope of this report.

Over the past two decades, sixteen vessels have been scuttled as artificial reefs for divers in British Columbia waters. Figure 1 shows their approximate locations. The vessels range in size from a small 5-m log dozer boat to a 134-m navy ship, one of the largest artificial reefs in the world. Together they amount to over 23,000 t of steel, aluminium, wood, cement and other materials disposed in coastal waters, but largely in Georgia Basin. Half of this total tonnage is attributed to the four nearly identical, Mackenzie class navy destroyers that were decommissioned and sold as surplus to one artificial reef developer. The latest and biggest ship to be reefed, again largely under the auspices of this developer, is a decommissioned Liberty ship that singly contributes over 40% of total tonnage.

The Department of National Defence has advertised four other decommissioned navy vessels for sale on Canada's West Coast. These wood hulled vessels are the Bay Class patrol boats HMCS *Miramichi* and HMCS *Chaleur*, the Annopolis Class HMCS *Annopolis* and Minesweeper Auxiliary HMCS *Morseby* (Appendix 2).

The earliest BC record (1980) of artificial reefs designed for divers are two relatively small boats placed in Howe Sound's Porteau Cove Provincial Park, 50 km from Vancouver. Here are found the highest concentration of reefs in any BC area – six vessels totalling 640 t in various stages of deterioration (Figure 2). More detailed development stages of the Porteau Cove reef complex are described later in this section.

Since 1991, six ships have been sunk as diving reefs in the Strait of Georgia, all organized by the Artificial Reef Society of British Columbia (ARSBC), a Canadian non-profit society advancing sport diving through public education and the creation and preservation of artificial reefs (Enemark 1996; Straith and Rogers 1999). BC Parks has also promoted the development of artificial reefs, funding, in part, the sinking of several vessels including the *GB Church* in Princess Margaret Marine Provincial Park. The efforts of the ARSBC and the local communities grew, in part, out of the international realization that historical shipwrecks were being damaged by recreational divers (Harriot *et al.* 1997). To relieve the diving pressure and potential damage on these shipwrecks, but also to create local economic activity (BC Ministry of Regional Development 1989; Nadeau 1995), organizations such as ARSBC, together with local governments and businesses, are striving to create and enhance awareness of premier scuba dive destinations through artificial reef development in British Columbia.

It is not surprising that these popular ship reefs are situated close to the coastal communities of Sidney, Sechelt, Campbell River and Nanaimo, where there is relatively easy and quick access by private boats and diver charters. Canadian Hydrographic Charts 3441, 3458, 3512 and 3539 show the location, depths and buoy markers of each: the steel coastal freighter *GB Church* near Portland Island (Figure 3), the steel destroyer HMCS *Mackenzie* near Rum and Gooch Islands (Figure 3), the steel destroyer HMCS *Columbia* off Maud Island (Figure 4), the steel destroyer HMCS *Chaudiere* near Kunechin Point (Figure 5), the steel destroyer HMCS *Saskachewan* off Snake Island and the steel HMCS *Cape Breton* also off Snake Island (Figure 6; at the time of writing the letter is not shown on the chart). More information about these vessels and their history, as well as photographs of their sinking and divers' narratives, are included in the appendices. Most of this information and the photographs have been compiled from WebPages courtesy of the ARSBC and several commercial charter companies.

Table 1. Locations of intentionally-scuttled vessels in British Columbia

Map No.	Name	Scuttled Date	Latitude	Longitude	Depth ft (m)	Location
Existing Vessels						
1	**M.V. *Cape Spruce*** Wooden naval vessel/ice	1980 February 17	49^{o} 33.60’N	123^{o} 14.00’ W	33(10)	Porteau Cove, Howe Sound, B.C.
2	**M.V. *Fort Langley*** Wooden ferry/liveaboard	1980 September 12	49^{o} 33.60’N	123^{o} 14.00’ W	50 (15)	Porteau Cove, Howe Sound, B.C.
3	**BCP 44** Wooden fishing boat	1986 March 31	49^{o} 08.00’N	123^{o} 32.00’ 1,185 (360)		Gabriola OD#113 Ocean Disposal Site
4	**M.V. *Nakaya*** Wooden minesweeper	1986 August 03	49^{o} 33.60’N	123^{o} 14.00’W	50 (15)	Porteau Cove, Howe Sound, B.C.
5	**M.V. *Centennial III*** Steel dredge tender	1991 November 28	49^{o} 33.60’N	123^{o} 14.00’W	50 (15)	Porteau Cove, Howe Sound, B.C.
6	**Sailboat** Fibrocement hull	1991 November 28	49^{o} 33.60’N	123^{o} 14.00’W	50 (15)	Porteau Cove, Howe Sound, B.C.
7	**M.V. *G.B. Church*** Steel coastal freighter	1991 August 11	48^{o} 43.323’N	123^{o} 21.339’W	90 (27)	Portland Island, Sidney, B.C.
8	**M.V. *Grant Hall*** Steel tug/packer	1992 March 11	49^{o} 33.60’N	123^{o} 14.00’W	33-50 (10-15)	Porteau Cove, Howe Sound, B.C.
9	**Unnamed boat** Steel dozer	1992 (approx.)	49^{o} 09.02’N	124^{o} 47.58’W	50 (15)	Underwood Cove, Port Alberni, B.C.
10	**HMCS *Chaudiere*** Steel navy destroyer	1992 December 5	49^{o} 37.64’’N	124^{o} 48.586’W	80-130 (24-40)	Kunechin Point, Sechelt, B.C.
11	**HMCS *Mackenzie*** Steel navy destroyer	1995 September 16	48^{o} 40.094’N	123^{o} 17.170’W	100 (30)	Rum Isl./Gooch Isl., Sidney, B.C.
12	**HMCS *Columbia*** Steel navy destroyer	1996 June 22	50^{o} 08.031’N	125^{o} 20.150’W	95-117 (29-36)	Maud Island, Campbell River, B.C.
13	**HMCS *Saskatchewan*** Steel navy destroyer	1997 June 14	49^{o} 12.96’N	123^{o} 53.070’W	130 (40)	Snake Island, Nanaimo, B.C.
14	**HMCS *Cape Breton*** Steel Navy Liberty ship	2001 October 20	49^{o} 12.70’N	123^{o} 53.150’W	120 (37)	Snake Island, Nanaimo, B.C.
15	***Yuang Yue* #603/ ”Babe”/"Blue"** Steel trawler/Chinese migrant	2001 July 12	49^{o} 09.02’N	124^{o} 47.58’W	>200 (60)	Underwood Cove, Port Alberni, B.C.
16	**“Rust Bucket”/”Big Red”** Steel trawler/Chinese migrant	2001 July 12	49^{o} 08.98’N	124^{o} 47.52’W	56-110 (17-33)	Underwood Cove, Port Alberni, B.C.
Proposed vessels						
17	***Gui Hai* #467** Steel fish catcher/ freighter/ Chinese migrant	2002	48^{o} 57.33’N	125^{o} 15.39’W	50-70 (15-23)	Canoe Island, Sechart Channel
18	***Heung Ryong* #765** Steel Korean freezer boat/ Chinese migrant	No details available	No details available	No details available	No details available	No details available

Table 2. Sizes and footprints of intentionally-scuttled vessels in British Columbia

Map No.	Name	Displace-ment (tons)	Length ft (m)	Max. Beam ft (m)	Max. Direct Footprint ft^2 (m^2)	Bottom Type
Existing vessels						
1	**M.V. *Cape Spruce*** Wooden naval vessel/ice barge	70	112(34)	66(20)*	7392 (680)	silt and sand, few boulders
2	**M.V. *Fort Langley*** Wooden ferry/liveaboard	34	53(16)	33(10)*	1749 (160)	silt and sand, few boulders
3	**BCP 44** Wooden fishing boat	70	--	--	--	--
4	**M.V. *Nakaya*** Wooden minesweeper	260	134.8 (41)	22.0 (6.7)*	2966 (275)	silt and sand, few boulders
5	**M.V. *Centennial III*** Steel dredge tender	15	34.5 (10.5)	16.4 (5.0)	566 (53)	silt and sand, few boulders
6	**Sailboat** Fibrocement hull	117	49.3 (15)	9.9 (3.0)*	488 (45)	silt and sand, few boulders
7	**M.V. *G.B. Church*** Steel coastal freighter	530	175 (53)	28 (8.5)	4,900 (450)	firm clay, sand-silt layer
8	**M.V. *Grant Hall*** Steel tug/packer	144	92.0 (28)	15.8 (4.8)*	1,454 (134)	silt and sand, few boulders
9	**Unnamed boat** Steel dozer	**--**	15 (4.6)*	10 (3.1)*	150 (14)	sand, gravel, bark mulch cover
10	**HMCS *Chaudiere*** Steel navy destroyer	2,890	366 (111.5)	42 (12.8)	15,400 (1,427)	mud and silt
11	**HMCS *Mackenzie*** Steel navy destroyer	2,890	366 (111.5)	42 (12.8)	15,400 (1,427)	firm clay, silt layer, rock
12	**HMCS *Columbia*** Steel navy destroyer	2,890	366 (111.5)	42 (12.8)	15,400 (1,427)	sand and rock
13	**HMCS *Saskatchewan*** Steel navy destroyer	2,890	366 (111.5)	42 (12.8)	15,400 (1,427)	firm clay, silt layer
14	**HMCS *Cape Breton*** Steel Navy Liberty ship	10,000	442 (134.7)	57 (17.3)	25,194 (2,330)	firm clay, silt layer
15	***YuangYue* #603/ "Babe"/"Blue"** Steel trawler/Chinese migrant	184	128 (39.0)	22.0 (6.7)	2,816 (261)	sand and gravel
16	**"Rust Bucket"/ "Big Red"** Steel trawler/Chinese migrant	165	120 (36.5)	23.6 (7.2)	2,832 (263)	sand and gravel, bark mulch cover
Existing vessels						
17	***Gui Hai* #467** Steel fish catcher/ freighter/ Chinese migrant	292	210.4 (64)	30 (9.1)	6,312 (582)	NA
18	***Heung Ryong* #765** Steel Korean freezer boat/ Chinese migrant	184	128 (39)	22 (6.7)	2,816 (261)	NA
* estimated						

Table 3. Ocean Disposal Database: Vessel Permit and Disposal Activity Information Report (as of Dec 04, 2002)

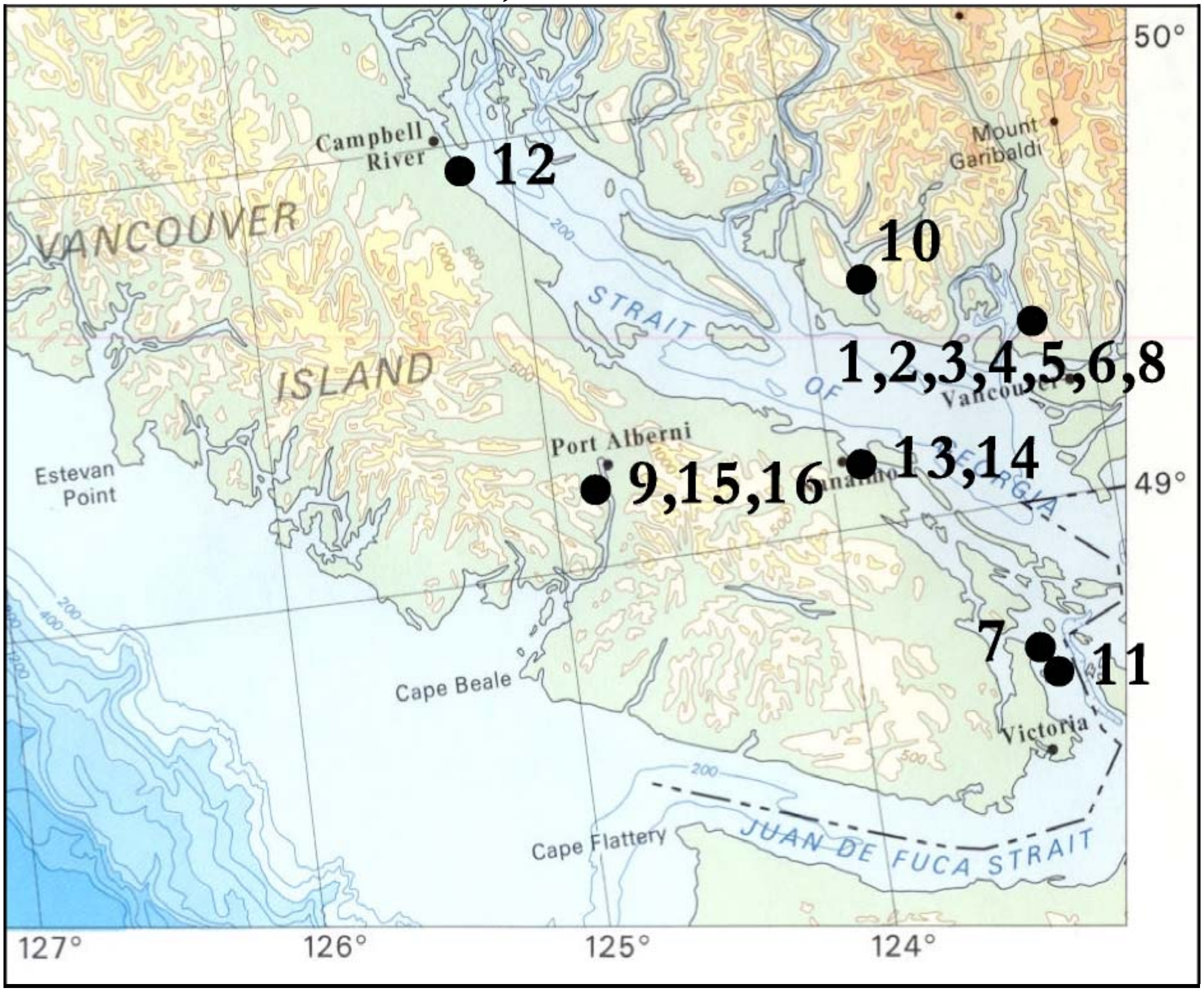
(Contact: Dixon Sullivan - Chief, Ocean Disposal Control Program, Environment Canada, Pacific and Yukon Region)

Permit	Permittee	Status	Comments
3281	ALBERNI REEF SOCIETY – CANOE ISLAND	Tech-Review	Partial application received 06 Mar 01; completed application rec'd 28 Aug 01
3257	ALBERNI REEF SOCIETY-UNDERWOOD COVE	Issued	Application for two migrant vessels in Underwood Cove, Port Alberni, BC; First vessel approx. 160 tons; second vessel approx. 165 tons
3242	ARSBC-HMCS CAPE BRETON	Issued	Co-applicant with Nanaimo Dive Association
3204	KENNETH RAPIN Loadsite: ZEBALLOS	Dump Finish	Disposal site is very near historic Zeballos Disposal Site numbered 82. Date: 07-Jun-98 Quantity:40 tonnes Disposal Zeballos
3173	ARSBC-HMCS SASKATCHEWAN Loadsite: FR-NEW WESTMINSTER QUAY	Dump Finish	Sinking of a vessel by the Artificial Reef Society of BC. Date: 14-Jun-97 Quantity:2400 tonnes Disposal Snake Island
3153	INTERCOAST TOWING Loadsite: FERN PASSAGE	Dump Finish	Sinking of a derelict barge. Date: 15-May-96 Quantity:563 tonnes Disposal Brown Passage
3151	ARSBC-HMCS COLUMBIA Loadsite: VAN IS-CAMPBELL RIVER-MARINA	Dump Finish	Sinking of a vessel by the Artificial Reef Society of BC Date: 22-Jun-96 Quantity:2400 tonnes Disposal Maud Island
3129	ARSBC-HMCS MACKENZIE Loadsite: VAN IS-PAT BAY	Dump Finish	Sinking of a vessel by the Artificial Reef Society of BC Date: 16-Sep-95 Quantity:2400 tonnes Disposal Rum Island-Haro Strait
3071	GOODWIN JOHNSON LTD.	Withdrawn	Application to sink a derelict vessel near Indian Arm. Application was never complete.
3043	BC PARKS Loadsite: HOWE SD-PORTEAU COVE	Dump Finish	Sinking of derelict vessel. Date: 11-Mar-92 Quantity:144 tonnes Disposal Porteau Cove Provincial Park
3035	BC PARKS Loadsite: HOWE SD-PORTEAU COVE	Dump Finish	Sinking of derelict vessel. Date: 01-Dec-91 Quantity:15 tonnes Disposal Porteau Cove Provincial Park
3033	ARSBC-HMCS CHAUDIERE Loadsite: SECHELT INLET-KUNECHIN POINT	Dump Finish	Sinking of a vessel by the Artificial Reef Society of BC Date: 05-Dec-92 Quantity:2370 tonnes Disposal Sechelt Inlet
3021	HELIFOR INDUSTRIES LTD	Withdrawn	Application to dispose of an old barge. Application withdrawn and cheque returned.

Table 3 (cont'd). Ocean Disposal Database, Vessel Permit and Disposal Activity Information Report

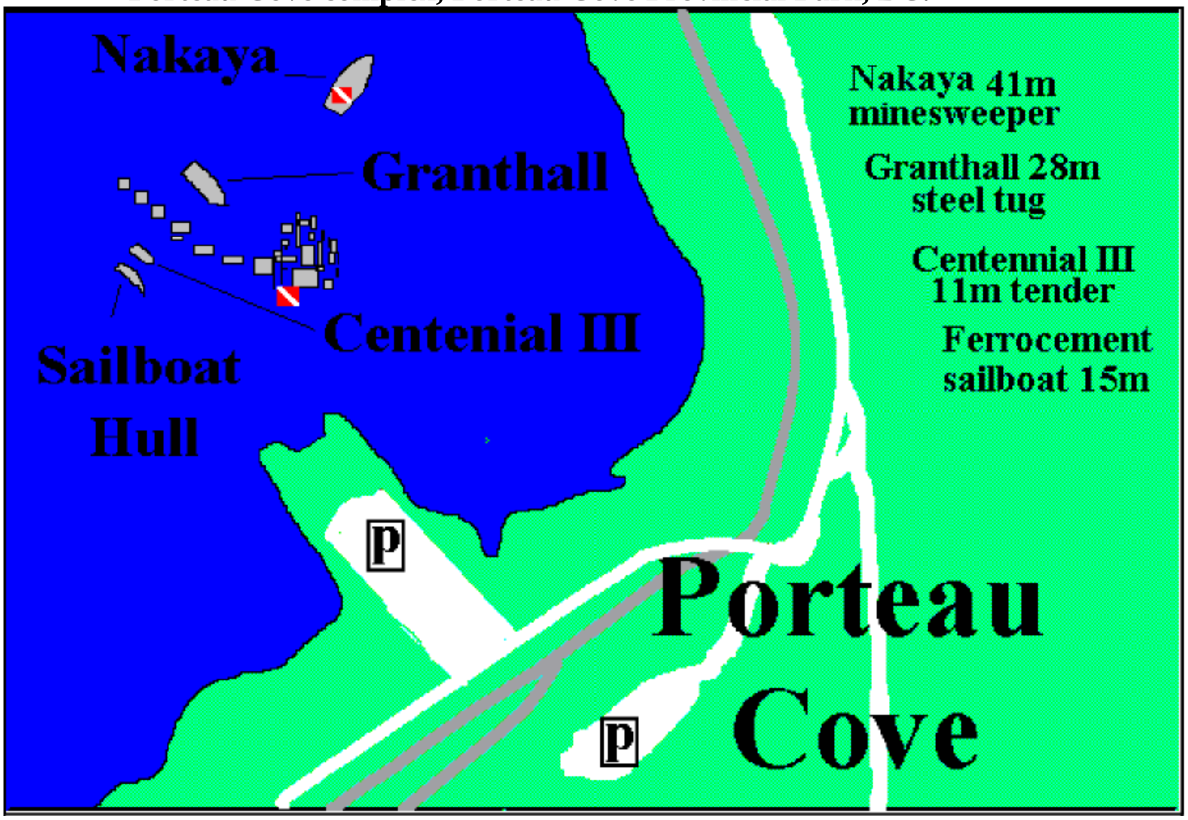
3012	NOEL SHARPE	Withdrawn	Application to raise a burnt, sunk boat and move to deeper location.				
2832	BC PARKS	Dump Finish	Sinking of derelict vessel.				
	Loadsite: FR-DEAS MAINTENANCE YARD		Date:	10-Aug-91	Quantity:500	tonnes Disposal	Princess Margaret Prov Park
2190	SLAVKO TABAKO-VESSEL	Not Used	Vessel broken up and burnt so that ocean dumping was not required.				
2172	TJ SCORETZ-VESSEL	Not Used	Application to sink damaged vessel. Permit was not used.				
2169	GENOA BAY MARINA	Not Used	Application to dispose of derelict CPR wood and steel barge				
1982	BARRY BEZAIRE	Dump Finish	Sinking of derelict vessel.				
	Loadsite: FR-LADNER (VESSEL)		Date:	31-Mar-86	Quantity:70	tonnes Disposal	Gabriola
1871	BC PARKS	Dump Finish	Disposal of the vessel Nakaya.				
	Loadsite: HOWE SD-SQUAMISH (VESSEL)		Date:	02-Aug-86	Quantity:260	tonnes Disposal	Porteau Cove Provincial Park
1846	ROBERT ZIELINSKI	Not Used	Sinking of derelict vessel - Permit was not used.				
1402	MB-KELSEY BAY	Dump Finish	Removal of a WWII steel ship hull previously used as a breakwater.				
	Loadsite: VAN IS-KELSEY BAY-MB		Date:	10-Feb-83	Quantity:40	tonnes Disposal	Johnstone Strait-Hickey Point
1211	BC LANDS, PARKS & HOUSING	Not Used	Sinking of derelict vessel - Permit was not used.				
906	BC LANDS, PARKS & HOUSING	Dump Finish	Sinking of three derelict vessels in Porteau Cove.				
	Loadsite: HOWE SD-PORTEAU COVE		Date:	15-Apr-80	Quantity:117	tonnes Disposal	Porteau Cove Provincial Park
	Loadsite: HOWE SD-PORTEAU COVE		Date:	08-Aug-80	Quantity:34	tonnes Disposal	Porteau Cove Provincial Park
	Loadsite: HOWE SD-PORTEAU COVE		Date:	15-Jul-80	Quantity:70	tonnes Disposal	Porteau Cove Provincial Park

Figure 1. Locations of marine artificial reefs constructed from derelict and surplus vessels in British Columbia, 1980 to 2001.



(Labels refer to Tables 1 and 2)

Figure 2. Locations of the *Granthal, Centennial III, Nakaya* and other artificial reefs in Porteau Cove complex, Porteau Cove Provincial Park, BC.



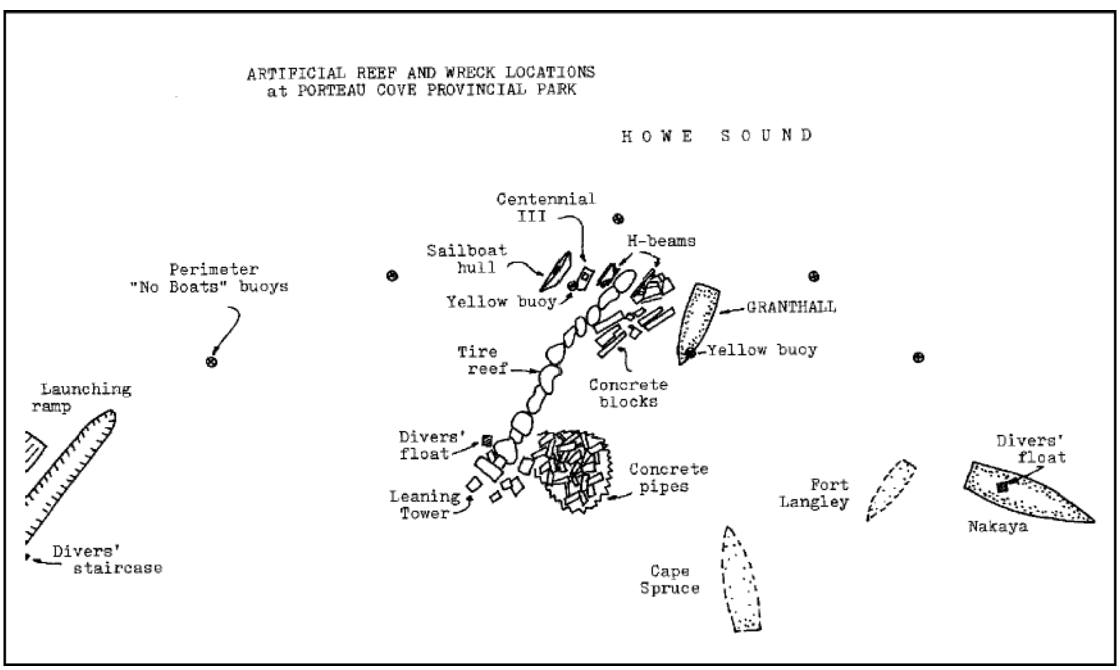


Figure 3. Location of the *Mackenzie* artificial reef off Rum and Gooch Islands, and the *Church* artificial reef off Portland Island, near Sidney, BC.

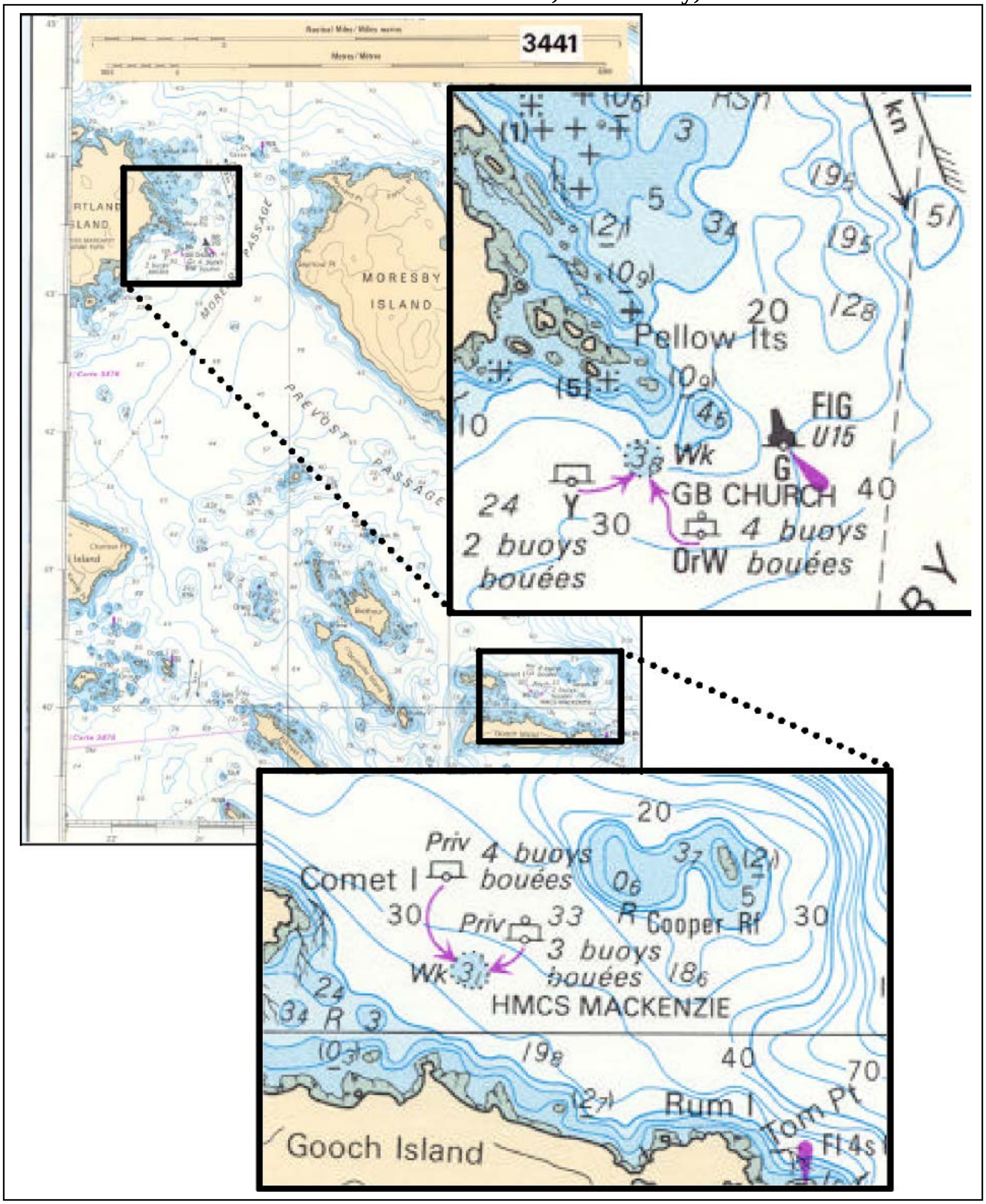


Figure 4. Location of *Columbia* artificial reef off Maud Island near Campbell River, BC.

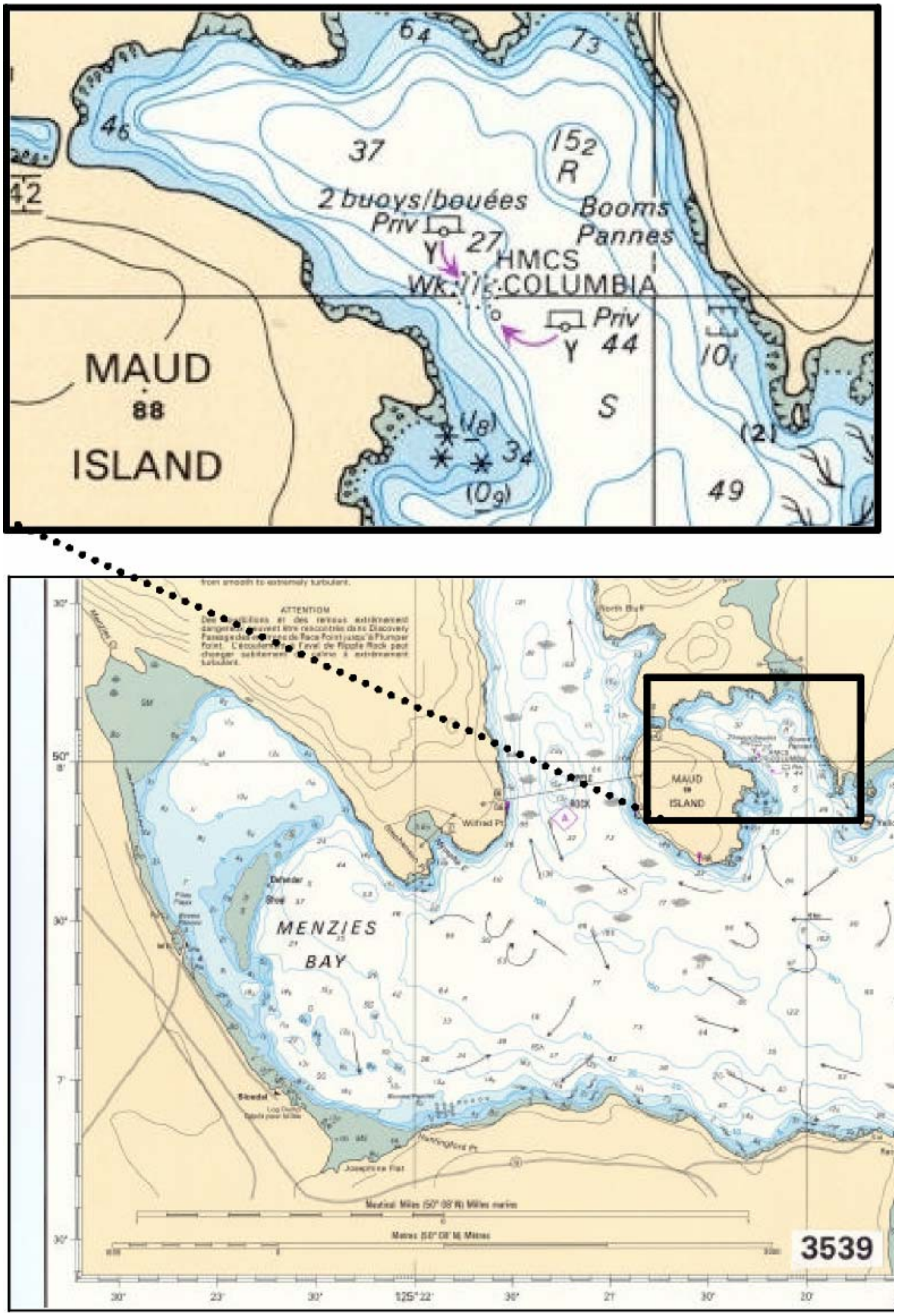


Figure 5. Location of the *Chaudiere* artificial reef off Kunechin Point near Sechelt, BC.

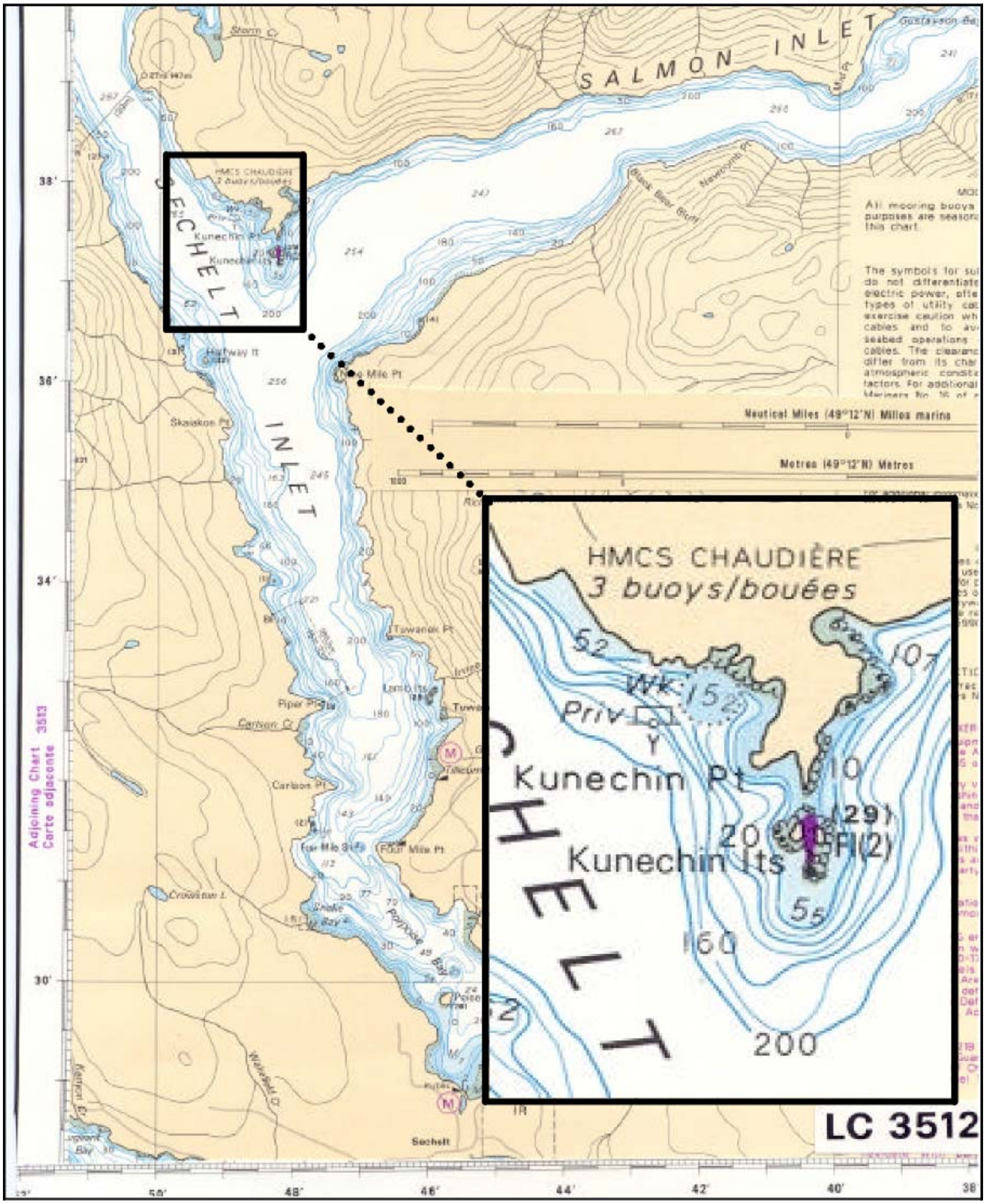


Figure 6. Location of the *Saskatchewan* artificial reef off Snake Island near Nanaimo, BC.

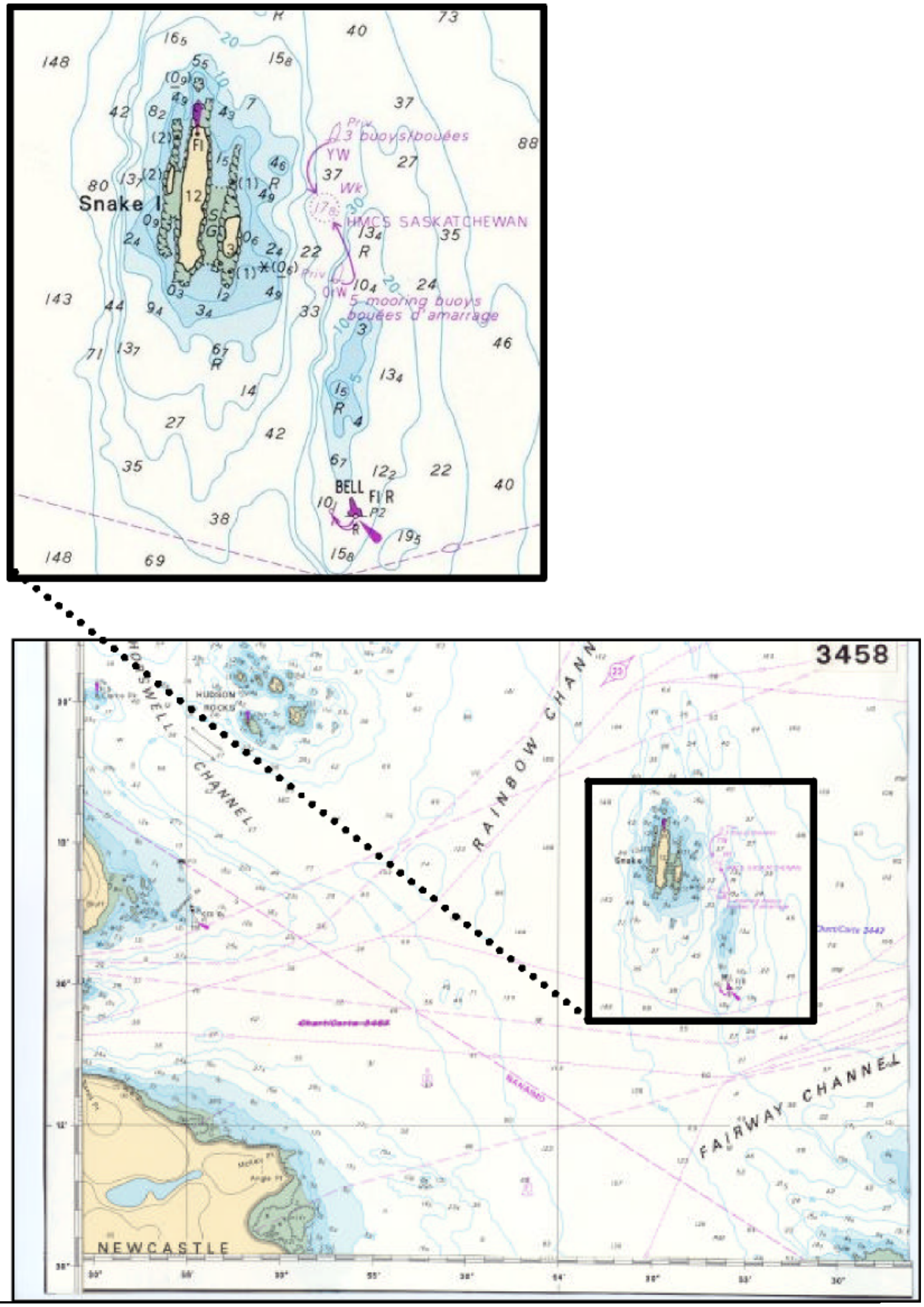
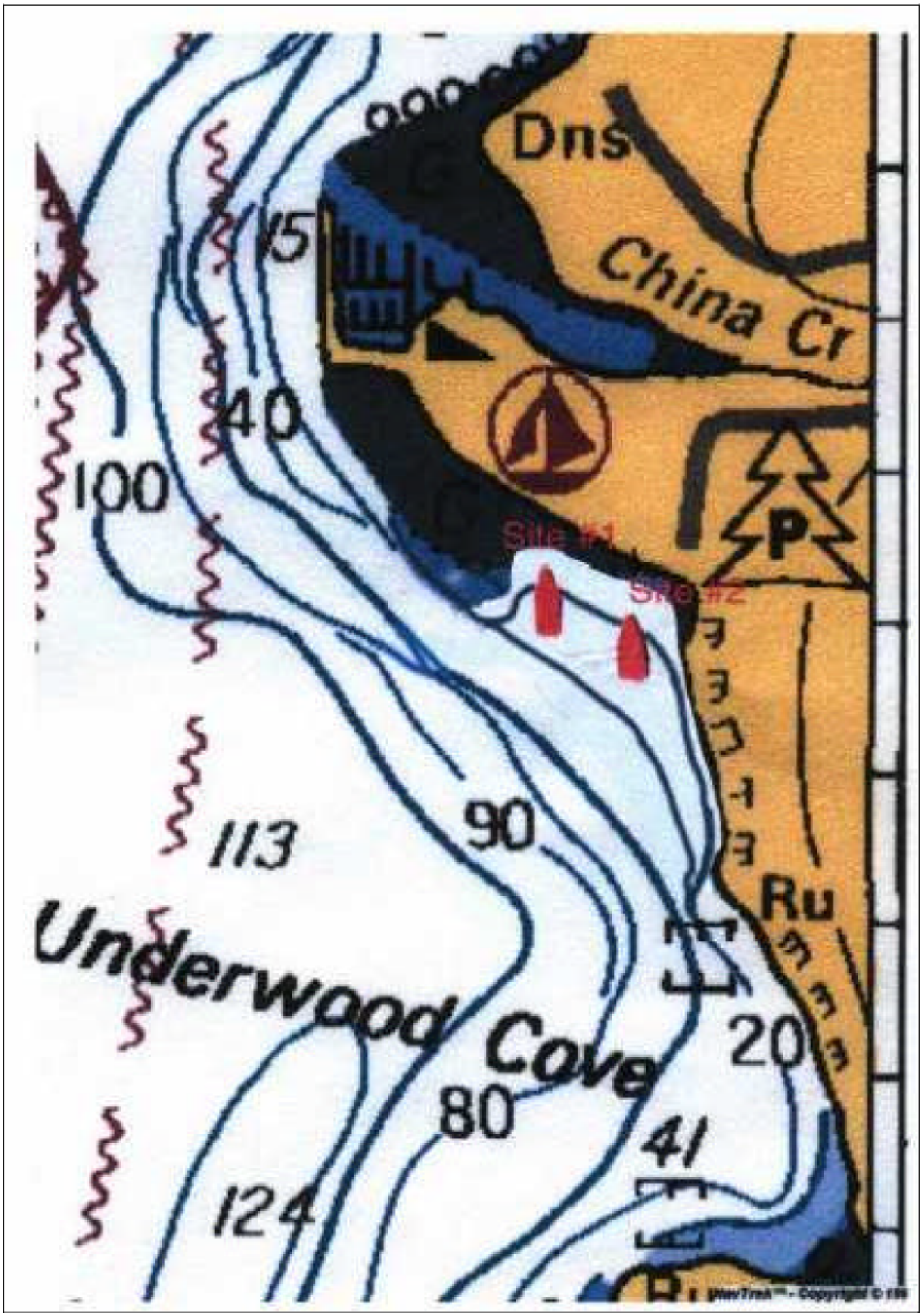


Figure 7. Approximate locations of the Yuang Ye and "Rust Bucket" artificial reefs in Underwood Cove near Port Alberni, BC.



Sinking a vessel for a reef is a difficult and complex challenge for all involved. For example, after acquiring a decommissioned navy ship, hundreds of volunteers under the direction of the ARSBC and other non-profit groups spend at least 75 man-months preparing it for the sinking event. Preparation includes removal of residual hydrocarbons, lubricating oils and other possible contaminants; removal of wire and other objects that potentially could ensnare a diver; closing off access to restricted compartments such as the boiler room; securing or removal of doors; and rendering the vessel safe for divers by opening holes in the exterior so that ambient light is allowed to penetrate the reef about every 20 meters.

Materials that would be hazardous or toxic to marine organisms such as mercury, PCB, hydrocarbons and other liquids including refrigerants are removed from the ship before sinking. This process is guided by the materials listed in the "Hazardous Substance Material Disposal Portfolio" prepared by the Canadian Navy, and directed by the inspection process of Environment Canada pursuant to issuance of an Ocean Disposal permit under the CEPA.

The reef developers also describe and sometimes map the sea bottom at the target site, using dive reconnaissance and video to determine the preferred location of baseline and orientation of the ship within the site. This largely qualitative information is helpful in planning the sinking and placement on the bottom.

To better manage the actual reefing of ships, the ARSBC has scuttled the ex-navy destroyers using high intensity explosives to create entry holes for water to quickly flood and sink the vessels. These holes also serve to allow divers access. The Royal Canadian Military Police Bomb Demolition Unit has volunteered, in the past, to direct these operations, using its divers to place small explosive charges inside the hull of the ship. These charges are set off in a rapid sequence, cutting eight to twelve holes, approximately 1 x 3 m. The objective is to quickly flood the lower parts of the ship as in an attempt to sink the ship upright and on target.

In BC, ship reef sites are usually marked with a buoy system to identify the location of the reef and to facilitate tie-up boat moorings. Over the vessel centre is an isolated danger buoy. Cautionary buoys mark the fore and aft of the reef. Buoys sit on each side of most reefs for ease of mooring by dive charter operators.

An easier and cheaper way to sink a vessel is to open the sea cocks and flood its chambers. The *Chaudiere* was sunk in this manner. However this slower approach is may result in the vessel heeling or listing heavily on the bottom. As well, the vessel may sink 10s or even 100s of meters off target in less than ideal diving depths. When this occurs, the divers' access, orientation and thus safety are compromised. Further, if the vessel sinks in shallower-than-planned water depths, it can pose a hazard to navigation. Over the last five reef developments in BC, the sinking times have decreased dramatically from about 18 minutes for the *Chaudiere* to less than 3 minutes for the *Saskatchewan* and *Cape Breton*. Experience gained has resulted in the latter ships reaching the bottom nearly upright. In contrast, the *Chaudiere* lists about 90^o to port.

Other sinkings by slow flooding have occurred in Alberni Inlet, near the Town of Port Alberni, Vancouver Island. Here the Alberni Reef Society (ARS) planned to sink the 184 and 165 ton steel trawlers/Chinese migrant boats. One is the *Yuang Yue* #603 (known as "Babe" or "Blue") and the other is known locally as"Rust Bucket"(Figure 7). Unfortunately both vessels were scuttled several days prematurely, probably by vandals, while tied together at the jetty in relatively shallow water. A few months later, they were refloated and towed to two sites about 0.5 km apart in Underwood Cove, where each vessels' seacocks were opened sinking them about 150 m from shore near China Creek. The "Rust Bucket" came to rest on the sloping sea bottom in 17- to 25-m of water, but not so the *Yuang Yue*. It ploughed down the slope into deeper water. The vessel is assumed to lie 100s of meters offshore of the target site in approximately 100-m of water, much beyond the limit of most SCUBA divers (pers. com. S. Juthans, ARS). Underwood Cove is also the reef site of a 5 m dozer boat, probably sunk without permits about ten years ago (pers.com S. Juthans, ARS); and possibly a derelict sailboat.

The ARS plans to sink the third of the four purchased migrant boats, the 292-t steel *Gui Hai* #467 further west in Sechart Channel Cove, Barkley Sound. The fourth boat, the 184-t *Hueng Ryong* #765 has been resold by the Society to an undisclosed party (pers. com. S. Juthans, ARS 2002). In addition, the ARSBC and/or another reef developer may seek government approval in 2002 to reef the *Rivtow Lion*, a 150-ft derelict tug seized and sold by the Canadian Coast Guard; competing interests have proposed sites near Vancouver or Nanaimo, the latter possibly in Departure Bay (pers. com. Tex Enemark, ARSBC).

There is a relatively long history of artificial reef system development in Howe Sound near Vancouver. Numerous derelict vessels have been installed in Porteau Cove Provincial Park since the 1960s. The Cove has been, and still is a convenient weekend destination for Vancouver-area dive clubs. Dungeness crab and lingcod were favoured catch of early "frogmen." The following description of the Porteau reef complex was compiled and reported by McDaniel (2001) specifically for inclusion in this report. For this reason, it is quoted here in detail:

> "The artificial reef at Porteau is currently comprised of many different structural elements sited over the past 30 years. Prior to the placement of these structures, the natural bottom at Porteau was characterized by a gradually sloping silt/sand bottom with a few scattered boulders. The abundance and diversity of marine life was limited by the relative lack of stable substrates.
>
> In 1971, local divers constructed the first primitive artificial reef using tires configured in a large necklace made up of over 700 automobile and truck tires. The tires were assembled on shore by tying them together rim to rim with rope, then the entire necklace was dragged out into 10 to 15 metres of water.
>
> In February, 1980, the BC government announced the establishment of a multiple use waterfront park facility providing 50 campsites, a boat launch, picnic area, toilet and changing facilities and a dedicated diving area located just north of the launching ramp.
>
> BC Parks staff, with the assistance of the author, undertook to scuttle a number of derelict ship hulls to provide new sites of interest for recreational divers. Over the next 20 years a number of additions were made to the reef complex as materials of opportunity became available.
>
> On February 17, 1980, the 34-metre wooden-hulled *Cape Spruce* was scuttled at Porteau, the first ship hull to be incorporated into the diving area. This ship was built in

North Carolina in 1942, served as an American naval vessel and ended its days as an ice barge servicing fish boats in the Strait of Georgia. The *Cape Spruce* was scuttled in 10 metres of water, its stern toward shore.

On the same day that the *Cape Spruce* was scuttled, Dillingham Construction dumped a large number of concrete pipe sections, some concrete slabs and a couple of massive concrete columns at the inshore end of the tire reef. One of the six-metrelong concrete columns landed on end with a slight tilt and has been dubbed "The Leaning Tower of Porteau." Its peak actually breaks the surface on very low tides.

On 12 September 1980, the 16-metre woodenhulled *Fort Langley* was scuttled north of the *Cape Spruce* in about 15 metres of water. It was built in Vancouver in 1913 and served as one of the first gasoline-powered passenger ferries on the Fraser River. It was later converted for use as a liveaboard vessel.

On the same day the *Fort Langley* was scuttled, Dillingham Construction dumped about a dozen massive (10- to 45-tonne) slabs of concrete near the offshore end of the tire reef. These large pieces of construction rubble landed in a scattered heap on the bottom in 15 metres of water.

On August 3, 1985, the 41-metre wooden-hulled *Nakaya* was scuttled near the northern edge of the diving area at Porteau. Commissioned as the minesweeper *Cordova*, the vessel was retired in the 1950s and spent its final years as a floating camp.

On March 3, 1990, about half a dozen large steel H-beam frames salvaged from the BC Ferries dock demolition at Horseshoe Bay were sunk near the seaward end of the tire reef, adding a large, threedimensional element to the artificial reef.

On November 28, 1991, the steel dredge tender *Centennial III* was scuttled just south of the seaward end of the H-beam reef in 15 metres of water. The 11-metre *CentennialI* was donated to BC Parks by Fraser River Pile and Dredge. Three large dredge floats also donated by Fraser River Pile and Dredge were also sunk near the inshore end of the tire reef. In addition, a 15-metre ferrocement sailboat hull was scuttled just to the south of the *Centennial III*. The hull was donated to BC Parks by Mr. and Mrs. McCall of West Vancouver. The hull lies on its starboard side in 15 metres of water with its bow facing shoreward.

On March 11, 1992, the 28-metre steel tug *Granthall* was scuttled just to the north of the Concrete Block Reef in 10- to 15-metre depths. The hull was donated to BC Parks early in 1992 and prepared for artificial reef use with the assistance and cooperation of BC Ferries at their Deas Dock facility on the Fraser River.

No further elements have been added to the reef since the scuttling of the *Granthall."*

5.2 Elsewhere in Canada and other countries

To provide context for a better understanding of the scale of BC reef development, the following is a brief but representative selection of the thousands of reefing projects outside of BC.

As a first in Atlantic Canada, the former HMCS *Saguenay*, a decommissioned ISL class destroyer DDH 206 was scuttled as an artificial reef for recreational diving in Lunenburg Marine Park, Nova Scotia on 25 June 1994. Here too, authorization was provided through an Ocean Disposal Permit process led by Environment Canada.

The Lake Ontario Scuba Association is planning to sink the Canadian destroyer HMCS *Nipigon* in 30 m of water about 3 km from Osahwa Harbour. Organizers hope to attract 60,000 divers annually to the site (http://www.sdoceans.org/divetrainingarticle.html). The HMCS *Gatineau* and HMCS *Terra Nova* are currently in Halifax's Canadian Naval shipyards, currently being decommissioned and 'stripped' by the Navy prior to sale by Crown Assets Disposal (Appendix 3)

Two former Canadian Navy destroyers, HCMS *Restigouche* and HCMS *Kootenay*, are presently in Mexico, undergoing cleanup preparations and regulatory approvals for scuttling as sports diving reefs near Acapulco and Puerto Vallarta (http://www.sdoceans.org/divetrainingarticle.html).

Aiming to become a major diving destination, Cuba recently scuttled a 96-m, 1000-t Koni-class frigate costing $200,000 to prepare to meet environmental standards and diving safety. This vessel now lies along side a 40-m patrol boat, an aircraft and a towboat. The next few years will see helicopters, armoured vehicles, tanks and MIG-21s sunk to the seabed. (http://www.divernet.com/wrecks/creation 1298.htm).

In June 2000, a 600-t Mexican Navy ship was sunk in Cozumel's National Marine Park, off Anguilla in the Caribbean. Authorities have sunk nine ships beginning in 1985.

In 1995, the Maltese government sank the 109-m former Libyan tanker *Um El Faroud* after it was torn apart by a drydock explosion. It lies in 35-m depth off the Malta coast. There may be three more ships being readied as diving attractions (http://www.divernet.com/wrecks/creation1298.htm).

The Taiwanese Fishery Administration sank the *Ling-Yun* and another retired supply warship off the Taiwan coast in 2000, launching a program to create artificial reefs in an attempt to conserve fishery resources (www.taipeitimes.com/news/2000).

In Australia, many hundreds of obsolete vessels have been sea dumped or abandoned, as reviewed by Branden *et al.* (1994). Several graveyard sites off Sydney Heads (New South Wales), near Rottnest Island (Western Australia) and near Barwon Heads (Victoria) have been heavily used. Between 1963 and 1984 in Queensland, the Australian Department of Harbours and Marine scuttled 15 vessels as a small craft harbour breakwater in Moreton Bay. Now called the Tangalooma Wrecks, these include dredges, cargo vessels and steamers totalling over 5,000 tons. The first boat scuttled specifically by Australians as an artificial reef was in 1967. Since then, about 62 more have been dumped, largely for recreational divers or to enhance fishing. Two popular locales are the seven vessels at the Hervey Bay artificial reef, and nineteen vessels (plus nine navigation buoys, 5,000 tires, 60 car bodies, 36 steel pontoons and sixty-four tons of concrete) at the Curtin artificial reef. The permits under the

Environment Protection (Sea Dumping) Act 1981 require the vessels to be cleaned and stripped of floatable material. (http://members.ozemail.com.au/ ~petendan/).

In December 1997, HMAS *Swan* was scuttled by the Geography Bay Artificial Reef Society near Cape Naturaliste off Dunsborough, about 255 km south of Perth. An estimated 20,000 spectators both on shore and aboard 300 vessels surrounding the ship watched the sinking that took less than four minutes. The proponents hoped to attract 6,000 divers in the first year, and 4,500 in successive years. Reports indicate that about 20,000 divers visited the *Swan* in the first two years. (http://www.divewreck.co.nz/OldShip.html).

HMAS *Hobart*, was to have been sunk I 2002 as part of the Fleurieu artificial reef near Port Adelaide (www.dive-southaustralia.com/overview/index.html).

In New Zealand, the former Green Peace vessel *Rainbow Warrior*, destroyed by French bombing saboteurs, is one of the most significant artificial reefs installed at Matauri Bay in July 1985 (Divine and Millar, 1999). More recently, The HMNZS *Tui* a 64-m Conrad Class oceanographic research ship was sunk off Tutukaka, Northland, New Zealand in February 1999 by the Tutukaka Coast Promotions Society.

Off the Cayman Islands, the *Keith Tibbets*, a former 100-m patrol vessel, was scuttled with poor preparation and at a poor site by local enthusiasts. Sloping at 18 degrees with its bow hanging 44m over the edge of a 600-m precipice, the vessel was projected in 1999 to fall over the edge within two years.

In the United States, reef development dates back to the 1830s and has grown dramatically in recent years. As of the late 1980s, 572 permitted reef sites were documented in US marine or estuarine waters, largely because of the rapid increase of saltwater anglers and new federal funds to promote reef construction (McGurrin *et al.* 1989). Texas has been involved in artificial reef development for nearly 50 years, using tires, automobiles and construction rubble. In the mid 1970s, twelve Liberty Ships were sunk at five different sites in the Gulf of Mexico. The 1980s decline in oil and gas activity in the Gulf resulted in rigs being scrapped. The Artificial Reef Act of 1989 directed the Parks and Wildlife Department to promote and enhance artificial reefs off Texas.

In Florida, dating back to 1920, more than 1,600 documented public artificial reefs have been placed in state and federal waters (Maher 1999). Most of this development has occurred over the past 20 or so years, with expenditures of nearly $13 million by the State of Florida. Local coastal governments hold all but two of the more than 300 active artificial reef permits off both Florida coasts. Today 30 to 70 artificial reefs are constructed annually at a cost of about $0.7 million. Material types used in 709 publicly funded reefs from 1994 to 2000 were mostly scrap concrete (43%), followed by concrete modules (24%), military equipment mainly armoured tanks (11%), steel vessels and barges (11%), scrap steel (6%), limestone (3%) and other material (2%) (http://floridaconservation.org/whoswho/00/reports/nov00/ reefs.html).

In particular the Florida Key – Shipwreck Alley is a 'trail' of historic shipwrecks including some sunk intentionally as artificial reefs at nine areas along the treacherous coral reefs a few miles off the Florida Keys. The most recent was the sinking of the decommissioned 170-m long U.S. Navy ship *Spiegel Grove*. It was set to be scuttled with explosives in May 2002. However hours before the scheduled time, first stage flooding caused the vessel to prematurely "turn turtle" and to initially settle bow-first in 50-m of water with its stern sticking above the sea surface. About 1-½ hours later, the whole vessel sank and remained upside down. The deployment of tugs and air bladders eventually rolled the ship over, (http://spiegelgrove .info/index.html). Future plans here include the reefing of the USAFS *Gen. Hoyt S. Vandenbery,* at 170-m and 13,000 tons, the largest ship ever intentionally sunk for recreational diving purposes.

In Virginia's coastal waters beginning in the early 1960s, artificial reefs were built by private individuals and fishing clubs. Reef development, however, has been co-ordinated since the 1970s by the Commonwealth of Virginia's Marine Resource Commission. At two offshore sites, the reefs were enhanced by the sinking of Liberty ships. In the Chesapeake Bay area, several reefs are constructed of "material of opportunity" including a scrapped vessel and a dry-dock (Lucy and Barr, 1994).

Closer to BC, the Washington Department of Fisheries has constructed thirteen artificial reefs in Puget Sound since the 1970s. They total over 42,000-m^2 in area, and are intended to enhance recreational fishery harvests. Made of large quarry rock boulders and scrap industrial concrete, these reefs were designed to enhance stocks of bottomfish, primarily rockfish *(Sebastes* spp.). The construction parameters, included siting within 500 m of shore in depths less than 30-m, large overall individual sizes greater than 3,000-m^2, high vertical relief, maximization of crevices and caves, and separated modular piles placed to reduce impacts on existing benthic habitats (West *et al.* 1994).

US Navy and US Maritime Administration have a surplus fleet, comprising of about 350 ships weighing 2.8 million tons stored, some since World War II, awaiting disposal in various river estuaries and embayments. The option of scrapping versus reefing is currently a matter of serious debate in the U.S.. In 2001, the Secretary of the Navy released a study lead by the Rand Corporation, a public policy research institution, that studied ship disposal and evaluated the alternatives – long term storage, recycling and reefing. The conclusion of the study's report (Hess *et al.* 2001) indicated that long-term storage was going to cost $4.9 billion, and scrapping to cost $1.9 billion plus the use of many dry docks needed for repair. Reefing on the other hand, was estimated at $500 million and is seen as an investment, returning that money in taxes within twelve years. Many are thus predicting accelerated reef development using ships along both the US Atlantic and Pacific coasts over the next ten to 20 years.

6.0 EFFECTS ON MARINE FISH, SEA MAMMALS AND THEIR HABITATS

Cripps *et al.* (1999) provides a list of the wide range of physical and biological effects of artificial reefs on local biota and their habitats:

- Changes in epifauna diversity - Hard, elevated substrata is placed in an area where there was formerly none. This habitat will result in the presence of some species not naturally present in the locale, in which soft sediments predominate. The reef also provides a range of habitats throughout the water column allowing different species to remain at their most favoured depth;

- Increase in the epifauna biomass - Compared to the existing muddy/sandy habitat an artificial reef provides a large hard surface area, which encourages abundant bio-fouling and hard bottom species, depending on the configuration and complexity of the reef;
- Changes in sediment fauna - A reef affects the local sediment fauna by altering the surrounding physical environment such as water motion, sediment grain size distribution, organic content of the sediment, altered light and so on;
- Smothering of endemic fauna - The construction of an artificial reef causes some sessile animals to be covered and destroyed by the reef's footprint. In addition, the impact of sinking causes a certain amount of resuspension of bottom sediment;
- Changes in infauna communities - If the reef attracts higher densities of fishes than the surrounding region, the levels of predation of the endemic sediment fauna may increase markedly, as a result of fish foraging in the adjacent sediments. Consequently, benthic organisms would be reduced in abundance and possibly changed in species diversity; and
- Scouring and deposition - The presence of a sizeable structure such as a reef would be expected to change local current flow patterns. This could lead to some areas being scoured and others receiving moved sediment.

The challenge is to assess the spatial and temporal extent of such effects by estimating the reefs' zone of influence both adverse and beneficial, cumulative and synergistic, local and regional. The following sections describe these and a few other effects in more detail, beginning with one not included in the list above -- the acoustic disturbances during reef construction.

6.1 Noise and explosions

As mentioned, the earliest BC reef development such as the scuttling of *GB Church* and *Chaudiere* were rather quiet, sombre events for most observers. The noise of the actual sinkings was largely the roaring, rushing sounds of trapped air forced out as bubbles and spray as the compartments gradually flooded. In recent years, the sinking procedures of large vessels have created considerably more noise and disturbance by using hull explosives and pyrotechnic displays. The pyrotechnics authorized by the developers usually involve a number of explosive blasts on the ship's decks with associated fire and smoke. This is solely for the purpose of creating a more dramatic Hollywood-like spectacle for the hundreds of officials, sponsors, media and the public watching from nearby boats and onshore.

During the recent *Cape Breton* sinking, the author observed and photographed the pyrotechnic display that was judged as relatively large. The spectacle was accomplished by the controlled ignition of about 45-kg of black gunpowder and about 200 litres of jet aviation fuel situated at six or so locations on the decks (pers. com. Mike Lovechio, ARSBC). The heat of the blasts could be felt by those watching from boats 300-m or more away. Even kilometres away, people heard the explosions and/or saw the rising smoke plume (see photographs in Appendix 16). The author and others also noted that the pyrotechnic, immediately at their onset, frightened 200 or more harbour seals *(Phoca vitulina)* that were hauled out less than 300-m away on nearby Snake Island. They stampeded into the water and stayed away for an undetermined period of time.

The explosions can have an adverse affect, not only on fishes, but also on marine mammals such as seals and whales. This technique was employed for sinking the HMCS *Mackenzie*, HMCS *Columbia*, HMCS *Saskatchewan* and HMCS *Cape Breton* in British Columbia (see photographs in Appendix 10, 13 and 16 respectively). Reef developers in Australia sank the *Swan* in this manner, accompanied by a very large pyrotechnic display (Appendix 20). This too was the plan for the HMCS *Yukon* off California, before the readied ship sank on its own, accidentally and prematurely during overnight winds and waves. Typically from ten or more charges, approximately 0.5 lb (0.23 kg) each, of GEOGEL or similar explosives are detonated sequentually, over a period of seconds. Spectators watching from boats positioned 100s of meters away can usually hear muffled explosions and even notice surface water sprayed above the detonation locations. However no actual acoustic measurements of the explosions and their environmental consequences were carried out either underwater or in the air during the sinking of these vessels.

The author, one of the spectators at the *Cape Breton*'s sinking, observed some evidence of detrimental effects immediately upon the ignition of the pyrotechnics and explosives. People in a small boat using dip nets retrieved floating debris – including ten or more dead or stunned fish, probably rockfish, some approximately 50-cm long.

The Environmental Impact Assessment prepared by the City of San Diego (1999) for the sinking of the HMCS *Yukon* states that, although technically considered "blasting", the shaped charges create more of an intensive burn, and do not result in a strong blast or explosive sound. This conclusion was not supported with any published references or actual studies. In the literature, the effects of underwater explosions and shock waves are widely documented for fishes and even marine mammals (Hill 1978; Young 1991; Keewin and Hampton 1997; Wright and Hopky 1998). Underwater shock waves, having extremely high peak pessures and rapid rates of pressure change, can cause severe damage to living organisms. Animals with internal air cavities e.g. fishes with airbladders and seals with lungs, are particularly sensitive, since a form of cavitation will occur explosively near the boundary of tissue and air. Tissues are destroyed and hemorrhaging occurs if capillaries or blood vessels are present, often leading to death. Calculating these probabilities and estimating the organisms' risk and sensitivities involves an interdisciplinary understanding of complicated technologies interacting with complex physics and intricate biology. There exist some 'simple damage' theoretical models that attempt to predict the kill radius or safe distances for different species of different ages and sizes. The calculations must also account for a range of water properties and sea bottom characteritistics involving various types and amounts of explosives that propagate different kinds of underwater shock waves.

Two publications (Hill 1978 and Wright and Hopky 1998) reviewed and/or applied lethal range models, offering helpful illustrative scenarios for representative arctic fish and/or mammal species. Fortunately these illustrations are particularly informative for this report. Readers are encouraged to review these publications for the model descriptions and their assumptions, equations and calculations. Wright and Hopky (1998), using Hill's model, begin with a question: what is the lethal range (assuming 50% mortality) for a 5-kg charge detonated at a water depth of 5 m, in the vicinity of Pacific herring *(Clupea harengus pallasii)* weighing 300 g, feeding on zooplankton at depths shallower than 10 m? Answer: 50% of the herring will be killed outright up to 82 m away; the remaining 50% probably will be sublethally impacted, rendering them more vulnerable to predation and disease. Likewise Hill (1978) posed two questions and provided the calculated results. First, what is the lethal range from a 25-kg charge for 250-gm boreal smelt *(Osmerus eperlanus)* similar in biology to Pacific herring, if the charge is detonated at 3.5 m and the smelt are concentrated at depths shallow than 20m. Answer: 50% of all smelt within 146 m of the explosion will be killed outright. Secondly, what is the safe distance for no harm to ringed seals *(Phoca hispida,* which are similar to harbour seals), from a 5-kg charge detonated at a depth of 5 m, assuming the seals are feeding in depths less than 25 m? Answer: there should be no risk of damage provided the charge is detonated at least 359 m from the seals.

It was considered beyond the scope of this paper to employ these or other models to calculate the lethal range for different fishes or the "no harm" distances for selected mammals during vessel reefing in BC waters. However assuming that the total amount of explosive involved in sinking the *Mackenzie, Saskatchewan* or *Cape Breton* was about 2–3 kg (10-12 charges of 0.23 kg each), the results of the above scenarios using 5 kg explosives for herring and ringed seal may be roughly the same. That is, the heaviest impact zone for fishes, particularly the smaller and more sensitivity species like herring, is probably within 200-m, and for seals about 400-m.

Most researchers including Hill (1978), and Wright and Hopky (1998) warn that their models can under-estimate lethal ranges and safe distances if, for example, the water depth is less than five times the detonation or the target depths, or the bottom is hard substrate. In the latter case, there may be a considerable bottom-reflected shock wave, which will increase the damaging impulses at any point. For these reasons, Hill (1978) recommends that the calculated lethal ranges or safe distance be doubled to ensure a conservation safety margin. This conservative approach may also be wise for future ship reefing that employ explosives, even recognizing that the shock wave zones are probably reduced by the mitigating procedure of placing the explosives inside the ship's hull and by not igniting them simultaneously.

6.2 Benthic smothering

Probably the most obvious and common detrimental effect of deploying any artificial marine reef is its direct smothering of the seabed and any natural biota directly beneath its construction materials – or "footprint". This smothering profoundly alters the bottom substrate and near bottom environment. This is especially true when a relatively large, heavy piece of steel like an ex-navy ship with steep vertical relief and high profile is dropped to the seabottom. Much of this habitat alteration is sudden. For example, divers describe the bow of the *Columbia* to be "crumpled like an accordion," presumably from its fall as a 2,900 ton object hitting a predominantly rock bottom.

Although the reef's footprint is localized, the modification of bottom type and relief is long term, persisting for many decades even as the vessel corrodes and deteriorates. The life span of a shipwreck ranges from 50 to 100 years, depending on its construction, preparation, depth, surrounding ocean and other conditions. Quigel and Thornton (1989) estimated a life of almost three centuries for the 3,175-mt oil production rig toppled as a reef off Louisiana in the Gulf of Mexico, using an average corrosion rate of steel immersed in saltwater. In BC waters, McDaniel (1993) reports that, after 44 years, the 37-m steel hull of the HMCS *Thiepval* that sank accidentally in 15-m deep waters off Barkley Sound is still in relatively good condition and has collapsed only at the stern where explosives were used to remove the propeller. Likewise the 37-m steel hull of the *Capilano I* wrecked on Grant Reefs is still intact, having rested in 40 m of water for nearly 80 years.

For purposes of perspective and scale, the direct footprint has been calculated here for the 16 known, purposely-scuttled ships in BC waters, simply by multiplying each ship's length by its beam (Table 1). These calculations are maximal values because of the "typical" boat shape. Furthermore, the full hull length of some vessels is not in direct contact with the bottom. For example, because of the vessel's orientation, the bow section of the *Chaudiere* hangs suspended above a rock ledge.

Added together, the existing direct footprint of the ship reefs in BC today amounts to less than 10,415-m^2 (112,106 ft^2) -- or 1.04-ha (2.57 acres) -- or 0.010-km^2 (0.004 mi^2). If and when the next two Chinese migrant vessels are reefed, the direct cumulative footprint on the seabottom will be an additional 848-m^2 (9,128 ft^2) -- or 0.09-ha (0.21 acres)

This estimated footprint value for BC waters is relatively small, by up to an order of magnitude when compared to other regions where reef structures are promoted, such as for fish production along the Atlantic coast of New Jersey. Here, between 1984 and 2000, the total cumulative footprint of sunken vessels, mostly military surplus, deployed as artificial reefs is estimated at nearly 399,000-yd^2 (333,614-m^2) -- or 82.5-acres (33.4 ha) (DFO National Artificial Reef Workshop, 2000). As mentioned earlier, Washington State has approved the construction of artificial reefs in Puget Sound that amounts to over 42,000-m^2 -- or 4.2-ha (10.4 acres).

Few studies have investigated the effects of artificial reefs on the biota immediately beneath the structures, simply because of the logistical impracticalities of sampling. However Hueckel *et al.* (1989) were able to look under two Puget Sound artificial reefs, one near Seattle covering cobble substrate, and the other smothering sandy mud off Tacoma. They used airbags to lift some of the cement slabs used to construct these reefs about six years earlier, and then sampled the infauna using a corer under and near the footprints. Not surprisingly the densities of infaunal organisms were 3 to 15 times less under the reef material, as compared to densities one meter away on the sand and cobble bottoms respectively. Average density decreased from 7,565/m^2 to 504/m^2 on the cobble bottom, and 1,675/m^2 to 570/m^2 on the sandy mud. The species diversity showed similar significant trends.

6.3 Altered currents and bottom scouring

When the physical dimensions of a large artificial reef, such as a sunken vessel, are similar to the water depths, the reef can be expected to alter local water circulation and sediment transport. The Japan Coastal Fisheries Promotion Association (JCFPA 1986), cited by Seaman (2000), reported that turbulence reaches 80% of the water column when the reef is only 10% of the water depth. Such is the case for the high vertically profiled Mackenzie class destroyers. For example, the *Saskatchewan* has its keel, its aft mortar bay, its fore and aft decks, its top-of-guns, its bridge and its radar platform at 43m, 35m, 32m, 28m, 22m and 15m water depths respectively (http://www.oceanexplorersdiving.com/hmcsask.html). For this, and probably the other three ex-navy destroyers, some protruding parts of their structures such as tunnels and masts occupy over 65% of the above-ship water column. One can assume that the turbulence caused by currents passing by these ship reefs extends throughout the water column.

Certain water circulation changes have been speculated as beneficial by Seaman (2000). For example, on a vessel's lee, there may be a large wake region with eddies and vortices that may shelter fish. Turbulence at the wake's edge, as well as the upwelled currents carrying sediments and nutrients may benefit some pelagic fishes and invertebrates. But the evidence is limited. Lindquist and Pietrafesa (1989) measured currents and observed fish around a 27-m tugboat wreck off the Atlantic coast of a North Carolina bay. They found that, although the wreck generated wide elliptically shaped eddies on the downstream side and even some eddies on the upstream, benthic reef species did not demonstrate any particular orientation to these current fields. Only the semi-pelagic round scad, *Decapterus punctatus,* tended to aggregate in tighter schools on the up current side of the tug.

In another study off Florida, Baynes and Szmant (1989) investigated the effect of water flow and sedimentation on the live cover and species diversity of a sessile benthic community that encrusted a 43-m long shipwreck in 20-m deep waters. The ocean currents, typically northerly at 10-20 cm/sec, flowed past the long axis of the reef at an incident angle of about 35^{o}. This made the bow and stern subject to higher velocity flows and subsequently lower sedimentation than those of the a midship region. The investigators found that these regions generally had higher cover, greater species richness and more diversity of sessile macro-invertebrates and algae, as compared to those of amidships. They speculated that many of the filter-feeding, sessile organisms such as porifera sponges benefited from strong water circulation and were likely stressed by sediments. The deck exhibited less cover and a lower species diversity than the sides of the ship, likely due weaker currents and higher sediment loads. However, more directed studies are needed before concluding with confidence a relationship between flow-reef-sediment interactions and habitat enhancement (Seaman 2000).

Current forces caused by tides, winds, swells, tsunamis and densities can combine to produce stress on the seafloor and in turn on the reef structure. For the artificial reef to be successful the bottom sediments must be able to support the reef structure weight under such varying hydrodynamic conditions. Thus in BC coastal areas such as Vancouver Island's Alberni Inlet (where the Chinese migrant ships were recently reefed), hydro-dynamic conditions should be considered when approving future reef sites, given the area's high earthquake hazard, tidal wave history and relatively soft substrates.

If ocean currents are significant, sediments can be scoured around the reef bottom and partly transported into the water column and onto the reef's lee side (Seaman 2000). Off the Taiwan coast, bathymetric changes due to current scouring are evident around three vessel reefs sunk on soft sediments in about 30-m water depths. The impacted zone of sediment erosion and accretion (shown as dark and light "halos" in Figure 8) extends up to 10-m or more away from the vessels, depending on the reefs orientation to the prevailing currents (Shyue and Yang, 1999). These hydraulic processes appear to have increased the vessels' footprint area by one-half to two times.

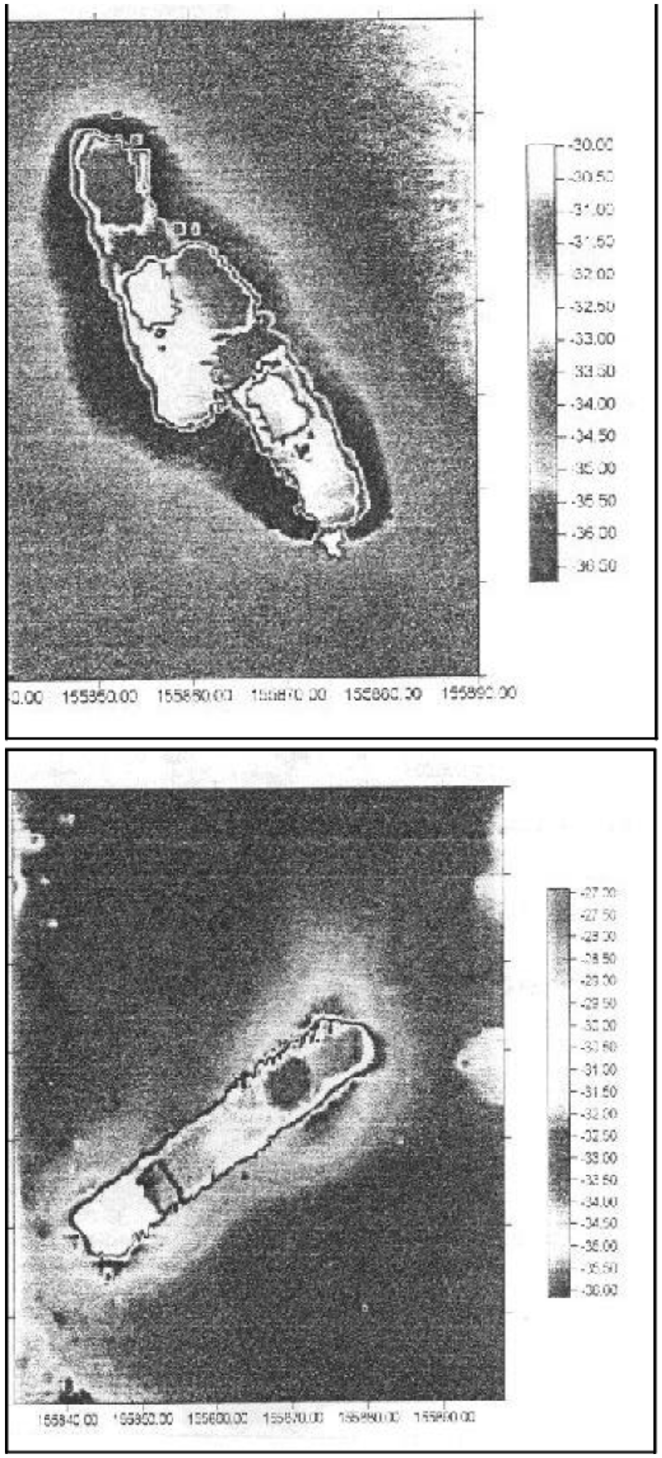
Davis *et al.* (1982) examined the effect of quarry boulder reefs and offshore oil-production platforms on natural sand bottoms off La Jolla, California in 13- to 30-m water depths. They found that discernible physical effects of the artificial reefs were confined to a small area. There were shallow scours of 20- to 40-cm depth as far as 15-m from some reefs. Beyond these scoured areas, there was no measurable effect on sand ripple patterns, grain size or organic content.

Along the south shore of Nova Scotia, the Geological Survey of Canada surveyed the relatively flat-bottomed seabed of Lunenburg Bay, where the HMCS *Saguenay* was sunk as a reef in 1994. The ship rests in about 22-m water depth surrounded by gravel sediments (Figure 9). There is a small patch of sand at the stern, thought to be the result of sediment transport associated with the vessel's position on the seabed. There are, however, no other strong indicators of current induced features such as erosional scour.

There is some evidence of physical habitat alteration beyond the immediate footprint of the HMCS Saskatchewan artificial reef off coastal British Columbia. The Canadian Hydrographic Service produced some preliminary bathymetric 2-D and 3-D representations of the vessel and surrounding seabottom, based on multibeam echo soundings taken in 1999 (Figure 10). Preliminary examination of the bathymetric map, showing one metre contours, shows some indication of sediment deposition on the west (left) of amidships, as depicted by the interruption of the 34-m contour. Likewise to the east (right) of the vessel, deposition may explain the apparent re-alignment of the 36-m and the 37-m depth contours by a distances of from 10 to 20 metres. However these observations are qualitative and require further study.

Based on limited studies in Taiwan, British Columbia, and Nova Scotia it is suggested that the total areal extent of a ship reef footprint on the sea bottom can be two to three times larger than that of the area directly beneath its structure. Using this multiplier for all BC ship reefs, the total bottom footprint of both direct and indirect physical effects is roughly 2 to 3 hectares (5 to 7.5 acres).

Figure 8. Bathymetric changes due to scouring, sand ripples and waves around scuttled ships along Taiwan Coast



(taken from Shyue and Yang, 1999)

Figure 9. Sidescan sonar mosaic of the HCMS *Saguenay*, a decommissioned ISL class destroyer, reefed in Lunenburg Marine Park, Nova Scotia

(source:http://agcwww.bio.ns.ca/pubprod/of3257/html_bm1326/bm132609sagu.html)

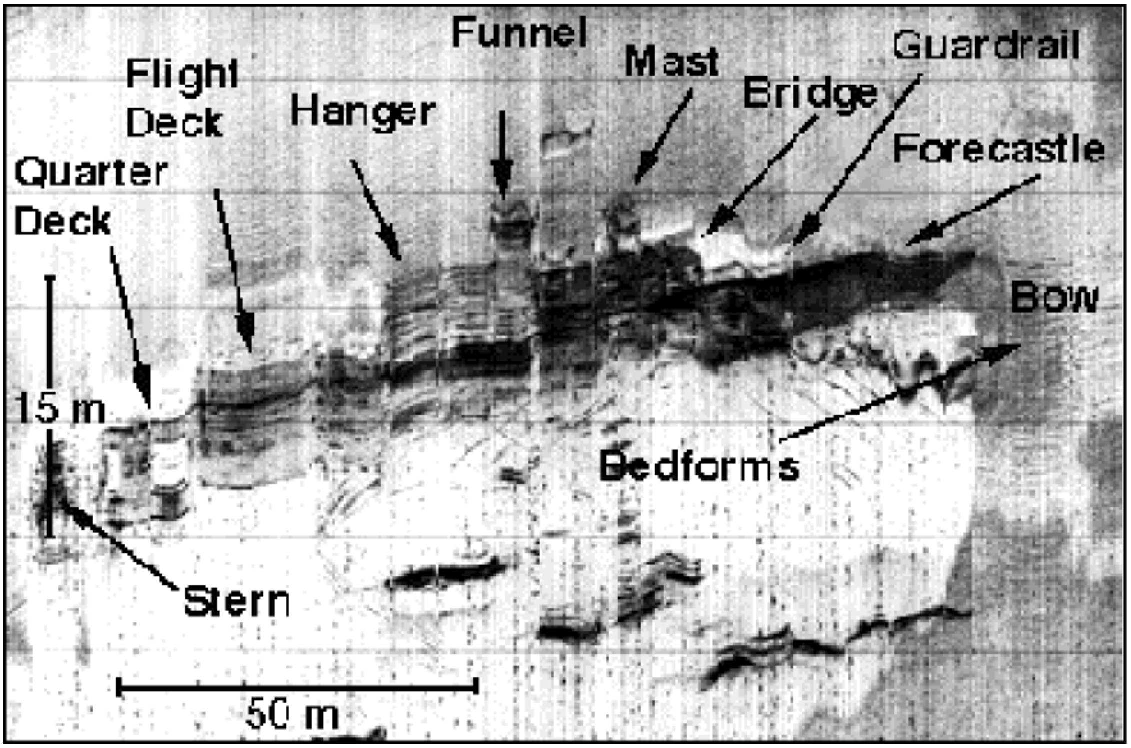
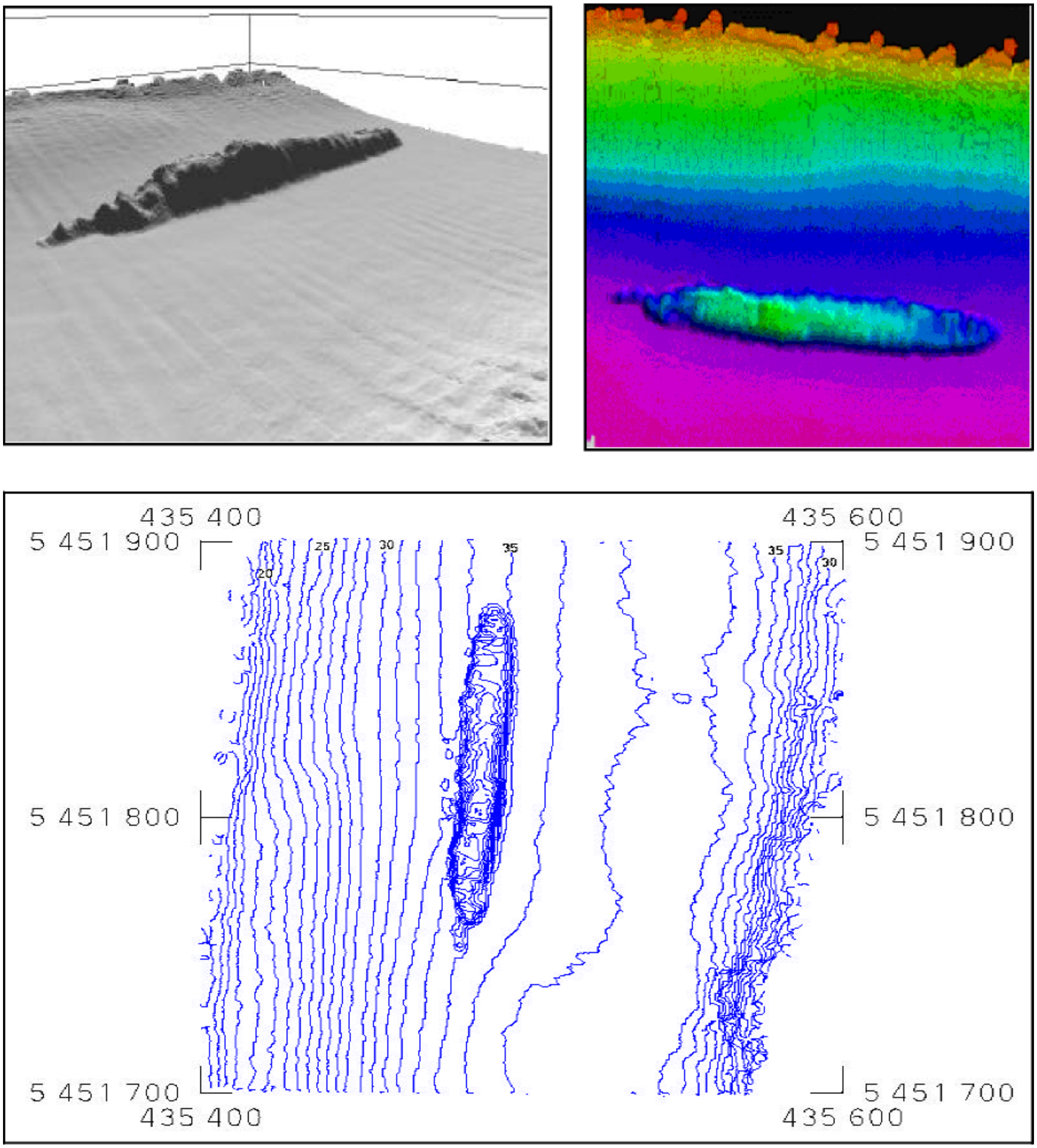


Figure 10. Multibeam bathymetric images of the *Saskatchewan* artificial reef located off Snake Island near Nanaimo, BC



(Courtesy of the Canadian Hydrographic Service, Sidney, BC).

6.4 Fish aggregation and species diversity

Artificial reefs have long been popular with the recreational diving community because divers believe they "enhance the biology" or "produce more fish" at locations where few or none had previously been observed. The ability of artificial reefs such as sunken ships to attract fish from adjacent areas is well established in the literature, but the extent to which the reefs actually produce fish, that is actually increase the greater area's fish biomass, is not clear.

There is conflicting information as to whether or not the deployment of man-made structures such as artificial reefs result in substantial, and possibly undesirable, changes in proximate fish communities. Some artificial reefs studied in Florida (Stone *et al.* 1979), Australia (Talbot *et al.* 1978) and the US Virgin Islands (Randall 1963) did not significantly alter the fish communities of nearby natural reefs; most of the fishes recruited to the artificial reef were juveniles. Other studies however, in California (Matthews 1985), Puerto Rico (Fast and Pagan 1974) and Florida (Alevizon *et al.* 1985) showed the artificial reefs were populated by adult fishes immigating from nearby natural reefs.

Many published studies have reported large numbers of many fish species at the artificial reef shortly after its construction. In fact, many artificial reefs are constructed intentionally as Fish Attracting Devices or FADs, using simple materials such as pipes with little structural complexity. For these, there is little argument the large numbers of fish associated with the reefs were not the result of increased fish production. Most studies reviewed by Bohnsack *et al.* (1991, 1997) conclude that the high density of fish common at a new artificial reef is due largely to attraction and aggregation; recreational divers tend to agree.

Several reasons are given in the literature to explain why artificial reefs generally attract fish. The reefs are usually constructed on low relief, sand and/or mud bottoms. This provides physical structure that fish find attractive for visual orientation or for shelter from predators. As noted earlier (p. 29), the high reliefs of many artificial reefs above the seabottom cause currents and waves passing over them to accelerate, hereby reducing sedimentation rates on the reef. In turn, this enhances the habitat for filter feeding invertebrates that are fish and other invertebrate (tunicates, sponges, tubeworms, and bivalves) forage.

Biologists such as Carr and Hixon (1997) argue that the best way to address the "attraction or production" question is to compare fish assemblages and their prey associated with both natural and artificial reefs, ideally using studies that employ before-and-after construction observations. Attraction is a relatively simple concept, defined as the net movement of individual fish from natural to artificial habitats. Nevertheless, this can be difficult to study logistically, even when fish tagging techniques are employed. In contrast, production is both a more complicated concept and more difficult to quantify. Defined as a change over time in biomass derived from the number and weight of individuals, production involves measuring births, growth, deaths, immigration and emigration. Adding to this complexity is the need to delineate the scale from local to regional.

6.4.1 International evidence

Bohnsack and Sutherland (1985) provide one of the earliest reviews of research on the effectiveness of artificial reefs to enhance fish production, including studies comparing the biology of natural reefs with artificial ones. They describe how many investigators in both tropical and temperate waters have found similarities in the assemblages of fishes, as well as higher densities of fish, on natural and artificial reefs, the latter constructed of tires, quarry rock, concrete blocks, rubble, pipes or boats. In southeastern Florida, Bohnsack *et al.* (1994) found artificial reefs to support 127 fish species and over 100,000 individuals compared to 93 species and about 16,000 individuals on nearby natural reefs, and only 17 species and about 1,000 individuals on the adjacent sand bottom. They also observed that colonization of artificial reefs was relatively rapid with high numbers of species and individuals occurring within the first two months.

In southern California waters, this was true for several studies (Stephens *et al.* 1984; Jessee *et al.*, 1985; DeMartinin *et al.,* 1989; Ambrose and Swarbrick, 1989) of the more than twenty five artificial reefs constructed since the late 1950's. The study by Ambrose and Swarbrick (1989) is particularly informative because of its relatively extensive comparison and evaluation of fish assemblages on ten of these artificial reefs including breakwaters (mean size of 2.66 ha) and 16 natural reefs (mean size 185 ha) in 9- to 24-m water depths between Santa Barbara and San Diego. Based on diver transect and video observations, forty-one species of fish were sampled on both the natural and artificial reefs. Artificial reefs had significantly more benthic fish species (mean species richness of 15.3 versus 10.9 for natural reefs), a greater density of benthic fishes (mean of 425 fishes per 1,000-m^3 versus 185/1000 m^3 on natural reefs) and a greater biomass of benthic fishes (mean of 30-kg/1,000 m^3 versus 22-kg/1,000 m^3 for natural reefs). For pelagic fish, there were no differences in species richness, diversity, density and biomass between the artificial and natural reefs.

In contrast, there are other studies in California (Matthews 1985) and elsewhere [Virgin Islands (Randall 1963), off Puerto Rico (Fast and Pagan 1974), in the Gulf of Mexico off Florida (Smith *et al.* 1979), in the Bahamas (Alevizon *et al.* 1985), and in a marine-dominated estuary off New South Wales in Australia (Burchmore *et al.* 1985)] that reported equal or higher species richness on natural reefs, when compared to artificial reefs.

Matthews (1985) examined the similarity of a new artificial reef off California with neighbouring natural reefs, by determining movements of tagged fishes between them. The Capitola artificial reef consisted of concrete pipes covering 1,200-m^2 of sand-covered mudstone in 14-m water depth. The four natural rocky reefs investigated were 3 to 166 times larger in size, located 0.8-1.6 km away in waters 10–30 m deep. The fish assemblage on the artificial reef after less than one year was similar to that of the natural reefs combined, suggesting that there was fish movement from all the local reefs. Most of these colonizers were adult and subadults. In six of the eight seasons studied, the artificial reef supported higher fish densities, up to three times the numbers observed on the natural reefs. The three dominant species were blue rockfish *(Sebastes mystinus),* olive rockfish *(S. serranoides)* and white surfperch *(Phanerodon furcatus).* As a result of tagging eleven species of rockfish, lingcod *(Ophiodon elongatus)* and kelp greenling *(Hexagrammus decagrammus)* on natural reefs, nearly 80% of the tagged fish were recaptured on the artificial reefs. Only 20% were recaptured up to 200 days later on their tagged reef. Over 10% of the fishes tagged on reefs located up to 1.5-km away eventually moved to the artificial reef. Using measures of fish density and reef size, Matthews estimated that these immigrants represented almost 50% of the total artificial reef population. In another tagging study here by Solonsky (1985), all fish marked on the artificial reefs were recaptured there, indicating little or no movement once fishes moved to the artificial reef. Both investigators concluded that, at least for months after construction, artificial reefs do not increase fish biomass, but merely attract biomass from natural reef populations, up to 2-km away depending on the fish species, their foraging behaviour, and suitability of the artificial reef.

The work by Turner *et al.* (1969) in California waters and Grove and Sonu (1983) in Japan, as cited by Jessee *et al.* (1985) recommended that artificial reefs be placed no closer than 0.6 km from natural rock habitats, if the goal is to attract and hold independent fish assemblages. Research in the Florida Keys (Stone *et al.* 1979) concluded that, if the goal of the artificial reef is to replace or enlarge portions of natural communities, then siting the reefs within 50-m of existing natural habitats may enhance recruitment of algae, invertebrates and fish to the artificial reefs.

In the cold temperate waters of Puget Sound, Washington, considerable research on artificial reefs has been carried out [Walton (1979), Grant *et al.* (1982), Laufle (1982), Buckley and Hueckel (1985), Hueckel *et al.* (1989) and Buckley (1997)]. Since Puget Sound and the Strait of Georgia (where most BC ship reefs are located) form a contiguous inland sea, these American findings are more applicable than the results from reefs studied elsewhere. All of these investigators concluded that early colonizing fish species were most likely itinerant in the surrounding environment. The fish initially aggregated on the artificial reef for orientation and protective habitat, rather than the reef serving as an immediate food source.

The study by Hueckel *et al.* (1989) is particularly relevant, having examined the density of economically important fishes on an artificial reef constructed of 14 piles of quarry rock covering a total of 8,610 m^2 of sand bottom near Seattle, Washington. After eight months of submergence, the reef had an average density of 344.3 fish/100 m^2, as compared to 5.1 fish/100 m^2 at a sandy bottom reference site. And few of these species were the same; they were largely surfperch, rockfish, lingcod and cabezon *(Scorpaenichthys marmoratus)* on the reef, and only soles and flounders on the sandy bottom. As further comparison with the artificial reef, the investigators also sampled a nearby natural rocky bottom site; here the average density was about 10.5 fish/100 m^2 or about 30 fold less than the artificial habitat.

Studying other artificial sportfishing reefs in Puget Sound, Laufle and Pauley (1985) found that the reefs made of concrete rubble and rubber tires supported larger fish populations than the adjacent open natural areas of sand/cobble substrate and kelp beds *(Nereocystis luetkenana).* Especially in fall and winter, both densities and biomass were usually higher for embiotocids (surfperches), scorpaenids (rockfishes), hexagrammids (greenlings) and cottids (sculpins). Schools of young striped seaperch *(Embiotoca lateralis)* and pile perch *(Rhacodchilus vacca)* often were observed above the reef in fall and winter, and young rockfish of 3 – 5 cm appeared in the spring. Egg masses of lingcod were frequently found on artificial reefs at 16- to 17-m depths, and sometimes as deep as 29-m.

A monitoring study in Puget Sound was conducted by Buckley and Hueckel (1985) at the Gedney Island artificial reef, a complex of fabricated cement materials in about 15-m water depth on flat, compact sand substrate. Observing the successional development of biota over several years, they recorded the colonization and utilization of the reef by filamentous diatoms, 18 other algae species, 39 invertebrates species and 8 recreationally important fishes. The diversity of algae and invertebrate species, dominated in highest densities by cancer crab *(Cancer oregonensis)* and coonstriped shrimp *(Pandalus danae)*, increased dramatically during the first 6 months. This was attributed to the predation of the pioneering, space-dominating barnacles *(Balanus crenatus* and *B. glandula)* by mottled seastar *(Evasterias troschelii)* and the barnacle-eating dorid nudibranch *(Onchidoris bilamellata)*. By far, the most abundant fishes colonizing the artificial reef were three embiotocid species that tend to congregate over reefs -- shiner perch *(Cymatogaster aggregata)*, striped seaperch *(Embiotoca lateralis)* and pile perch, although their numbers widely fluctuated seasonally. The five sedentary fish species that usually inhabit reef crevices were observed in numbers ten-fold less: copper rockfish *(Sebastes caurinus)*, quillback rockfish *(S. maliger)*, brown rockfish *(S. auriclatus)*, cabezon and lingcod. Nevertheless most of these fish species rapidly colonized the new reef in substantial numbers within one to three months. Lingcod males, in low densities, established spawning territories and protected egg masses.

The average densities of the fish species selectively studied by Buckley and Hueckel (1985) on the Gedney reef were considerably greater than those of the same and comparative species reported by Moulton (1977) on productive natural rocky reef habitat in the nearby San Juan Island area. For example, the mostly juvenile embiotocids averaged 5.4 fish/m^2 on the Gedney reef, in contrast to about 0.03 fish/m^2 on the natural reefs. Buckley and Hueckel speculated that the development of such large densities of reef fishes was likely due to the "oasis"- or "home base"- effect of the artificial reef in the otherwise open, featureless sand habitat. The embiotocids were probably utilizing the artificial reef for protective habitat and orientation, while ranging and feeding at night in the surrounding sand environment.

Reviewing the Japanese literature, Grove *et al.* (1989) report that the effective range of an artificial reef, that is the boundary of fish aggregation measured from the edge of a reef, is about 200-m for most soft bottom dwelling species, even as much as about 600-m for some species of sole, flounder and dab. Maximum abundance of rockdwelling fishes occurs when the artificial reefs are spaced less than 400-m apart, but grouped reefs are still effective at distances up to one kilometre apart.

Studying the distribution of fish schools around an artificial reef off Nagi, Japan, Shimizu (1981) reports that fish are attracted to a reef from a distance of up to 300-m.

Off the northern coast of Rio de Janeiro, Brazil, Zalmon *et al.* (1999) evaluated a 1500-m^2 artificial reef as a habitat enhancement tool to attract nearshore fishes on a typically low relief bottom. They found that the artificial reef demonstrated a strong aggregating influence, with up to three times the fish biomass, density and catch of those measured at the sand bottom reference site about one kilometre away.

Alevizon *et al.* (1985) conducted before-and-after experiments using small cement block and pipe reefs in the Lower Florida Keys. There were no measurable effects, either through attraction or predation, on the fifty-six species of the resident fish community studied over twelve hectares of sand bottom. This finding was not considered surprising because the fishes, most commonly labrids and serranids, are more adapted to the open plain habitat. In addition, the most common species observed on the artificial reefs were lutjanids (snappers) and haemulids (grunts) that prey largely on benthic invertebrates that were not numerous on the sand plain.

In summary, while artificial reefs merely attract and concentrate some fish species, they promote the production of others. However researchers such as Bohnsack (1989) and Ambrose and Swarbrick (1989), conclude that the situations for most fish probably lie somewhere between the two extremes. Despite hundreds of published studies, the attraction production controversy for artificial reefs still persists as a research question. Researchers give several reasons. Studies need to be: first, conducted over longer times than the typical few months that most studies are conducted; secondly, on reefs more than a few square meters in size; and thirdly, the studies need to be experimental before they can conclude that a higher density of fishes around artificial reefs is sufficient evidence of increased production. When natural reef habitat is a limiting factor for certain biota in some waters, the construction of small artificial reefs may have negligible effects because they add only 100s of square meters of hard substrate compared with 1000s of hectares of adjacent rocky reef habitat.

6.4.2 British Columbia evidence

Compiled in the following sub-sections are the existing data (limited) and information about colonization, diversity, abundance and distribution of biota reported on ship reefs in BC waters. Most of these findings are unpublished, gleaned from little known survey reports and narrative accounts of diving biologists who, mostly as volunteers, were committed to improving the knowledge base of reef ecosystems. Direct quotations (more lengthy than usually found in this report style) and tables with modification have been extracted from these unpublished sources and included here.

In addition, some findings are summarized from reported biological surveys, recently overviewed by Naito (2001), for BC artificial reefs constructed of scrap concrete, steel or blasted rock in shallower waters on southeast Vancouver Island.

6.4.2.1 Porteau Cove artificial reef complex

Over the past two decades, the Porteau artificial reef complex has been gradually colonized by marine life typical of Howe Sound. Some recreational divers report that there seems to be little life on and amongst the Porteau wrecks. For example one diver states, “I saw a few small lingcod and some shrimp, but that was about it. Noticeably missing were the white metridium and sea anemone that are so common in the lower Puget Sound. A small variety of marine life lives on the Nakaya. Calcareous tube worms coat the sides. Shrimp and galathaeid crabs hop about the decks. An occasional long ray star or plumose anemone can be spotted. Rockfish and lingcod drift over the decks. The *Nakaya* is great to dive on and has many lingcod which call the old timbers home." (http://carver.pinc.com/home/jimandella/porteau.html). But such anecdotal observations are not supported by more systematic surveys. Although comprehensive data documenting the chronological changes in diversity and abundance of subtidal marine life are not available for Porteau, limited routine and standard biological surveys or video recordings have been undertaken, such as one detailed survey carried out in 1990 (Birch *et al.* 1990). Of necessity, much of the species-list information presented here is based on this survey.

Specifically for this report, McDaniel (2001) summarized the species observed and noted changes in community structure of the various Porteau Cove artificial reefs including the vessels. These observations are based on consulting more than 100 of his dive log entries for Porteau. Not all these dives were strictly biological in nature, but involved reef assessments, maintenance or repair. Nevertheless, these unpublished observations portray the current status of the primary reef elements at Porteau, and for these reasons are quoted. McDaniel observed considerable variation in the diversity and abundance of various species depending on the specific reef component (steel, wood, concrete) and the siting depths:

> "The tire reef, installed in 1971, is the oldest component of the artificial reef complex at Porteau, and provides shelter for a large variety of marine creatures. Lingcod, rockfish, gobies, ronquils and perch live on this part of the reef, and several types of seaweeds and marine invertebrates such as anemones live attached to the tires. The interior cavities of the tires provide security for several species of shrimps, including the striped shrimp and juveniles of the commercially important spot prawn.
>
> Scuttled in February, 1980, the wooden-hulled *Cape Spruce* deteriorated quickly under the attack of boring shipworms and has been reduced to a mere skeleton of metal components, the most interesting of which is the rudder quadrant. The remains are not frequently dived because they are not marked by a buoy and are difficult to find.
>
> The concrete pipe reef, established in February, 1980, is well colonized by marine life, with many invertebrates and fishes living among the nooks and crannies provided by this material. This component of the reef lies in relatively shallow water and supports a diverse assemblage of marine algae. Schools of striped and pile perch are common on this part of the reef, as well as lingcod. This area has become a significant lingcod spawning area.
>
> Scuttled in September, 1980, the wooden-hulled *Fort Langley* was in poor condition and did not take long to succumb to the ravages of shipworms. Within a year the hull was nearly gone, leaving only the 10-tonne concrete block, which was used to sink the hull. Now only the rough outline of the hull can be seen on the bottom and little remains of interest. The site is not often dived because it is not marked with a buoy and is difficult to locate.
>
> The concrete block reef was established in September 1980 and now supports the most diverse assemblage of marine life at Porteau. This part of the reef is comprised of several massive pieces of concrete demolition material, some U-shaped and oriented to create cave-like habitats. In the 1990 biophysical inventory of conspicuous marine life 64 species of invertebrates, 18 species of seaweeds and 20 species of fishes were observed on the reef itself. By comparison, non-enhanced areas of "natural" substrate near the artificial reef supported 11 species of invertebrates, three species of seaweeds and eight species of fishes (Birch *et al.,* 1990). The most conspicuous animals are large (60 cm-tall) plumose anemones that cover much of the reef surface.
>
> Scuttled in August, 1985, near the northern border of the diving area, the wooden-hulled *Nakaya* became one of the most popular dives in the lower mainland. It lies in fairly deep water with the stern about 18 m deep and the bow at 30 metres. Due to its depth and wooden construction, the hull of the *Nakaya* has never supported a large diversity or abundance of marine life. The wooden hull is slowly but surely crumbling, and

marine life tends to be concentrated on steel structures such as railings and other metal fixtures.

The H-beam reef (also known as the Jungle Gym) was established in March, 1990, near the offshore end of the tire reef and adjacent to the concrete block reef. These large steel structures stand up to four metres high and are now densely encrusted with marine life, including tubeworms, anemones and barnacles. Schools of tube-snouts *(Aulorhynchus flavidus)* and shiner seaperch also frequent this part of the reef.

Scuttled in November, 1991, the *Centennial III* is a popular dive site and has gradually become colonized by marine life, including plumose anemones and lingcod. The top of the wheelhouse is home to a large, particularly aggressive male lingcod that regularly chases divers away from his turf. The hull is marked by a yellow buoy attached to its bow, so it is readily located by divers.

Also scuttled in November, 1991, just south of the *Centennial III*, the concrete sailboat hull (also known as McCall Reef, after the donor) lies apart from the main reef and is seldom dived. By June, 1992, the hull was encrusted with tubeworms and several juvenile plumose anemones were observed. All of the wooden hull frames and supports were deteriorated by shipworm activities. Currently the hull is heavily colonized with marine life such as tubeworms, tunicates, crinoids and anemones. The port gunnel is entirely overgrown with plumose anemones.

Scuttled in March, 1992, the steel hull of the 28-m tug *Granthall* has become one of the most popular attractions at Porteau since it is shallow and easily explored by novice divers. The hull is marked by a yellow buoy attached to its bow, so it is easily located. Only three months post-sinking, large numbers of juvenile spot prawns *(Pandalas platyceros)* were observed on the hull, as well as barnacles, small tubeworms, bryozoans and juvenile striped shrimp *(Pandalas danae)*. Currently the hull is heavily overgrown with marine life, including tunicates, bryozoans, crinoids and plumose anemones."

In 1990, as part of a broader marine biophysical inventory and recreational assessment of Porteau Cove Provincial Park, a species list of subtidal invertebrates and fishes was compiled by Birch *et al*. (1990). Table 4 summarizes this list, the most comprehensive for this area. Of a total 145 species observed, the most common species grouping were as follows; fishes (35 species), molluscs (21), arthropods (19), seaweeds (19) and echinoderms (17).

Table 4. Conspicuous marine biota observed by divers on and adjacent to the Porteau Artificial Reef complex, Howe Sound, BC

INVERTEBRATES

Porifera
Cloud sponge *Aphrocallistes vastus*
Chimney sponge Rosellidae
Sponge *Halichondria* sp.
Finger sponge *Neoesperiopsis rigida*
Puffball sponge *Stylinos* sp.
Sponge *Polymastia* sp.
Sponge *Iophon* sp.
Sponge *Hamigera* sp.

Cnidaria
Red medusa *Cyanea capillata*
Cream medusa *Phacellophora camtshatica*
Plumose anemone *Metridium giganteum*
Swimming anemone *Stomphia didemon*
Spotted anemone *Stomphia coccinea*
Tube-dwelling anemone *Pachycerianthus fimbriatus*
Dahlia anemone *Urticina crassicornis*
Anemone *Urticina coriacea*
Hydroids Hydrozoa
Tan cup coral *Caryophyllia alaskensis*
Zoanthid *Epizoanthus scotinus*
Orange sea pen *Ptilosarcus gurneyi*
White sea pen *Virgularia tuberculata*

Brachiopoda
Brachiopod *Terebratulina unguicula*
Brachiopod *Terebratalia transversa*

Mollusca
Lined chiton *Tonicella lineata*
White-lined chiton *Tonicella insignis*
Merten's chiton *Lepidozona mertensii*
Hairy chiton *Mopalia ciliata*
Giant Pacific chiton *Cryptochiton stelleri*
White-lined Dirona *Dirona albolineata*
Giant white Dorid *Archidoris odhneri*
Shaggy mouse nudibranch *Aeolidia papillosa*
Brown-striped nudibranch *Armina californica*
Leopard dorid Diaulula sandiegensis
Nanaimo Dorid *Acanthodoris nanaimoensis*
Red Flabellina *Flabellina triophina*
Opalescent nudibranch *Hermissenda crassicornis*
Spiny pink scallop *Chlamys hastata*
Pacific blue mussel *Mytilus edulis*
Green false jingle *Pododesmus macrochisma*
Blunt-nose clam *Mya truncata*
Ribbed clam *Humilaria kennerlyi*
Nuttall's cockle *Clinocardium nuttallii*
Stubby squid *Rossia pacifica*
Octopus *Octopus dofleini*

Arthropoda
Acorn barnacle *Balanus glandula*
Spot prawn *Pandalus platyceros*
Striped shrimp *Pandalus danae*
Yellow-leg pandalid *Pandalus tridens*
Two-spined Crangon *Rangon communis*
Short-scaled eualid *Eualus suckleyi*
Three-spined coastal shrimp *Heptacarpus tridens*
Stiletto coastal shrimp *Heptacarpus stylus*
Spiny lebbeid shrimp *Lebbeus groenlandicus*
Spider crab *Chorilia longipes*
Decorator crab *Oregonia gracilis*
Red rock crab *Cancer productus*
Dungeness crab *Cancer magister*
Umbrella crab *Cryptolithodes typicus*
Lithode crab *Rhinolithodes wosnessenskii*
Cobbler crab *Chionoecetes bairdi*
Hermit crab *Elassochirus tenuimanus*
Hermit crab *Pagurus armatus*
Galatheid crab *Munida quadrispina*

Echinodermata
Feather star *Florometra serratissima*
Purple seastar *Pisaster ochraceus*
Pink seastar *Pisaster brevispinus*
Mottled seastar *Evasterias troschelii*
Long ray seastar *Stylasterias forreri*
Sunflower seastar *Pycnopodia helianthoides*
Blood seastar *Henricia leviuscula*
Ridged blood seastar *Henricia aspera*
Vermilion seastar *Mediaster aequalis*
Painted seastar *Orthasterias koehleri*
Leather seastar *Dermasterias imbricata*
Cushion seastar *Pteraster tesselatus*
Rose seastar *Crossaster papposus*
Grey brittlestar *Ophiura lutkeni*
Creeping pedal cucumber *Psolus chitonoides*
California sea cucumber *Parastichopus californicus*
Crevice-dwelling cucumber *Cucumaria miniata*

Annelida
Stopper tubeworm *Serpula vermicularis*
Spiral tubeworm *Crucigera* spp.
White tubeworm *Protula pacifica*
Parchment tubeworm *Sabella crassicornis*
Ascidacea
Vase tunicate *Ciona intestinalis*
Stalked hairy tunicate *Boltenia villosa*
Pacific sea peach *Halocynthia aurantium*
Spiny tunicate *Halocynthia igaboja*
Glassy tunicate *Ascidia paratropa*
Flattened tunicate *Ascidia callosa*
Shiny orange tunicate *Cnemidocarpa finmarkiensis*

FISHES
Spiny dogfish *Squalus acanthias*
Ratfish *Hydrolagus colliei*
Pacific herring *Clupea harengus pallasi*
Tube-snout *Aulorhynchus flavidus*
Striped seaperch *Embiotoca lateralis*
Pile seaperch *Rhacochilus vacca*
Shiner seaperch *Cymatogaster aggregata*
Blackeye goby *Coryphopterus nicholsi*
Copper rockfish *Sebastes caurinus*
Quillback rockfish *Sebastes maliger*
Whitespotted greenling *Hexagrammos stelleri*
Kelp greenling *Hexagrammos decagrammus*
Lingcod *Ophiodon elongatus*
Padded sculpin *Artedius fenestralis*
Sailfin sculpin *Nautichthys oculofasciatus*
Great sculpin *Myoxocephalus polyacanthocephalus*
Grunt sculpin *Rhamphocottus richardsoni*
Longfin sculpin *Jordania zonope*
Scalyhead sculpin *Artedius harringtoni*
Roughback sculpin *Chitonotus pugetensis*
Roughspine sculpin *Triglops macellus*
Pacific staghorn sculpin *Leptocottus armatus*
Rock sole *Pleuronectes bilineatus*
English sole *Pleuronectes vetulus*
C-O sole *Pleuronichthys coenosus*
Starry flounder *Platichthys stellatus*
Speckled sanddab *Citharichthys stigmaeus*
Walleye pollock *Theragra chalcogramma*
Pacific tomcod *Microgadus proximus*
Blackbelly eelpout *Lycodopsis pacifica*
Pacific snake prickleback *Lumpenus sagitta*
Plainfin midshipman *Porichthys notatus*
Sturgeon poacher *Podothecus acipenserinus*
Spinycheek starsnout *Bathyagonus infraspinata*
Northern spearnose poacher *Agonopsis vulsa*

SEAWEEDS
Sea lettuce *Ulva lactuca*
Wireweed *Sargassum muticum*
Broad leaf kelp *Laminaria saccharina*
Red alga *Grifithsia pacifica*
Red alga *Membranoptera platyphylla*
Red alga *Weeksia coccinea*
Red alga *Fryella gardneri*
Red alga *Rhodymenia pertusa*
Red alga *Sarcodiotheca furcata*
Red alga *Sarcodiotheca gaudichaudii*
Red alga *Haraldophyllum notti*
Red alga *Haraldophyllum mirabile*
Red alga *Heterosiphonia densiuscula*
Red alga *Rhodoptilum plumosum*
Red alga *Fauchea fryeana*
Red alga *Callophyllis cristata*
Red alga *Botryocladia pseudodichotoma*
Red alga *Myriogramme pulchra*
Red alga *Polyneura latissima*

(Birch et al. 1990; McDaniel 2001)

6.4.2.2 *Mackenzie* artificial reef

The final resting place of the HMCS *Mackenzie* is on a firm bottom of sedimented clay and rock in 30 m of water, near Rum and Gooch Islands. Based on local dive reports by Shallon Charters, the area is swept by steady currents that are gentle enough for diving except during large ebbs. These currents diminish as you descend to the ship. Divers believe that these currents are a major factor turning this artificial reef into one of the premiere dive sites in North America. Shallon Charters also reports on its WebPage that shrimp moved on to the ship within days of the sinking. Fish soon followed, and "permanent" residents were taking hold in weeks. The upper horizontal surfaces of the ship were first to be covered with hydroids, diatoms and algae. A month later, barnacles appeared on the vertical surfaces (www.shalloncharters.com/mackenzie.htm).

In April 2001, approximately 67 months (5 ½ years) after the *Mackenzie*'s sinking, Valkenier (2001) more carefully recorded the diversity and abundance of conspicuous biota on the reef. A total of 47 animals and two algal taxa in 12 phyla were observed and identified usually to genera or species, as listed in Table 5. Over 40% of these were arthropods (8 species including shrimps and crabs), cnidaria (6 including anemones and hydroids) and echinoderms (6 including sea stars and urchins). The remainder were fishes (5), tunicates (5 including sea squirts), univalve molluscs (5 including snails and chitons), nudibranches (3), bivalve molluscs (3 including scallop and mussels), porifera sponges (3), brachiopods (1), annelid worms (1) and bryozoa (1). The fish species observed were lingcod, copper rockfish, kelp greenling – with estimated low abundance from two to ten individuals – and unidentified gunnels and sculpins; the latter was estimated in numbers up to 100. The most common organisms judged as abundant (>100 animals) were mussels *(Mytilus* spp), acorn barnacles, coonstripe shrimp and hydroid sea fir *(Abietinaria* spp.). The only identified seaweed was iridescent seaweed *(Mazzaella spp.*, formerly *Iridaea* spp.), a bladed red algae more typical of rocky, exposed areas and low intertidal zone.

6.4.2.3 *Columbia* artificial reef

There is only one survey (Valkenier 1998) of the species diversity for the Columbia artificial reef, which was carried out in August 1998, approximately 2 years after its sinking. As summarized in Table 6, the total taxa recorded during one observational dive was 38 animals and 3 seaweeds, usually identified to genus or species and representing 12 phyla. The most diverse phylum was the Mollusca with 9 species, followed by echinoderms (7), arthropods (5) and fishes (5). The fish species were grunt sculpin *(Rhamphocottus richardsoni)*, quillback rockfish, copper rockfish, lingcod, northern anchovy *(Engraulis mordax)*, or less likely Pacific herring *(Clupea harengus pallasi)*. The remaining animal taxa were representatives of the following: Cnidaria (5), Tunicata (2), Porifera (2) and Annelida (1).

6.4.2.4 *Chaudiere* artificial reef

There are more post-sinking inventories and assessment reports for the Chaudiere artificial reef than for other ship reefs in BC including one limited to pollutant measurements (Kim 1994). Based on a video record and qualitative observations of biota on and around the reef, Ellis (1993) reported that “algal growth had developed over the entire surface of the vessel within two months of its sinking. Plankton were observed in the water column outside and around the ship. The outer hull supported rockfish, starfish, shrimp and sculpin. Adjacent to the ship in the surrounding water column, large numbers of juvenile pelagic fish were noted.”

Recently a biologist who often recreationally dives the Chaudiere artificial reef analysed 11 videotapes and 13 observational dives over 7½ years, from December 1992 to June 2000, to determine the patterns of marine colonization (McDaniel 2001). Under contract to Fisheries and Oceans Canada, this unpublished, semi-quantitative analyses estimates the abundance of the invertebrates and fishes most conspicuous to divers (Table 7). The surveys were not always carried out at the same locations on the reef, because the ship is relatively large and the recreational, non-decompression dives are quite short, less than 30 minutes. Nevertheless these observations represent the only long-term biological dataset presently available for any ship reef in BC waters. For this reason, the findings are directly quoted in considerable detail, as follows:

> "The *Chaudiere* lies on its port side on a sloping mud bottom with its bow offshore at a depth of about 32-m, and its stern at about 20-m. The inlet is largely an enclosed bay with limited water exchange, mild tidal currents (less than one knot) and subsequently relatively low diversity of marine organisms. The reef is considered too deep to be affected by wave action. Water clarity is usually good to excellent, giving typical visibility in winter months of 20 - 30 metres.
>
> (The) estimated abundance of 32 conspicuous invertebrates and fishes representing 8 phyla was observed (and recorded) during eleven survey dates, beginning one day post sinking and continuing to 91 months later. Not surprisingly one day after the *Chaudiere* was sunk, the parts of ship’s hull and propeller shafts were already colonized by four sessile species: acorn barnacles, bay mussels *(Mytilus edulis),* northern feather duster worms *(Eudistylia vancouveri),* another parchment tubeworm *(Schizobranchia insignis)* and plumose anemones; the decommissioned ship had been gradually bio-fouled during its many years of mooring in Esquimalt and Vancouver harbours.
>
> Within about two months or 72 days post-sinking, the only new arrivals were shiner seaperch and pile perch, apparently attracted in the moderate-to-large numbers of barnacles and mussels. Seven months post sinking, the upper side of hull was coated with a brown diatom layer, and the added arrival of large colonies of unidentified hydroids and a few patches of vase tunicates *(Ciona intestinalis)* were recorded.
>
> Less than two years later on two surveys 21 and 24 months post sinking, the reef was dramatically transformed with the presence of a total 24 species. Vase tunicates numbering in the many thousands covered the hull, railings, stanchions, gangways and other locations. Other invertebrate species but in much smaller numbers were observed such as crinoid *(Florometra serratissima),* striped shrimp, spider crab *(Chorilia longipes),* spiny pink scallop *(Chlampys hastata),* sunflower seastar *(Pycnopodia helianthoides),* green urchin *(Strongylocentrotus droebachiensis),* shiny orange tunicate *(Cnemidocarpa finmarkiensis),* sea cucumber *(Parastichopus californicus)* and two calcareous tubeworm species. Together with the still large schools of sea perch, other fishes -- lingcod, copper rockfish, quillback rockfish, padded sculpin *(Artedius fenestralis)* and northern ronquil *(Ronquilus jordani)* were now evident but in much

lower numbers.

Over the next 6 or so years the total species diversity of the reef changed little, with the addition of only 3 new species but merely as occasional sightings of a few animals: chimney sponges (Rosellidae), leather star *(Dermasterias imbricata)* and grunt sculpin *(Rhamphocottus richardsoni).* Numbers of some early colonizers continued to increase, becoming common or abundant such as the yellow encrusting sponge, plumose anemone, crinoids, calcareous tubeworms *(Serpula vermicularis, Curcigera* spp.) and padded sculpin. The vase tunicate and plumose anemones dominated in abundance and aerial extent, spreading in enormous numbers over much of the exterior surfaces and many interior areas of the reef.

Within 34 to 42 months post-sinking, there also was the disappearance of some species -- the acorn barnacle and bay mussel (likely both eaten by the abundant seaperch), spiny pink scallop, spider crab, painted seastar *(Orthasterias koehleri),* rock jingle *(Pododesmus cepio)* and northern ronquil.

Interesting diver log entries that further suggest new productivity of this reef include: juvenile green urchins apparently grazing the diatom mat on the upper hull surfaces (25 months postsinking); juvenile quillback rockfish and pregnant copper rockfish observed in the mortar bay (39 and 52 months post-sinking, respectively).

Within tens of metres just off the stern of the ship, there is a small rocky reef that offers natural habitat for plumose anemones, crinoids, vase tunicates and various sea stars typical of Sechlet Inlet. It is unknown what role this adjacent natural reef may have played in the colonization patterns and trends observed on the Chaudiere artificial reef."

Taken from the REEF's Internet database, Table 13 shows two recent records of fish observations (Geographical Zone Code 13590401) from the Chaudiere reef. Recreational divers reported the abundance of shiner surfperch and quillback rockfish as many, pile perch and yelloweye rockfish as few, and lingcod as one (www. reef.org/cgibin/georep.pl?region=PAC&geogr=13590401).

Table 5. Relative abundance of conspicuous marine biota observed by divers on the *Mackenzie* artificial reef near Rum and Gooch Islands, Haro Strait, BC, 7 April 2001

Abundance Codes: [S] = single, 1 [F] = few, 2-10 [M] = many, 11-100 [A] = abundant, >100 [P] = present

FISHES
Copper rockfish *(Sebastes caurinus)* [F]
Lingcod *(Ophiodon elongatus)* [F]
Kelp greenling (females) *(Hexagrammos decagrammus)* [F]
Unidentified sculpin [M]
Unidentified gunnel [S]

INVERTEBRATES

Urochordata
Stalked hairy sea squirt [M]
or Strawberry sea squirt *(Boltenia villosa)*
Broad base sea squirt *(Cnemidocarpa finmarkiensis)* [M]
Transparent sea squirt *(Corella willmeriana)* [F]
Horse-shoe tunicate *(Chelyosoma productum)* [M]
Peanut sea squirt *(Styela gibbsii)* [M]

Echinodermata
Sunflower star *(Pycnopodia helianthoides)* [F]
Brittle star *(Ophiopholis aculeata)* [S]
Six-rayed star *(Leptasterias hexactis)* [S]
Giant red sea urchin (juveniles)
(Strongylocentrotus franciscanus) [M]
Green sea urchin
(Strongylocentrotus droebachiensis) [M]
California sea cucumber *(Parastichopus californicus) [??]*

Mollusca

Univalves
Lined chitons *(Tonicella lineata)* [F]
Leafy hornmouth snail *(Ceratostoma foliatum)* [F]
Hairy or Oregon triton (Fusitriton oregonensis) [F]
Blue topsnail *(Calliostoma ligatum)* [M]
Large white whelks (unidentified species) [M]

Bivalves
Pink Pacific spiny scallop *(Chlamys hastata hericia)* [M]
Mussels *(Mytilus* spp.) [A]
Jingle shells *(Pododesmus* spp.) [M]

Nudibranchs:
Brown spotted nudibranch or Leopard dorid
(Diaulula sandiegensis) [F]
Common orange spotted nudibranch
or Clown dorid *(Triopha catalinae)* [S]
Red aeolid nudibranch *(Flabellina* spp.) [F]

Brachiopoda
Common lampshell *(Terebratalia transversa)* [F]

Arthropoda
Acorn barnacle *(Balanus* spp.) [A]
Giant barnacle *(Balanus nobilus)* [M]
Coon-stripe shrimp *(Pandalus danae)* [A]
Broken-back shrimp *(Heptacarpus* spp.) [M]
Butterfly crab *(Cryptolithodes typicus)* [S]
Widehand hermit crab *(Elassochirus tenuimanus)* [S]
Kelp crab *(Pugettia producta)* [F]
Decorator crab *(Oregonia gracilis)* [F]

Annelida
Calcareous tubeworm *(Serpula vermicularis)* [M]

Bryzoa
Northern staghorn bryozoa *(Heteropora pacifica)* [S]

Cnidaria
Sea fir hydroid *(Abietinaria* spp.) [A]
Snail-fur hydroid *(Hydractinia echinata)* [P]
Delicate plumed hydroid *(Plummularia* spp.) [A]
Giant plumose anemone *(Metridium gigantium)* [M]
Short plumose anemone *(Metridium senile)* [M]
Painted tealia *(Tealia crassicornis)* former name
Now called Painted anemone (*Urticina carssicornis)* [M]

Porifera
Trumpet sponges *(Stylissa stipitata)* [F]
Yellow encrusting sponge (unidentified species) [F]
Rough encrusting sponge on scallops
(Myxilla incrustans) [M]

SEAWEEDS
Iridescent red algae *(Iridea* spp.) [F]
Unidentified species [A]

(Valkenier 2001)

Table 6. Conspicuous marine biota observed by divers on the *Columbia* artificial reef, near Maude Island in Campbell River area, BC. 29 August 1998

CHORDATA:
Grunt sculpin *(Rhamphocottus richardsoni)*
Scaleyhead sculpin *(Artedius harringtoni)*
Quillback rockfish *(Sebastes malinger)*
Copper rockfish *(Sebastes caurinus)*
Lingcod *(Ophiodon elongatus)*
Northern anchovy *(Engraulis mordax)*
[or less likely Pacific herring *(Clupea harengus pallasi)]*

UROCHORDATA :
Stalked hairy sea squirt
or Strawberry sea squirt *(Boltenia villosa)*
Transparent sea squirt *(Corella willmeriana)*

ECHINODERMATA:
Sunflower star *(Pycnopodia helianthoides)*
Blood star *(Henricia leviuscula)*
Brittle star *(Ophiopholis aculeata)*
Crinoids or Feather star *(Florometra serratissima)*
Red sea urchin *(Strongylocentrotus franciscanus)*
Green sea urchin *(Strongylocentrotus droebachiensis)*
California sea cucumber *(Parastichopus californicus)*

MOLLUSCA

Nudibranchs
Hudson's dorid *(Acanthordoris hudsoni)*
Red-gilled aeolid *(Falbellina* spp.)
Alabaster doronid *(Dirona albolineata)*
Opalescent nudibranch *(Hermissenda crassicornis)*
Dironid nudibranch *(Janolus fuscus)*

Univalves
Blue topsnail *(Calliostoma ligatum)*
Ringed top snail *(Calliostoma annulatum)*
Speckled limpet *(Notoacmea persona)*
Shield or Plate limpets *(Notoacmea* spp.)

Bivalves:
Pink Pacific spiny scallop *(Chlamys hastata hericia)*
Jingle shells (*Pododesmus* spp.)

ARTHROPODA
Acorn barnacle *(Balanus* spp.)
Skeleton shrimp or caprella amphipod *(Caprella* spp.)
Broken back shrimp *(Heptacarpus* spp.)
Amphipods (unidentified species)
Decorator crab *(Oregonia gracilis)*

ANNELIDA
Tiny calcareous tubeworms (unidentified species)

CNIDARIA
Sea fir hydroids *(Abietinaria* spp. or *Thuiaria* spp.)
Plumose anemone *(Metridium senile)*
Plumose anemone *(Metridium gigantium)*
Swimming anemone *(Stomphia didemon)*
Orange cup coral *(Balanophyllia elegans)*

PORIFERA
Tiny vase sponge *(Scypha* spp.)
Rough encrusting sponge
or Pecten sponge *(Myxilla incrustans)*

SEAWEEDS
Iridescent red algae *(Iridea* spp.)
Unidentified red alga
Unidentified green alga

(Valkenier 1998a)

Table 7. Trends in abundance of conspicuous marine biota observed by divers on the *Chaudiere* artificial reef in Sechlet Inlet, BC. 1992 to 2000

Abundance Code		
(black)	Abundant	- Occurs in large
(dark grey)	Common	- Occurs in moderate numbers
(grey)	Few	- Occurs sponadically or in small patches
(light grey)	Rare	- Occurs as one or two
(white)	Absent	- Not observed

	Date of survey	Dec. 6 1992	Feb 14 1993	Jun. 20 1993	Sept. 5 1994	Dec. 29 1994	Sept. 2 1995	Feb. 10 1996	May 10 1996	Mar. 15 1997	July 24 1999	Jun. 23 2000
	Age of reef (in days)	1	70	196	638	753	1000	1161	1251	1560	2421	2756
	(in years and months)	0-0	0-2	0-6	1-9	2-1	2-9	3-2	3-5	4-3	6-8	7-7
INVERTEBRATES												
Porifera												
Yellow encrust.	Demospongiae				Few		Few	Common	Common	Common	Common	Common
Chimney sponge	Rosellidae										Few	
Cnidaria												
Plumose anemone	*Metridium giganteum*	Few	Few	Few	Few		Abundant	Abundant	Abundant	Abundant	Abundant	Abundant
Hydroids	Hydrozoa			Abundant	Abundant		Abundant	Abundant	Abundant	Abundant	Abundant	Abundant
Crustacea												
Acorn barnacle	*Balanus glandula*	Common	Common	Common	Common	Common	Common					
Striped shrimp	*Pandalus danae*				Few	Few	Few	Few	Few	Few	Few	Few
Spider crab	*Chorilia longipes*				Few	Few	Few	Few				
Mollusca												
Spiny pink scallop	*Chlamys hastata*				Few		Few	Few				
Bay mussel	*Mytilus edulis*	Abundant	Abundant	Abundant	Few		Abundant	Few				
Rock jingle	*Pododesmus cepio*					Few		Few	Few			
Echinodermata												
Sunflower seastar	*Pycnopodia helianthoides*				Few	Few	Few	Few	Few	Few	Few	Few
Painted seastar	*Orthasterias koehleri*				Few	Few	Few					
Mottled seastar	*Evasterias troschelii*					Few		Few			Few	
Leather seastar	*Dermasterias imbricata*										Few	
Green urchin	*Strongylocentrotus droebachiensis*				Few	Few	Few	Few	Few	Few	Few	Few
Sea cucumber	*Parastichopus californicus*					Few	Few	Few	Few	Few	Few	Few
Crinoid	*Florometra serratissima*					Common	Abundant	Abundant	Abundant	Abundant	Abundant	Abundant
Annelida												
Parchment	*Eudistylia vancouveri*	Few	Few	Few	Common	Common		Common	Common	Common	Common	Common
Parchment	*Schizobranchia insignis*	Few	Few	Few	Common	Common	Abundant	Common	Common	Common	Common	Common
Calcareous	*Serpula vermicularis*				Common	Common	Abundant	Abundant	Abundant	Abundant	Abundant	Abundant
Calcareous	*Crucigera* spp.			Few	Abundant	Abundant	Abundant	Abundant	Abundant	Abundant	Abundant	Abundant
Urochordata												
Vase tunicate	*Ciona intestinalis*			Few	Abundant	Abundant	Abundant	Abundant	Abundant	Abundant	Abundant	Abundant
Shiny orange	*Cnemidocarpa finmarkiensis*				Few		Few	Few	Few	Few	Few	Few
FISHES												
Padded sculpin	*Artedius fenestralis*				Few	Few	Common	Common	Common	Common	Common	Common
Grunt sculpin	*Rhamphocottus richardsoni*								Few			
Lingcod	*Ophiodon elongatus*				Few	Few	Few	Common	Common	Common	Common	Common
Copper rockfish	*Sebastes caurinus*				Few	Few	Few	Few	Few	Few	Few	Few
Quillback rockfish	*Sebastes maliger*				Few	Few	Few	Common	Common	Common	Common	Common
Yelloweye rockfish	*Sebastes ruberrimus*					Few				Few	Few	Few
Northern ronquil	*Ronquilus jordani*				Few		Few					
Shiner sea perch	*Cymatogaster aggregata*		Abundant	Abundant	Abundant	Abundant	Abundant	Abundant	Abundant	Abundant	Abundant	Abundant
Pile perch	*Rhacochilus*		Common	Common	Common	Common	Common	Common	Common	Common	Common	Common
Total number of species		5	7	10	24	22	25	25	22	21	24	21

(Modified from McDaniel, 2001)

6.4.2.5 *Church* artificial reef

The *GB Church* lies on an even keel in 30-m of water. The tops of her aft and forward masts are at 10-m and 7-m respectively. The bottom substrate is firm clay with a layer of silt.

There is one unpublished report (Subsea Enterprise, 1994) for the Church reef that assesses the diversity and abundance of its associated marine life approximately 32 months after the ship's sinking. The study, involving visual and video observations of the most conspicuous organisms, was carried out in March 1994, on behalf of the BC Ministry of Environment, Lands and Parks. Since Neil McDaniel was one of the contracted biologists, the survey protocol was similar to that outlined above by McDaniel (2001) for the Chaudiere artificial reef. In addition, the reef survey includes photographic analyses of standard quadrats located at five locations.

Table 8 lists the species richness of the most conspicuous marine organisms together with their relative abundance on the Church Reef. A total of 96 species were observed on or in association with the reef; more than twice the number reported by divers on other ship reefs in BC.

Since Subsea Enterprise (1994) provides one of the most descriptive biological assessments of any of the ship reefs in BC waters, but one that is unpublished and not widely available, it is quoted in considerable detail as follows:

> "Since its sinking on August 11, 1991, the *G.B. Church* artificial reef has been colonized by many different types of marine organisms. This colonization has been a gradual process as the bare steel and painted surfaces of the hull have been settled by various species. Some of the colonizers have been seasonal in appearance, such as certain nudibranchs, while other species have become permanent settlers, firmly attached to the hull.
>
> Since the reef has been in place over 2½ years, a reasonably stable assemblage of marine life has colonized the reef, although seasonal fluctuations in the abundance and diversity of certain invertebrates, seaweeds and fishes have been observed. Further changes in the composition of marine life inhabiting the reef can be expected as certain colonizers expand their population on the reef surface. Predation will also affect the number and distribution of other species.
>
> Close to 100 species of conspicuous marine organisms, that is those easily visible to the unaided eye,were found to be living on or in association with the reef. These include 62 invertebrates, 20 fishes and 14 species of seaweeds. Crustaceans were the most varied group of invertebrates with 17 species recorded, followed by molluscs (14), urochordates (9), echinoderms (6), annelids (5), cnidarians (5), bryozoans (4), sponges (2), and brachiopods (1). Among the fishes, sculpins were most diverse with eight species recorded, followed by rockfish (5), greenlings (3), pricklebacks (1), gobies (1), surfperches (1) and poachers (1). Among the seaweeds, red algae were most diverse with eight species recorded, followed by brown algae (5) and green algae (1)."

Because of its structural complexity, the Church artificial reef has a wide variety of different habitats for marine life. Subsea Enterprise (1994) observed some marked differences among various parts of the reef (quoted below). The original report includes photographs that further support these findings.

> "Under the hull at the bow: Because the forward part of the bow of the ship is elevated off the bottom, a dark, cave-like habitat has been created. The underside of the hull at this site is heavily colonized by plumose anemones, some reaching 25 cm in height. There are also very large numbers of striped shrimp living on the hull and on the muddy substrate directly beneath the bow overhang. Densities were estimated at more than 300 shrimp per square metre, which is the highest the author has ever observed. At the time of these observations a 1.5 m lingcod was seen living under the ship just where the hull met the substrate.
>
> On outer hull surfaces: In general these are well colonized by a variety of marine creatures, such as the portside bow and starboard stern. At several spots on the hull large spawning masses of dog whelks *(Nucella Lamellose)* were observed laying eggs. There are bare bands on the hull where it seems that anti-fouling coatings are still effectively preventing the settlement of marine life.
>
> Inside the main hold: Rock oysters *(Pododesmus macrochisma)* in very large numbers (over 600 per square metre) dominate the painted surfaces. The floor of the hold has a layer of silt and is home to many striped shrimp.
>
> On the foredeck: The foredeck is encrusted with a layer of barnacles and tiny tubeworms. The area around the base of the foremast and the anchor winch seems particularly attractive to rockfish, and there are several copper rockfish living here. Both hawsepipes are occupied by rockfish; a copper rockfish in the starboard side and a quillback rockfish in the port side. Just beneath the overhang the foredeck by the port ladder a small school of juvenile rockfish was observed. Another school of these unidentified juvenile rockfish was observed on the starboard side near the fuel tanks.
>
> Inside the forecastle: The forecastle receives very little ambient light and would appear to have reduced water circulation, however the inside walls and overhead beams are heavily colonized by marine growth. Tunicates (especially *Styela gibbsii)* are very abundant in this area. Decorator crabs *(Oregonia glacilis)* and lyre crabs *(Hyas lyratus)* are also found here. A small school of juvenile rockfish was found just inside the entrance to this area.
>
> On the foremast and stays: The very top of the foremast has been scraped almost clean of marine life by the chafing action of the chain. The upper ends of the mast stays are colonized by several species of red algae and a few species of brown algae. The foremast is colonized by barnacles and other small invertebrates, including compound tunicates *(Pistaplia occidentalis).*
>
> Inside the accommodations at boat deck: Tubeworms dominate the fauna attached to the walls here. A small school of striped seaperch was observed swimming through this area.

Table 8. Relative abundance of conspicuous marine biota observed by divers on the *Church* artificial reef near Rum and Gooch Islands, Haro Strait, BC, 26 March 1994

Estimate of Abundance Codes: [A] = Abundant [F] = Few [R] = Rare

INVERTEBRATES		
Crustacea: crabs, barnacles, amphipods		
Giant barnacle	*Balanus nubilus*	[F]
Acorn barnacle	*Balanus glandula*	[A]
Caprellid amphipod	*Caprella* sp.	[A]
Tube-dwelling amphipod	*Corophium* sp.	[A]
Striped shrimp	*Pandalus danae*	[A]
Short-scaled eualid	*Eualus suckleyi*	[A]
Shrimp	Caridean shrimp	[F]
Oregon Cancer	*Cancer oregonensis*	[F]
Red rock crab	*Cancer productus*	[F]
Kelp crab	*Pugettia producta*	[F]
Graceful kelp crab	*Pugettia gracilis*	[F]
Decorator crab	*Oregonia gracilis*	[A]
Lyre crab	*Hyas lyratus*	[A]
Spider crab	*Scyra acutifrons*	[F]
Heart lithode crab	*Phyllolithodes papillosus*	[R]
Hermit crab	*Elassochirus tenuimanus*	[F]
Hermit crab	*Pagurus hirsutiusculus*	[F]
Mollusca: snails, nudibranchs, oysters		
Chiton	*Mopalia* sp.	[F]
Clown nudibranch	*Triopha catalinae*	[F]
Spotted nudibranch	*Diaulula sandiegensis*	[R]
Lemon nudibranch	*Archidoris montereyensis*	[R]
Dog whelk	*Nucella lamellose*	[A]
Leafy hornmouth	*Ceratostoma foliatum*	[F]
Ring-top snail	*Calliostoma ligatum*	[A]
Snail	*Trichotropis cancellata*	[A]
Snail	*Margarites* sp.	[F]
Spiny pink scallop	*Chlamys hastate*	[F]
Purple hinged rock scallop	*Crassodoma gigantean*	[R]
Rock oyster	*Pododesmus macrochisma*	[A]
Pacific blue mussel	*Mytilus edulis*	[F]
Shipworm	*Bankia setacea*	[A]
Urochordata: sea squirts (tunicates)		
Transparent tunicate	*Corella willmeriana*	[F]
Shiny orange tunicate	*Cnemidocarpa finmarkiensis*	[A]
Hairy stalked tunicate	*Boltenia villosa*	[A]
Horseshoe tunicate	*Chelyosoma productum*	[A]
Peanut tunicate	*Styela gibbsii*	[A]
Flattened tunicate	*Ascidia callosa*	[A]
Glassy tunicate	*Ascidia paratropa*	[R]
Orange sea peach	*Halocynthia aurantium*	[R]
Compound tunicate	*Distaplia occidentalis*	[F]
Echinodermata: sea stars, urchins, cucumbers		
Mottled seastar	*Evasterias troschelii*	[A]
Sunflower seastar	*Pycnopodia helianthoides*	[A]
Long-rayed sunstar	*Solaster stimpsoni*	[R]
Green sea urchin	*Strongylocentrotus droebachiensis*	[F]
Giant sea cucumber	*Parastichopus californicus*	[F]
White sea cucumber	*Eupentacta* sp.	[F]
Annelida: segmented worms		
Coiled tubeworm	*Crucigera* spp.	[A]
Calcareous tubeworm	*Serpula vermicularis*	[A]
Mucous tubeworm	*Myxicola infundibulum*	[A]
Parchment tubeworm	*Schizobranchia insignis*	[A]
Thread-gilled worm	*Thelepus crispus*	[F]
Cnidaria: hydroids, anemones		
Plumose anemone	*Metridium giganteum*	[A]
Dahlia anemone	*Urticina crassicornis*	[R]
Hydroid	*Abietinaria* sp.	[A]
Hydroid	*Obelia* sp	[F]
Hydroids	Hydrozoan species	[A]
Bryozoa: moss animals		
Lacy bryozoan	*Phidolopora pacifica*	[A]
Bryozoan	*Schizoporella bicornis*	[A]
Bryozoan	*Bugula* sp.	[A]
Porifera: sponges		
Yellow encrusting sponge	Porifera, Demospongia	[A]
Sponge	*Mycale adhaerens*	[R]
Brachiopoda: lamp shells		
Brachiopod	*Terebratalia transversa*	[F]
FISHES		
Cottidae: Sculpins		
Cabezon	*Scorpaenichthys marmoratus*	[R]
Red Irish Lord	*Hemilepidotus hemilepidotus*	[R]
Grunt sculpin	*Rhamphocottus richardsoni*	[F]
Sailfin sculpin	*Nautichthys oculofasciatus*	[R]
Buffalo sculpin	*Enophrys bison*	[R]
Longfin sculpin	*Jordania zonope*	[A]
Scalyhead sculpin	*Artedius harringtoni*	[F]
Padded sculpin	*Artedius fenestralis*	[A]
Scorpaenidae: Scorpionfishes		
Copper rockfish	*Sebastes caurinus*	[A]
Quillback rockfish	*Sebastes maliger*	[F]
Yelloweye rockfish.	*Sebastes ruberrimus*	[R]
Puget Sound rockfish	*Sebastes emphaeus*	[F]
Juvenile rockfish	*Sebastes* sp.	[A]
Hexagrammidae:		
Lingcod	*Ophiodon elongatus*	[F]
Whitespotted greenling	*Hexagrammos stelleri*	[R]
Kelp greenling	*Hexagrammos decagrammus*	[R]
Stichaeidae: Pricklebacks		
Mosshead warbonnet	*Chirolophis nugator*	[F]
Gobiidae: Gobies		
Blackeye goby	*Coryphopterus nicholsi*	[R]
Embiotocidae: Surfperches		
Striped seaperch	*Embiotoca lateralis*	[F]
Agonidae: Poachers		
Smooth alligatorfish	*Anoplagonus inermis*	[R]
SEAWEEDS		
Red algae		
Coralline red alga	*Lithothamnium* sp.	[F]
Red alga	*Ceramium* spp.	[F]
Red alga	*Callophyllis* spp.	[F]
Red alga	*Mastocarpus* spp.	[F]
Red alga	*Delesseria decipiens*	[F]
Red alga	*Polyneura latissima*	[F]
Red alga	*Polysiphonia* spp.	[F]
Red alga	*Rhodymenia pertusa*	[F]
Brown algae		
Bull kelp	*Nereocystis luetkeana*	[F]
Five rib kelp	*Costaria costata*	[F]
Blade kelp	*Laminaria saccharina*	[F]
Mid-rib kelp	*Alaria marginata*	[F]
Alga	*Desmarestia* sp.	[F]
Green algae		
Green tissue	*Ulva lactuca*	[F]

(Taken from Subsea Enterprise 1994)

Inside the accommodations at main deck: The inside walls of this area are similar to what was observed at boat deck accommodations described above. The deck at this level is not heavily sedimented, although there is a considerable accumulation of shell hash (barnacle and rock oyster shells). There are some striped shrimp here but not large numbers. The overhead beams in this area are well colonized in some sections. For example, the passage on the starboard side has considerable numbers of small plumose anemones. Water flow through this area appears to be adequate due to the large holes that were cut into the side of the ship's hull.

Under the hull at the stern: When the ship hit the bottom during sinking a depression was formed under the keel. This crevice is now home to a group of rockfish, including both copper rockfish and quillbacks. One of the largest plumose anemones found on the reef is attached to the hull on the stem near the rudder.

Inside the wheelhouse: The wooden wheelhouse is gradually deteriorating under the attack of shipworms but appears to be reasonably sturdy. Inside the wheelhouse the walls and overheads are colonized by a variety of invertebrates including tubeworms. Striped perch were observed swimming through this area.

In the engine room: This area receives very little of ambient light and negligible water exchange, therefore marine growth is sparse. However, there are some colonizers on the walls and overhead beams, including rock oysters and tubeworms.

Top of wheelhouse and mainmast: This area is shallow enough to support a limited growth of algae. Red and green algae were observed here. A large cabezon can regularly be found in this area; during our dives we observed it with a red Irish lord *(Hemilepidotus hemilepidotus)* in its jaws."

In March 1994, the following observations were also made by Subsea Enterprise (1994) at the five sampling sites using standard-sized quadrats around and inside the *GB Church,* (see Table 9).

"Outer hull on port bow: The quadrat was hung from the lower aft corner of the square hole cut into the hull allowing light to enter the forecastle. The quadrat was pushed against the sloping hull to permit observations to be made. The outer hull at the port bow is heavily encrusted with marine life, as indicated in the photographs. The substrate is unpainted steel and the hull is fully exposed to the tidal currents, which sweep across the reef; depth is 20-m below datum. Percent cover was estimated at 80%. Close examination of the photographs shows that numerically, tiny tubeworms and barnacles are most abundant. There are also large numbers of the conspicuous white lacy bryozoan and several species of tunicates. Both diversity (12 species) and abundance are relatively high at this site.

Inside wall of hold: The quadrat was located on the starboard wall of the hold near the forward end. The side of the quadrat was placed against the forward bulkhead of the hold. The quadrat was hung from a weld running horizontally along the side of the hold. The wall inside the hold supports a markedly different assemblage of organisms than the outer hull. This site is not exposed to full force of tidal currents since it is located down inside the shelter of the main hold; depth is 20-m below datum. Percent cover was estimated at 60%. The surface of the hull at this site is painted with white paint. The most conspicuous organism is the rock oyster. Other species present include tubeworms, encrusting yellow sponge and lacy bryozoan.

Diversity is lower (eight species) than on the outer hull, although abundance of one particular species, the rock oyster, is high (estimated at 600 per square metre).

Inside wall of accommodation, boat deck: The quadrat was hung from a round hole about one foot from the ceiling on the aft wall of this accommodation area. This site is located on the aft wall of the accommodation area on the boat deck level. The site is subject to very subdued light levels since it is inside the ship. The substrate is the rusted steel bulkhead; depth is 13-m below datum. Percent cover was estimated at 80%. The marine assemblage at this site is dominated by calcareous tubeworms. Also present are barnacles (mostly empty shells), tunicates, snails and bryozoans. Diversity is relatively high (10 species), and abundance of certain species (i.e., tubeworms) is extremely high.

Outer wall of engine room shaft, boat deck: The quadrat was located below the funnel on the port side of the engine room shaft. The quadrat was hung from the lip of the ceiling of the shaft, just below a pipe, which projects vertically. This site is located on the boat deck, on the outer wall of the engine room on the port side. The substrate at this site is painted steel; depth is 13-m below datum. The percent cover was estimated at 50%. The most conspicuous feature of this site is the large number of empty barnacle casings attached to the hull. Almost all of the barnacles are empty shells, possibly the prey of sea stars and snails. There is little other marine life at this site excepting a few tunicates, tubeworms, chitons and tiny patches of calcareous red alga. Both diversity (six species) and abundance are relatively low at this site.

Outer hull on starboard stern: The quadrat was hung from the lower aft corner of the diver entrance hole on the starboard side of the hull at the stern. The quadrat was pushed against the sloping hull to permit observations. This site is located on the curve of the hull at the starboard stern; 16-m below datum. The percent cover was estimated at 80%. This site is dominated by impressive bouquets of parchment tubeworms, which extend out from the hull up to 10-cm. Also observed at this site were tunicates, lacy bryozoans, tubeworms, barnacles and encrusting sponge. This site is fully exposed to the tidal currents, which sweep over the reef site. Both diversity (15 species) and abundance are high at this site."

A biological survey of the *Church* artificial reef was carried out in February 2002 by Carol Valkenier, using the “rove diver” methodology. The reef had been submerged for 10 ½ years when surveyed. A list of the most conspicous species observed and their abundance estimates are shown in Table 10. The total taxa observed were 43 animals and 2 seaweeds, usually identified to genera or species, of which 26 were enumerated as either many (11-100 individuals) or abundant (>100). The most diverse was the molluscs with nine species, followed closely by fishes (8) and arthopods (8). The remaining eight were represented by urochordates (8), echinoderms (8), annelids (3), cnidaria (3), seaweeds (2), brachiopods (1) and porifera (1).

Compared to the reef’s survey about 8 years earlier by Subsea Enterprise, the decline in species richness has been dramatic, from 96 to 45 taxa. Much of this decline was attributed to the fishes (from 20 taxa to 8), anthropods (from 17 to 7) and seaweeds (from 14 to two)(Table 14). Although both surveys occurred at the same time of year, this apparent difference is difficult to explain without more information about other variable factors such as observer bias, observation effort, survey sites and dive conditions (e.g. visibility).

There are narrative report (two are quoted immediately below), often with little detail such as survey dates, on WebPages provided by divers that visit the *Church* artificial reef.

> "She *(G.B. Church)* is now festooned with a diverse population of invertebrates and fish. Large lingcod and octopus can often be found under the ship. The ocean floor around the ship is carpeted with shrimp, as are the decks. Forests of plumose anemones are to be found under the bow and in the bridge. The elusive spiny lump sucker is frequently seen scurrying along the rails. Giant nudibranchs feed on the anemones hanging from the ceiling in the galley. As a maturing artificial reef the ship is taking on the character of a natural reef." (http://www.shallonharters.com/gbchurch.htm).

> "The ship *(GB Church)* was quickly overcome with rich marine life including octopus and wolf eels and today is testimonial to the positive environmental impact that artificial reefs have on the marine ecosystem. Not only do artificial reefs promote marine life, they also reduce diver impact on surrounding natural and historical shipwreck dive sites by diverting diver traffic from those sites." (http://www.artificialreef.bc.ca/dive_sites/).

6.4.2.6 *Saskatchewan* artificial reef

There is one unpublished diver survey of the *Saskatchewan* artificial reef, provided for this report by Carol Valkenier. In fall 1998, she observed a total of 46 species/taxa of conspicuous biota, as listed in Table 11. The numerically important groupings were mollusca (9 species), echinoderms (7), crustaceans (6), urochordates (6), cnidarians (6), fishes (5) and seaweeds (5). Least common were the annelids (1) and porifera (1). Valkenier made no estimates of species abundance.

Comparing the *Saskatchewan* reef findings with that of the other ship reefs (see Table 12), what is noteworthy is the relatively high species richness given the young age of the reef. On the survey date, the *Saskatchewan* artificial reef was only 448 days old. Although these findings have not been statistically analysed, the species richness (46 taxa) was apparently similar to those of the *Columbia* reef (43), *Mackenzie* reef (45) and *Church* reef (45), structures that were from two to ten times older, respectively, when surveyed. Furthermore, the relative species richness within each phyla were also similar for the four reefs, possibly with the exception of the urochordates (tunicates and sea squirts). Valkenier recorded these observations at all three reefs.

In the REEF's Internet database, five recent records of fish observations (Geographical Zone Code 13300101) by divers on the *Saskachewan* reef report that lingcod, quillback and copper rockfish were most frequently observed (Table 13). However the most abundant fish were tubesnout and arrow goby. Other less common fish were longfin sculpin, cabezon, kelp greenling and unidentified sculpins and rockfish (www.reef.org/cgi-bin/georep.pl?region=PAC&geogr=13300101).

Table 9. Comparison of marine biota densities on the *Church* artificial reef, 26 March 1994

Quadrat samples at five sites:

#1/ Outer hull on port bow #2/ Inside wall of hold #3/ Inside wall of accommodation, boat deck
#4/ Outer wall of engine room shaft, boat deck #5/ Outer hull on starboard stern

Species		**Number of individuals per square metre** (Extrapolated from counts per 1/4-metre quadrat, rounded)				
		Site #1	**Site #2**	**Site #3**	**Site #4**	**Site #5**
Horseshoe tunicate	*Chelyosoma productum*	40	--	30	50	40
Hairy stalked tunicate	*Boltenia villosa*	30	<10	--	--	<10
Flattened tunicate	*Ascidia callosa*	<10	--	--	--	--
Peanut tunicate	*Styela gibbsii*	80	--	--	-	200
	Mopalia sp.	--	--	--	<10	--
Rock oyster	*Pododesmus macrochisma*	20	600	50	20	20
Snail	*Margarites* sp.	--	--	50	--	--
Snail	*Trichotropis cancellata*	--	--	--	--	--
Dog whelk	*Nucella lamellosa*	--	--	--	--	<10
Parchment tube worm	*Schizobranchia insignis*	--	--	--	--	100
Plumose anemone	*Metridium giganteum*	--	--	--	--	<10
Calcareous tubeworm	*Serpula vermicularis*	10	100s	100s	--	50
Coiled tubeworm	*Crucigera* spp.	100s	100s	1000s	--	--
Short-scaled eualid	*Eualus suckleyi*	<10	--	<10	--	--
Caridean shrimp		<10	--	--	--	<10
Decorator crab	*Oregonia gracilis*	--	--	--	--	<10
Acorn barnacle	*Balanus glandula*	100s	<10	100s	mostly shells	100s
Bryozoan	*Schizoporella bicornis*	20	<10	80	--	20
Lacy bryozoan	*Phidolopora pacifica*	250	20	<10	--	80
Encrusting demosponge		--	<10	--	--	<10
Red bladed alga		--	--	--	<10	--
Red calcareous alga		--	--	--	10	--

(Taken from Subsea Enterprise 1994)

Table 10. Relative abundance of conspicuous marine biota observed by divers on the *Church* artificial reef, 23 February 2002

Abundance Codes:
S - Single (1); F - Few (2-10); M - Many (11-100); A - Abundant (> 100); P - Present

FISHES:
Copper rockfish *(Sebastes caurinus)* - M
Quillback rockfish *(Sebastes maliger)* - F
Lingcod & eggs *(Ophiodon elongatus)* - F
Scalyhead sculpin *(Artedius harringtoni)* - A
Great sculpin *(Myoxocephalus polyacanthocephalus)* - S
Longfin sculpin *(Jordania zonope)* - S
Striped sea perch *(Embiotoca lateralis)* - F
Tube-snouts *(Aulorhynchus flavidus)* - A

INVERTEBRATES

Urochordata:
Stalked hairy sea squirt
or Strawberry sea squirt *(Boltenia villosa)* - M
Broad base sea squirt *(Cnemidocarpa finmarkiensis)* - M
Horseshoe tunicates *(Chelyosoma productum)* - A
Wrinkled sea squirt *(Pyura haustor)* - M
Stalked solitary sea squirt *(Halocynthia aurantium)* - F

Echinodermata:
Sunflower star *(Pycnopodia helianthoides)* - M
Blood Star *(Henricia leviuscula)* - F
False ochre star *(Evasterias troschelii)* - F
California sea cucumber *(Parastichopus californicus)* - M
Sea urchin (baby) *(Strongylocentrotus sp.)* - F

Mollusca:
Unidentified snails/whelks - A
Lined chiton *(Tonicella lineata)* - M
Lewis' moon snail eggs *(Polinices lewisii)* - F
Leafy hornmouth snail *(Ceratostoma foliatum)* and eggs - M
Hairy triton *(Fusitriton oregonensis)* - M
Pacific pink scallop *(Chlamys rubida)* - M
False Pacific jingle shell *(Pododesmus macrochisma)* - A
Common orange-spotted nudibranch *(Triopha catilinae)* - F
Sea lemon nudibranch *(Anisodoris nobilis)* - F

Brachiopoda:
Lampshells *(Terebratalia transversa)* - F

Arthropoda:
Acorn or thatched barnacle *(Balanus sp.)* - M
Giant barnacle *(Balanus nobilus)* - M
Broken-back shrimp *(Heptacarpus sp.)* - A
Slender decorator crab *(Oregonia gracilis)* - M
Northern Kelp crab *(Pugettia producta)* - F
Heart crab *(Phyllolithodes papillosus)* - F
Bering hermit crab *(Pagurus beringanus)* - M

Annelida:
Calcareous tubeworms *(Serpula vermicularis)* - A
Feather duster tube worm *(Eudistylia vancouveri)* - M
Slime tube worm *(Myxicola infundibulum)* - A

Bryozoa:
Lacy bryozoan *(Phidolopora labiata,*
formerly *Phidolopora pacifica)* - A

Cnidaria:
Delicate plumed hydroids *(Plummularia* spp.) - P
Pink-mouth hydroid *(Ectopleura marina,*
formerly *Tubularia marina)* - F
Giant plumose anemones *(Metridium gigantium)* - M

Porifera:
Unidentified sponges - A

SEAWEEDS:
Iridescent red algae *(Iridea* spp.) - M
Unidentified alga - M

(Valkenier, 2002)

6.4.2.7 *Cape Breton* artificial reef

There are four records of fish observations for the *Cape Breton* reef (Geographical Zone Code 13300103) in the REEF's Internet database (Table 13). Divers report that tubesnout were abundant during all surveys. Much less common and abundant were quillback rockfish, juvenile (young of the year) rockfish and cabezon (www. reef.org/cgibin/georep.pl?region=PAC&geogr =13300103).

6.4.2.8 Other BC artificial reefs

Several studies of other BC artificial marine reefs are relevant here, even though they are not vessel structures and are in shallower waters. The findings are briefly summarized here since Naito (2001) has recently compiled the largely unpublished information from physical and biological assessments of three ship reef complexes and twelve reefs constructed of materials such as rock rip rap, broken concrete, cinder blocks and tires. From these sources and three of the ship reef complexes, he compiled a list of 86 taxa grouped by fishes (18 taxa), crustaceans (4), molluscs (7), urochordates (3), echinoderms (11), annelids (1), cnidaria (7), bryozoans (2), porifera (1), annelids (1), hydroids (2), red algae (17), brown algae (11) and green algae (1). This list may not be complete because the comprehensive inventory report by Birch *et al*. (1990) for Porteau Cove reef complex was not referenced.

Some SCUBA diver observations of fishes, invertebrates and algae are available largely as unpublished reports and internal memos for artificial reefs installed in Nanaimo Harbour and Departure Bay (McElderry 1987, McElderry 1988, Armstrong 1993, Naito 1989, Naito 1991b), French Creek (Naito 1991a), Campbell River (Naito 1988a), Tzartus Island and Ross Inlet in Barkley Sound near Bamfield (Gascon and Miller 1981), Roberts Bank near Vancouver (Roberts Bank Environmental Review Committee 1996) and Burrard Inlet in Burnaby (ECL Envirowest Consultants 1992).

Gascon and Miller (1981) conducted one of the few published studies in BC waters. In 1978, ten cinder block reef structures each 2.4-m x 0.6-m in size were installed in Ross Inlet near the Bamfield Station in Barkley Sound. An experimental study over 1½ years assessed the development of nearshore fish assemblages on these structures, in relationship to adjacent habitats. Divers enumerated individual fishes and estimated the invertebrate and algae abundance at approximately two week intervals. The most abundant of thirty fish species observed on these reefs were black rockfish *(Sebastes melanops),* blackeye gobies *(Coryphotereus nicholsi)* and quillback rockfish, followed by copper rockfish, kelp greenling, canary rockfish *(Sebastes pinniger)* and longfin sculpin *(Jordonia zonope).* The species diversity was largely the same between the artificial reefs and and adjacent rock rubble, with fish colonization occurring more rapidly for those reefs directly contacting the rubble. Seasonal differences were reported; numbers of fish especially rockfishes, greenlings and surfperches increased from winter through summer/early fall. All species were present as both juveniles and adults, with exception of the rockfish *(Sebastes* spp.) observed only as juveniles. Within the study period, the authors concluded that both invertebrate and algal communities became well established, and represented by the following; hydroids *(Obellia* spp.), serpulids (worms), red sea urchins *(Strongylocentrotus franciscanus),* red algae *(Neoagardhiella luetkenana* and *Porphyra* spp.), brown algae *(Costaria costata* and *Laminaria* spp.), green alga *(Ulva* spp.) and encrusting corralline algae.

Table 11. Conspicuous marine biota observed by divers on the *Saskatchewan* artificial reef near Snake Island, Nanaimo, BC, 5 September 1998

FISHES
Scaleyhead sculpin *(Artedius harringtoni)*
Cabezon *(Scorpaenichthys marmoratus)*
Quillback rockfish *(Sebastes maliger)*
Tubesnout *(Aulorhynchus flavidus)*
Sculpin (unidentified species)

INVERTEBRATES

Urochordata
Stalked hairy sea squirt
or Strawberry sea squirt *(Boltenia villosa)*
Broad base sea squirt *(Cnemidocarpa finmarkiensis)*
Transparent sea squirt *(Corella willmeriana)*
Glassy sea squirt *(Ascidia paratropa)*
Sea peach *(Halocynthia aurantium)*
Tall transparent tunciate *(Ciona intestinalis)*

Echinodermata
Sunflower star *(Pycnopodia helianthoides)*
Brittle star *(Ophiopholis aculeata)*
Feather star *(Florometra serratissima)*
Painted star *(Orthasterias koehleri)*
Green sea urchins *(Strongylocentrotus droebachiensis)*
California sea cucumber *(Parastichopus californicus)*
Creeping pedal sea cucumber *(Psolus chitonoides)*

Mollusca
Blue topsnail *(Calliostoma ligatum)*
Ringed topsnail *(Calliostoma annulatum)*
Spiral velvet snail (*Velutina prolongata)*
Pink Pacific spiny scallop *(Chlamys rubida)*
Blue or bay mussels *(Mytilus edulis)*
Jingle shells (*Pododesmus* spp.)

Nudibranchs
Red-gilled aeolid (*Flabellina* spp.)
Salmon-gilled aeolid (possibly *Salmonacea* sp.)
Opalescent nudibrach *(Hermissenda crassicornis)*

Arthropoda
Acorn barnacles (*Balanus* spp.)
Coon-stripe shrimp *(Pandalus danae)*
Brokenback shrimp (*Heptacarpus* spp.)
Skeleton shrimp or caprella amphipod (*Caprella* spp.)
Sea flea (*Amphipod* spp.)
Squat lobster or Calathaeid crab *(Munida quadrispina)*

Annelida
Tiny calcareous tubeworms (unidentified species)

Bryzoa
Encrusting bryozoa (unidentified)

Cnidaria
Wine glass hydroid (*Obelia* spp.)
Sea fir hydroids (*Abietinaria* spp. or *Thuiaria* spp.)
Delicate plumed hydroid (*Plummularia* spp.)
Giant plumose anemone *(Metridium gigantium)*
Short plumose anemone *(Metridium senile)*
Swimming anemone *(Stomphia didemon)*
Sea blubber *(Cyanea capillata)*

Porifera
Tiny vase sponge (*Scypha* spp.)

SEAWEEDS
Turkish towel red algae (*Gigartina* spp.)
Short branching bladed red alga (unidentified species)
Round bladed/branching red alga (unidentified species)
Tall branching red alga (unidentified species)
Green sea lettuce (*Ulva* spp.)

(Valkenier 1998b)

Table 12. Comparison of species richness of conspicuous marine biota observed by divers on five ship reefs in British Columbia waters.

	Church		Mackenzie	Columbia	Chaudiere	Saskatchewan
Location	Near Rum and Gooch Islands, Sidney, B.C.		Near Rum and Gooch Islands, Sidney, B.C.	Near Maude Island, Campbell River, B.C.	Near Kunechin Point, Sechlet Inlet, B.C.	Near Snake Island, Nanaimo, B.C.
Survey date	26 Mar. 1994	23 Feb. 2002	7 April 2001	29 Aug. 1998	2 Sept. 1995	5 Sept. 1998
Age of reef -- in days	959 da	3,849 da	2,030 da	798 da	1,001 da	448 da
-- in years & months	2 yr 7 mo	10 yr 6 mo	5 yr 7 mo	2 yr 2 mo	2 yr 9 mo	1 yr 3 mo
Source	McDaniel (1994)	Valkenier (2002)	Valkenier (2001)	Valkenier (1998)	McDaniel (2001)	Valkenier (1998)
Phyla	**Species Richness (number of observed taxa)**					
Crustaceans- Crabs, shrimp, barnacles, etc	17	7	8	5	3	6
Molluscs- Oysters, snails, nudibranches, etc	14	9	11	11	2	9
Urochordates- Tunicates, sea squirts, etc	9	5	1	2	2	6
Echinoderms - Sea stars, urchins, cucumbers, etc	6	5	6	7	5	7
Annelids - Tubeworms, etc	5	3	1	1	3	1
Cnidarians - Hydroids, anemones, etc	5	3	6	5	2	6
Bryozoans - Moss animals	3	1	1	0	0	0
Porifera - Sponges	2	1	3	2	1	1
Brachiopods - lamp shells	1	1	1	0	0	0
Fishes - sculpins, rockfish, seaperch, ling cod, etc	20	8	5	7	7	5
Seaweeds - red algae, brown algae, green algae	14	2	2	3	0	5
Total	**96**	**45**	**45**	**43**	**25**	**46**

Table 13. Sighting frequency and density of fishes observed by divers on the *Chaudiere*, *Saskatchewan* and *Cape Breton* artificial reefs, as archived in the REEF database

Code	Site	Surveys Expert SA	Surveys Expert SO	Surveys Novice SA	Surveys Novice SO	Bottom Time (H:M)
135904	Salmon Inlet	0	0	2	0	1:18
13590401	Scuttled Chaudiere	0	0	2	0	1:18
TOTALS		0	0	2	0	1:18

%SF = Sighting Frequency; DEN = Density Score help

Click headers to sort and to switch between common and scientific names.

Rank	Common Name	Total SF%	Total DEN	Expert SF%	Expert DEN	Novice SF%	Novice DEN
1	Shiner Surfperch	100%	3			100%	3
2	Quillback Rockfish	100%	3			100%	3
3	Pile Perch	100%	2.5			100%	2.5
4	Yelloweye Rockfish	100%	2			100%	2
5	Lingcod	50%	1			50%	1
Total Species		5		0		5	

Code	Site	Surveys Expert SA	Surveys Expert SO	Surveys Novice SA	Surveys Novice SO	Bottom Time (H:M)
133001	Nanaimo Bay	0	0	8	0	3:56
13300101	Saskatchewan Wreck	0	0	8	0	3:56
TOTALS		0	0	8	0	3:56

%SF = Sighting Frequency; DEN = Density Score help

Click headers to sort and to switch between common and scientific names.

Rank	Common Name	Total SF%	Total DEN	Expert SF%	Expert DEN	Novice SF%	Novice DEN
1	Lingcod	87.5%	1.5			87.5%	1.5
2	Quillback Rockfish	75%	2			75%	2
3	Copper Rockfish	50%	2			50%	2
4	Longfin Sculpin	50%	1.7			50%	1.7
5	Tube-Snout	37.5%	4			37.5%	4
6	Juvenile (YOY) Rockfish	37.5%	2.6			37.5%	2.6
7	Unidentified Sculpin	37.5%	2			37.5%	2
8	Kelp Greenling	25%	1.5			25%	1.5
9	Arrow Goby	12.5%	3			12.5%	3
10	Unidentified Rockfish	12.5%	2			12.5%	2
11	Cabezon	12.5%	1			12.5%	1
Total Species		11		0		11	

Table 13. (continued) Sighting frequency and density of fishes observed by divers on the *Chaudiere*, *Saskatchewan* and *Cape Breton* artificial reefs

		Surveys				Bottom Time
Subset Data		Expert		Novice		
Code	Site	SA	SO	SA	SO	(H:M)
133001	Nanaimo Bay	0	0	4	0	1:57
13300103	Cape Breton Wreck	0	0	4	0	1:57
TOTALS		0	0	4	0	1:57

%SF = Sighting Frequency; DEN = Density Score help

Click headers to sort and ↵ to switch between common and scientific names.

		Total		Expert		Novice	
Rank	Common Name ↵	SF%	DEN	SF%	DEN	SF%	DEN
1	Tube-Snout	100%	3.7			100%	3.7
2	Quillback Rockfish	25%	2			25%	2
3	Juvenile (YOY) Rockfish	25%	1			25%	1
4	Cabezon	25%	1			25%	1
Total Species		4		0		4	

(Source: www. reef.org August 2002)

6.5 Reef production and predation

On both natural and artificial reefs, there are at least three biotic compartments that interact together: (i) sessile communities of seaweeds and invertebrates such as sponges, anemones, barnacles and mussels; (ii) small mobile epifauna such as nudibranchs, seastars, urchins and shrimp; and (iii) large mobile epifauna such as rockfishes. To understand the predator-prey relationships of these compartments, biomass is the most common metric used as an indicator. The numbers (and indirectly biomass) of fish and to a lesser extend mobile invertebrates such as commercially valuble crabs have been widely studied on and around artificial reefs. The biomass present at one time is most often referred to as standing biomass or standing crop. A more exact measure of biomass is productivity, that is the rate of biomass change per unit time per unit area or volume. Such rates are difficult, to measure because of the highly mobile and elusive nature of most reef organisms. Nevertheless productivity has been generally inferred from standing biomass (Bohnsack and Sutherland 1985).

Many studies have reported observations of fishes feeding at artificial reefs, but many others have not. Often these studies only report incidental sightings, but some research is based on stomach content examination. Bohnsack (1989) concludes that added artificial substrate undoubtedly provides a source of additional food for predators, but that it remains to be shown how much new fish biomass is consequently produced, and whether the added biomass is a significant contribution to the size of the areas fish population. He reports evidence that artificial reefs increase feeding efficiency, provide shelter from predation, provide recruitment habitat for settling individuals that would have been lost to the biota otherwise, and increase the production of natural reef environments by creating new space. Bohnsack also concludes that increased fish production will most likely occur at locations isolated from natural reefs, while fish attraction may be more important in locations where natural reef habitats are common and nearby. In their review of reef research, Bohnsack and Sutherland (1985) concluded that, although the ecological basis for artificial reef function is only poorly understood, they do encourage either the aggregation of existing scattered individuals or allow secondary biomass production through increased survival and growth of these new individuals.

As already stated, to really understand whether or not artificial reefs replace, restore or enhance natural habitats, there is a need for meaningful and reliable measurements of the habitats' productivity. Simply put, if and to what degree do artificial reefs, such as scuttled ships, enhance biological productivity. Answers to this question have been attempted by many such as Bohnsack (1987), Polovina (1991), Harmelin and Bellan-Santini (1997), Leeswis *et al.* (1997) and Grossman *et al.* 1997. Some biologists such as Bohnsack *et al.* (1997) report that older artificial reefs with more mature biota assemblages, of growing algal and invertebrate populations have higher densities of fish. But other biologists such as Ambrose and Swarbrick (1989) caution that the presence of high densities of fish even on artificial reefs with abundant foraging habitats does not guarantee that the reefs have increased net productivity, nor can one assume that all the fish on the reef were produced there.

Using a manned submersible with video profiling, Shinn and Wicklund (1989) studied 10 derelict ships, five obsolete oil production platforms and other structures sunk as artificial reefs off south-east Florida. The shallow ship wrecks in depths less than 46-m were heavily encrusted with sponges, gorgoniams, small corals, bryozoa and fleshy algae. Herbivorous fish were observed feeding on the attached algae.

Hueckel and Stayton (1982), who studied the Gedney Island artificial reef in Puget Sound, Washington, reported embiotocids feeding only 5.5% on organisms directly related to the artificial reef. Buckley and Hueckel (1982) also analysed the diets of adult copper and quillback rockfish. The fishes' stomaches averaged a relatively full 50% to 75%, and contained mostly prey items associated with the reefs, such as fish (largely embiotocids), coonstripe shrimp, cancer crab and lingcod eggs. The only diet items from the adjacent sand habitat was a sand dwelling shrimp. This diet analysis also showed that the increased abundance of adult copper and quillback rockfish, measured over several years, was correlated with the successional development of benthic invertebrates on the reef; the researchers concluded that the benthos probably provided alternative prey when the normal forage fish were in low abundance. Quillback rockfish increases appeared to be correlated with increasing reef-associated prey following the proliferation of algal growth.

In the lower Florida Keys, Alevizon and Gorham (1989) studied the effects of artificial reefs on nearby fish communities by experimentally deploying small artificial reefs made of PVC pipe and concrete blocks in water depths 8-10 m on sand plain habitat. After one year, they found that, although the reef arrays covered less than 1% of the study area's seabottom, the reefs resulted in an increase of about 20% in the numbers of adult reef-associated fish mainly lutjanidae (snappers) and haemulidae (grunts), and about two times more fish biomass. Over the same period, there was no measurable increase in sand bottom fish (Labridae and Serranidae). The reef fish species were neither preying directly on the sand-bottom fish, nor competing for food or space. Alevizon and Gorham concluded that, in some regions, artificial reefs can result in a marked increase in number of local resident reef fishes, without notable effects on fishes dwelling in nearby non-reef habitats.

As well as very localized physical effects of artificial reefs on natural sand bottoms in California, Davis *et al.* (1982) found no significant relationship between distance from the reefs, and infauna such as total Crustacea, Polychaeta and Mollusca. However, foraging by reef-associated fishes such as embiotocids, serranids, pomacentrids and scorpaenids produced profound alterations in the epifauna populations of the sea pen *Stylatula elongata.* The sea pen densities were 4-10 m^{-2} before the reefs were established, but within 5 months were virtually eliminated by fish grazing to distances greater than 200-m around the reefs. This was confirmed by observed fish behaviours, fish stomach analyses and experimental control cages. The investigators concluded that the infaunal populations of soft bottom habitats are probably less sensitive to reef-associated disturbances than large, sessile epifauna. However they warn that there are many factors to consider in understanding and predicting the possible effects of artificial reefs on the biota of the natural bottom: size and complexity of the reef, the time elapsed since construction, the foraging behaviour of mobile predators attracted to the reef, the productivity of the flora and fauna attached to the structure, and most importantly the susceptibility and resilience of the natural bottom community to physical and biological disturbance.

Likewise around another quarry rock artificial reef off southern California, Ambrose and Anderson (1990) measured the densities of the infaunal communities mostly comprised of polychaetes (57%) and gammarid amphipods (26%) up to 20-m distant. Among the 15 most common taxa of the 121 observed, eight taxa were motile, six foraged in a restricted area and one was sessile. Regardless of their motility, most of these common species (10 out of 15) were deposit-feeders that ingest sediment and/or detritus and thus are strongly influenced by sediment characteristics. Distance effects within the 20-m zone were detected in only 13% of the different taxonomic and functional groups studied. They concluded that there was no evidence that foraging by reef-associated fishes caused a widespread reduction in infaunal densities near the reef.

In contrast, California research by Prince and Gothall (1976) found that small copper rockfish fed on reef-associated organisms, but larger individuals tended to feed on prey found away from artificial reefs. Off North Carolina, natural hard-bottom reefs that are prominent features along the Atlantic and Gulf coast of North America were studied to determine whether or not the fish and invertebrate predators that use these reef habitats for shelter are dependent on food from adjacent, soft bottom habitats (Lindquist *et al.* 1994; Posey and Ambrose 1994). Posey and Ambrose found significantly higher abundances of total infauna, and of polychaetes, bivalves, isopods and scaphopods, 75 m from the reefs. Bottom feeding fish such as sparidae (porgies), haemulidae (grunts) and carangidae (jacks) decreased in abundance away from the reefs.

A study of secondary productivity by Steimle *et al.* (1999) in lower Delaware Bay USA is particularly informative in terms of the potential enhancement value of an artificial reef. In this case the artificial reef was constructed of sixteen tiered concrete panels, and was much smaller (36-m^2 footprint, 2.7-m height) and shallower (11- to 15-m deep) than a typical BC ship reef. Divers scraped and collect epifauna dominated by blue mussel and the anemone from the reef. Bottom grabs were used to collect infauna samples, largely Atlantic razor clam *(Ensis directus)* and blue mussel, from the adjacent fine sand area. The wet-weight biomass of each prey species or major taxon was converted to its approximate energy (kcal) equivalent using production-to-biomass ratios from the literature. Although there was considerable annual variability, the mean production of natural sand infauna was estimated from 217 to 251 kcal $m^{-2}yr^{-1}$ while the artificial reef epifauna was from 3,994 to 9,281 kcal $m^{-2}yr^{-1}$. Using the 36-m^2 footprint of the reef as a base comparison, the reef’s surface area of 407-m^2 that covered this footprint produced on average 1,610,000 to 3,740,000 kcal yr^{-1} of epifauna. This compares with only 7,830 to 9,050 kcal yr^{-1} per equivalent footprint area for the adjacent sand infauna. The authors concluded that the reef epifauna enhanced the annual secondary productivity of benthic invertebrates in the reef footprint area by three orders of magnitude (several hundred fold).

On the southeast Florida shelf, Eklund (1997) cited in Miller (1999) used standard hollow artificial reef units to test the relative importance of forage and refuge in sustaining reef fish assemblages. The biologist painted half of the units with anti-fouling paint to inhibit benthic forage growth. In addition, half were filled with broken cinder blocks to increase the structural complexity and refuge space. The findings showed that the filled reefs supported significantly greater abundances and species richness of fishes, however, the painted reefs did not differ significantly from the unpainted ones. At least in these marine waters, the refuge space provided by artificial reefs is much more important for fish abundance than the reefs’ benthic forage. By implication, predation on fishes probably limits fish production more so than the fishes’ competition for food.

Chandler *et al.* (1985) compared the fish communities of two equal- sized steel barges sunk for 15 years, 3.3-km off Florida’s Gulf coast, and positioned about 200 m apart in 22-m of water. The only difference between the barges was the condition of their metal plating. Deterioration of metal on one barge, especially its deck, resulted in every compartment being exposed and accessible to fish and invertebrates, whereas the other barge had few holes and thus restricted access to the barge’s interior. As a consequence, the barges’ vertical relief and available space resources differed significantly as measured by substrate rugosity, that is the ratio of reef contour to linear distances. The substrate rugosity was 1.89 and 3.3 respectively for the intact and exposed barges. On average the latter barge had 1.75 times more accessible substrate area than the former barge.

In fact, Chandler *et al.* concluded that the structural complexity of both barges was comparable to that reported on Caribbean coral reefs in the Netherlands Antilles (Luckhurst and Luckhurst 1978); here the mean substrate rugosity was 1.93, with no individual measurement higher than 4.9. The mean abundance of both resident and semi-resident fishes on the exposed barge were about twice as large as those on the intact barge, in both summer and winter. Likewise species richness of resident fish was higher on the exposed barge, by over 1.5 times. The investigators concluded that the greater availability of space allowed the exposed barge to consistently support a larger, more diverse community of resident fishes. The reason why artificial reefs generally support high densities of fishes is not fully understood. Some suggest that this is related to the vertical relief offered by the artificial habitats, or to the relevance of sheltered holes.

Studying artificial and natural reefs in California waters, Pequegnat (1964, 1968), cited in Patton *et al*. (1985) report that abundance and biomass of epimacroinvertebrates increase with increasing bottom relief and elevation above the sand. This would likely apply to sunken vessels that exhibit particularly high vertical profiles.

Leewis and Waardenburg (1991) report that shipwrecks in the North Sea support epifaunal biomass levels between 0.04 kg/m^2 (pioneer hydroids in inshore waters) to 4.1 kg/m^2 for blue mussel communities.

7.0 CONCLUSIONS AND RECOMMENDATIONS

- Since 1980, in BC, sixteen vessels of different sizes ranging from about 10-m to 134-m in length and 15 t to 10,000 t in displacement (with a total displacement of 23,000 t) were intentionally sunk as recreational diving attractions, largely in the Strait of Georgia. Most vessels were placed near urban centres such as Victoria, Nanaimo, Campbell River and Port Alberni largely for economic and recreational reasons. Most ship reefs are situated in water depths of 10-m to 40-m, and usually within 500 m of rocky shores and/or natural reefs. The largest reefs are decommissioned navy ships prepared and sunk by the Artificial Reef Society of British Columbia with the volunteer support of many individuals, groups and associations.

- The sixteen vessels sunk in British Columbia as reefs have a maximum cummulative footprint (or direct impact zone) of about one hectare on the seabottom immediately beneath their hulls. In addition, an additional one to two hectares immediately adjacent to the ship reefs are probably altered to varying degrees, due to ambient light shading, current scouring, sediment deposition, infaunal shifts, foraging predation and so on. The overall total of three hectares or less of direct/indirect adverse effects distributed between more than a dozen sites are considered as localized and not a significant alteration or destruction of benthic habitats, at least in a regional context where subtidal eco-units are typically 10s hectares or more in size.

- Based on world evidence of ship wrecks, the life span of ships made of iron and steel is estimated to be 100 years or more. Thus ships reefs may be considered as permanent features that alter existing benthic habitat. Most ship reefs have been sited on featureless, low relief plains of sand, mud, clay and gravel sediments, and therefore change the benthic habitat locally from soft or coarse substrates to a hard one. Directly beneath the ships' footprint, the infaunal organisms are smothered and the species diversity and animal density are reduced by 15 times or more.

- The high profile (relative to typical reef depths) and steep vertical relief of most ship reefs changes the local circulation by causing upwelled currents that mix the entire water column, probably within a zone of 100s of meters. In turn this can alter the local water properties such as temperature, salinity, turbidity and nutrient levels. Where current speeds are 10 cm/sec or more, pockets of turbulence, vortices and eddies are created downstream of the reef. Limited evidence suggests that this phenomena can provide new shelter for schooling pelagic fishes. Also, by increasing circulation and reducing sedimentation on exposed reef surfaces, habitats may be enhanced for encrusting filter feeders such as tunicates, sponges and tubeworms.

- When vessels are sunk in locales of tidal and other currents, the erosion and accretion of mud and sand alter the nature of adjacent substrates in terms of scour depth, surface rippling, grain size and organic content. Typically this modified zone can be measured up to 10–20 meters away from the sunken reef.

- While artificial reefs, such as sunken ships, may merely attract and concentrate some fish species, they may promote production in species. It is difficult to distinguish how much of the "reef effect" is from increased production, that is greater food availability or reduced mortality, and how much is the consequence of simple attraction from surrounding natural reefs. There is little doubt, however, that sunken ships and other artificial reefs enhance the production of new sessile invertebrate and algal biomasses. This is the result of the immersion of suitably hard and stable surfaces for settling larvae which otherwise would be lost.

- For one to two years or more after construction, most artificial reefs probably do not increase fish biomass even locally, but merely attract biomass from neighbouring natural reef populations located up to 1 to 2 km away. Based on research in Puget Sound, Japan and elsewhere, artificial reefs can eventually support fish densities 30 to 70 times greater than those of nearby natural reefs and adjacent sandy areas, respectively. As well, biologists report fish abundances larger by one and two orders of magnitude, and species richness more than 25% and 85%, often within only three to eight months of reef development. Reasons postulated for this "oasislike" phenomena are many: artificial reefs increase feeding efficiency; provide shelter from predation; and increase the production of natural reef environments by creating habitat.

- Fishes most commonly observed on the larger BC ship reefs are typical inhabitants of natural reef habitats: copper rockfish, quillback rockfish, lingcod, kelp greenling, shiner perch, pile perch, padded sculpin, grunt sculpin and scalyhead sculpin. Copper rockfish were most commonly recorded in largest numbers.

- The time lag for ship reefs to become colonized by fishes such as shiner and pile perch is usually measured in days, because of the immediate attraction and immigration from adjacent natural habitats. For diatoms and invertebrates both motile and some sessile, their colonization also commences relatively rapidly, i.e. within months. Limited evidence from BC ship reefs such as the *Chaudiere* suggests that the species richness reaches a maximum in about two years. However species abundance varies greatly over time. For example, some early *Chaudiere* colonizers such as acorn barnacle and bay mussel disappeared after three years, whereas others like yellow encrusting sponge, padded sculpin, lingcod and quillback rockfish did not become common or abundant for three years after reef development.

- The benthic habitat is altered for decades under and immediately adjacent to the ship-reef's footprint, but is replaced by habitat that is larger in size (volume), higher in vertical relief and more complex in rugosity.

- The functioning of ship reefs as fish habitat can be improved by increasing their structural complexity, by adding more refuge-type materials to the decks and/by providing access to inside compartments. Habitat values can also be increased by siting and orienting the vessels to ocean currents to reduce siltation, to increase water circulation within the reef, and to foster outside eddies and stagnant areas that offer shelter to pelagic fishes.

- Of the BC ship reefs, the *Chaudiere* in Sechlet Inlet and *Church* in Haro Strait are the best studied (repeated surveys over seven years). The Porteau Cove reef complex is the longest studied.

- The species richness for conspicuous plants and animals observed on the four nearly identical ship reefs (the *Saskatchewan*, *Chaudiere*, *Columbia* and *Mackenzie* reefs) and a much smaller one (*Church* reef) varied between reefs by four-fold among reefs, from a low of 25 taxa on the *Chaudiere* to nearly 100 on the *Church*. There was little or no relationship between species richness and the reef's age (ranging from about one to 10 years) or season of survey (from February to September). Phyla most commonly represented by different species were the molluscs (including oysters, snails, nudibranchs), echnoderms (sea stars, urchins, cucumbers), cnidarians (hydroids, anemones) and chordates (fishes). "Before and after" studies were, unfortunately, not carried out.

- Little evidence exists world-wide that productivity of artificial reefs is greater (or less) than the replaced habitats. One experimental study did show that the reef epifauna enhanced the annual net secondary productivity of benthic invertebrates by three orders of magnitude, over the pre-existing natural sand infauna.

- Ship reef developers prefer to sink the vessels quickly using several kilograms of shaped explosives to cut holes in the hulls. No studies of the impact of underwater acoustics have been carried out in BC or other waters. Observations suggest that fish kills and seal disturbance occurred during the *Cape Breton* sinking. Experimental studies and theoretical models published in the literature report that the zones of detrimental effects from shock waves are 200 m or less for herring and other fishes, and 500-m or so for seals and other sea mammals. Some biologists advise that these zones should be doubled to account for uncertainties and variables.

- When sinking ex-navy vessels, reef developers often put on public, wartime-like pyrotechnic displays using black powder, aviation fuel or other explosive/incendiary materials. These produce considerable noise and smoke for several kilometers, as well as flames and heat for 100s of meters. Although relatively localized and temporary, these disturbances frighten locally occurring seabirds and marine mammals such as harbour seals.

- Adverse impacts of ship reef placement can largely be mitigated by careful location and timing of vessels sinking. This is particularly true when they are sited on fine-grained, level-bottom environments in areas that are not important fishing grounds or critical habitat for feeding, breeding and/or migratory fishes and sea mammals such as harbour seals.

Listed in the report's Introduction were some conclusions and recommendations arising from a one-day DFO workshop on scuttling ships as artificial reefs. These have been largely substantiated by this review of the published literature and unpublished information.

The following Recommendations are offered in working to improve the soundness of decision-making and the effectiveness of environmental mitigative measures associated with future ship reef development.

- **The use of pyrotechnics and explosions for public and media display during the sinking events should be discontinued because of the risk to marine mammals and other wildlife.**

- **The practices and procedures of using explosive detonations to sink vessels should be examined more closely, in order to devise means of avoiding or reducing potential disturbance and injury to fishes and marine mammals.**

- **The value and techniques of increasing the structural complexity of scuttled ships should be considered in order to increase habitat complexity.**

- **Potential for detrimental "oasis" attraction of some fish species to artificial reefs may be mitigated by siting ship reefs two or more kilometers away from natural rocky habitats.**

- **Governments together with stakeholders and the public should prepare a Regional management plan for coastal development of artificial reefs involving derelict and surplus vessels.**

- **Research and monitoring to evaluate the effectiveness of ship reefs in enhancing biodiversity and production of BC marine waters should be carried out.**

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10.0 APPENDICES

APPENDIX 1. Request for PSARC Habitat Subcommittee working paper

Date Submitted: April 11, 2001

Individual or group requesting advice: Marine and Estuarine Focus Group

Subject of Paper: Ships as Artificial Reefs – Net Gain, or Habitat Destruction?

Environmental Science Lead Author: Brian Smiley

Habitat Management Author/Reviewer: Mel Kotyk

Rationale for request: Decommissioned and derelict vessels have become objects of choice in creating artificial reefs for recreational and sports diving in British Columbia and other waters around the world. However the scuttling and sinking of vessels not only create new habitats for fish and other marine animals, but also alter or destroy existing habitats and their associated biota. The purpose of the paper is to summarize the existing published and other available information about these habitat effects, in order to improve the scientific basis for estimating the net gain or loss of fish habitat due to scuttled ships. This will help in better guiding habitat managers in determining the numbers, types and locations of scuttled ships that can be approved as artificial reefs.

Question(s) to be addressed in the Working Paper:

- What are the optimal habitat-related requirements of scuttled ships as artificial reefs in terms of depth, substrate, currents and so on.
- How much of these habitats exist in Georgia Strait? Coast wide?
- What proportion of these habitats would be considered a habitat alteration, destruction or disturbance by projected artificial reefs?
- How many scuttled ships are planned or forecasted for BC waters in next the 10 years?
- Will there be a net gain or loss habitat important for the reproduction, survival and migration of utilized fish species?

Objective of Working Paper:

- Identify the key areas, habitats and candidate locations for consideration of an Artificial Reef.
- Quantify the net gain or the HADD (habitat alternation, disruption or destruction) to a fishery.
- To provide scientific support about the quantity and quality of existing marine habitat available as candidate sites for reviewing and approving applications for scuttling vessels as artificial reefs for recreation diving.
- Identify Data gaps and recommend research priorities.

Stakeholders Affected: Habitat managers, recreational divers and charter businesses, tourism industry, local governments, commercial fishers, First Nations, coastal residents, environmental groups

How Advice May Impact future Habitat Management Decisions:

The scuttling of ships as Artificial Reefs is increasing becoming a highly public and desired option for diversifying local economic activity. Habitat Managers are often placed in a position of making decisions and recommendations in the absence of clear scientific evidence on the benefits or detriments of scuttling ships. This paper will assist Managers in determining candidate sites, establishing guidelines and provide some Regional consistency in the review of applications.

Timing Issues Related to When Advice is Necessary

The ex-navy *Cape Breton* is scheduled to be sunk in September 2001, and one to four derelect Chinese migrant ships are scheduled to be sunk in Alberni Inlet earlier in the year.

APPENDIX 2. Department of National Defence surplus vessels on Canada's West Coast

Source: http://www.dnd.ca/ddsal/

The following naval vessels are or will become surplus: (Note that listed dates are subject to change)

BAY Class Patrol Boats:
- HMCS *Miramichi* - available 2000
- HMCS *Chaleur* - available 2000

ANNAPOLIS Class:
- HMCS *Annapolis* - available 2001

Minesweeper Auxiliary:
- HMCS *Morseby* - available 2000

For information regarding the sale of surplus naval vessels, interested parties are requested to contact the Department's Liaison Officer with the Crown Assets Distribution Directorate:

Mr. Jim Hoskins Manager of Operations Public Works & Government Services Canada Crown Assets Distribution Directorate 12C1 Phase III Place du Portage Hull, Quebec, K1A 0S5 Phone: (819) 956-5026 Fax: (819) 956-5165 E-mail: Jim. Hoskins@pwgsc. gc. ca

APPENDIX 3. Status of decommissioned Canadian Navy Destroyer Escorts in Canada

Source: http://www.artificialreef.bc.ca/dive_sites/dde_info.html

HMCS Nipigon, HMCS Gatineau and HMCS Terra Nova in Halifax's Canadian Naval shipyards. They are currently being decommissioned and 'stripped' by the Navy prior to sale by Crown Assets Disposal. (Photo credit - Ian MacCorquodale) (Information updated to December 2000)

Class	Ship's No.	Ship's Name	Commissioned	Paid Off	Disposition
St. Laurent Class					
1	DDE 205	St. Laurent	29-Oct-55	14-Dec-74	Sunk while being towed to the scrap yard, 1980.
2	DDE 206	Saguenay	15-Dec-56	26-Jun-90	Artificial Reef 1994 Nova Scotia
3	DDE 207	Skeena	30-Mar-57	01-Nov-93	Scrapped 1996
4	DDE 229	Ottawa	10-Nov-56	31-Jul-92	Scrapped 1994
5	DDE 230	Margaree	05-Oct-57	02-May-92	Scrapped 1994
6	DDE 233	Fraser	28-Jun-57	05-Oct-94	Museum Bridgewater NS 1997
7	DDE 234	Assiniboine	16-Aug-56	14-Dec-88	Scrapped 1995
Restigouche Class					
1	DDE 235	Chaudiere	14-Nov-59	23-May-74	ARSBC Artificial Reef, Sechelf Inlet, B.C. 1992
2	DDE 236	Gatineau	17-Feb-59	24-May-96	In storage, Halifax, Nova Scotia
3	DDE 256	St. Croix	04-Oct-58	15-Nov-74	Scrapped 1991
4	DDE 257	Restigouche	07-Jun-58	31-Aug-94	Sold by ARSBC to Acapulco Mexico interests Dec 1999. To be sunk early 2001
5	DDE 258	Kootenay	07-Mar-59	18-Nov-95	Sold by ARSBC to Puerto Vallarta Mexico interests Nov 2000. Sinking date to be announced
6	DDE 259	Terra Nova	06-Jul-59	11-Jul-97	In storage, Halifax, Nova Scotia
7	DDE 260	Columbia	07-Nov-59	18-Feb-74	ARSBC Artificial Reef, Campbell River, B.C. 1996
Mackenzie Class					
1	DDE 261	Mackenzie	06-Oct-62	03-Aug-93	ARSBC Artificial Reef, Near Sidney B.C. 1995
2	DDE 262	Saskatchewan	16-Feb-63	01-Apr-94	ARSBC Artificial Reef, Near Nanaimo, B.C. 1997
3	DDE 263	Yukon	15-May-63	12-Mar-93	Prematurely sank off Mission Beach San Diego as artificial reef July 2000.
4	DDE 264	Qu'Appelle	14-Sep-63	31-Jul-92	Sold for scrap
Annapolis Class					
1	DDH 265	Annapolis	19-Dec-64	15-Nov-96	Proposal as floating Museum. No further details available at Feb 2000
2	DDH 266	Nipigon	30-May-64	02-Jul-98	Decommissed July 1998. Used in the Swissair disaster search and recovery September 1998 - destined to be artificial reef near Oshawa Ontario - sinking date to be announced.

APPENDIX 4. Photographs and information about the M.V. GB Church artificial reef

Source:
http://www.artificialreef.bc.ca/dive_sites/

Sunk: Portland Island on August 11, 1991 (48 43.323 N, 123 21.339 W) 175 foot (53 meter) 530 tonne Coastal Freighter (Built in 1943 in Goole, England)

History of the *G.B. Church*

The *G.B. Church*, originally called the *Cerium*, and later the *G.H. Velie*, was built in 1943 in Goole, England and initially served in World War II as a supply ship provisioning the allied effort in Europe. She was part of the D-Day landings. To protect the cargo, fuel and water tanks were built around the hold instead of in the bottom as in other freighters. When the ship came to BC in the sixties it was used for hauling explosives to remote sites up the BC coast for Continental Explosives Ltd, basing it operations from James Island, not far from its current resting place.

After leaving the service of ConEx in 1973 the ship sufferred through a variety of financial troubles and was seized a number of times for non-payment of debts. Bill Church, who owned the ship for most of this period renamed the ship after his father, George Bennett Church.

For the last ten years of her life above water the *G.B. Church* was moored in the Pitt and Fraser rivers near Vancouver, slowly deteriorating through neglect. Her final private owner, Cambie Mortgage Real Estate Services donated the ship to the B.C. Parks branch of the provincial government, who in turn, passed the ship into the hands of the ARSBC together with a $15,000 grant to fund the cost of the artificial reef project. Due to the many hours of volunteer labour and donated services and materials the project's total cost totaled $34,000, and became the first of a series of successful artificial reef projects.

BC's first Artificial Reef!
The *G.B. Church* was the first project of the ARSBC initiated in 1989. It served an important role as a proving ground for the larger and more complex naval artificial reef projects that were to follow. The *G.B. Church* project was completed over a two year period. She was sunk in August 1991

within the Princess Margaret Marine Park off Portland Island near Sidney, British Columbia. Preparation of the ship included stripping out the ship down to the steel, cutting holes for diver access and removing any hazardous obstacles. Diver saftey is a key consideration -- confined spaces are either sealed off or opened up for easy entry and exit.

The final preparation of the ship included cleaning up all environmental hazards including cleaning all fuel and oil lines in the ship and the bilges.

The sinking site was chosen for close proximity to local dive shop operators to enable positive economic spin-offs from the new diving attraction, and for a flat sandy bottom on which to land the ship. All coast guard and navigation requirements were also met with this location.

On this sandy bottom the ship was quickly overcome with rich marine life including octopus and wolf eels and today is testimonial to the positive environmental impact that artificial reefs have on the marine ecosystem. Not only do artificial reefs promote marine life, they also reduce diver impact on surrounding natural and historical shipwreck dive sites by diverting diver traffic from those sites.

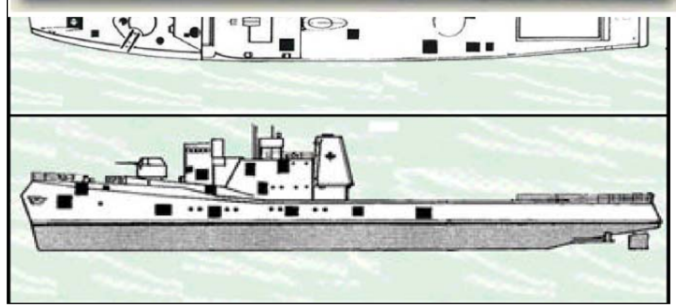
APPENDIX 5. Photographs and information about the HMCS Chaudiere and its artificial reef

Source: **http://www.clever.net/kerry/scuba/ss-site.htm**

Located in Sechelt Inlet off Kunichin Point this is an excellent dive for all avid wreck divers. Laying on it's side means this is a deep dive with the stern at 55fsw and bow at 105fsw depending on tides. Access holes have been cut into the hull and super structure to allow access to the three diveable decks. This 366ft vessel offers many areas for exploration and interior penetration to those qualified. Glassy tunicates are everywhere on this wreck, initially appearing in the first 6 months of being underwater, and this has only attracted more marine life. The *Chaudiere* is a destroyer escort built during the post wars years along with a number of other vessels of this class. Visibility in this area usually averages 30-50ft and has been known to exceed 100ft. This wreck is only accessible by boat. The wreck is marked but 3 yellow marker buoys at the bow, amidships and the stern.

Source:
http://www.porpoisebaycharters.com/diving.htm

In 1992 the *HMCS Chaudiere* was the first destroyer -escort to be sunk to form an artificial reef. Since then "The Chaud", as she is affectionately known, has become home to a diverse community of marine creatures. Having deservedly gained a reputation as one of the best wreck dives on the Pacific Coast, "The Chaud" gets more amazing with each year. Porpoise Bay Charters is the Official Charter and Caretaker of the *HMCS Chaudiere*, having been involved from the initial planning, cleanup and sinking to the ongoing maintenance of the ship and site.

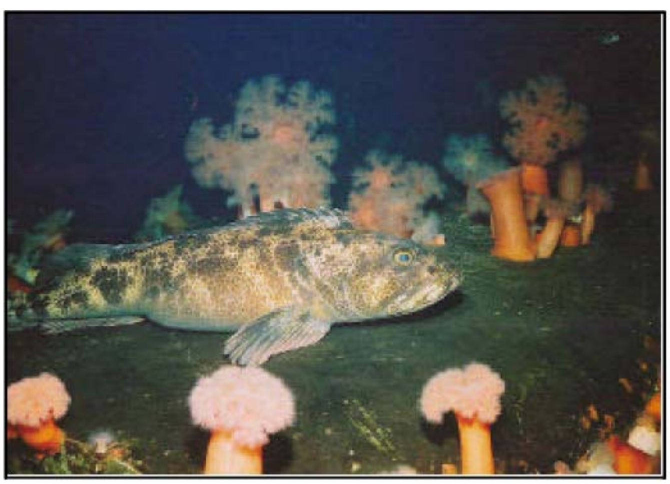


The 366-ft ship settled on her port side (~90^{o}). The deck at the stern is 50-60ft deep, at the superstructure is about 80' and at the bow is 90-100 ft. The bottom at the stern is about 80-ft, at midship is about 110-ft, beneath the guns is about 140' and the bow hangs over a ledge. Large, yellow cautionary buoys (X) are attached to the ship at the stern, mid-ship and bow. Orange and white mooring cans (X) are attached to the ship just forward of the superstructure and mid-mortor bay.

Source: **http://www.porpoisebaycharters.com/hmcs_chaudiere.htm**

APPENDIX 6. Photographs of conspicuous marine life on the HMCS Chaudiere artificial reef

(Source: http://www.artificialreef.bc.ca/Ships/235_Chaudiere/235_RecentPhotos.htm)



APPENDIX 7. Photographs and information about the HMCS Columbia and its artificial reef

Source: http://www.artificialreef.bc.ca/dive_sites/

Sunk: June 22, 1996 off Maud Island near Campbell River, B.C. (50 08.031 N, 125 20.152 W)
366', 2900 ton Restigouche Class Destroyer Escort.

ARSBC's Third Destroyer Escort Project
HMCS Columbia, was the third naval destroyer sunk by the ARSBC as an artificial reef, just nine months after *HMCS Mackenzie*. Again, knowledge gained from two prior destroyer projects further improved the preparation efficiency, budget control, and diver access and saftey features incorporated into the ship. The sponsoring community, Campbell River, B.C. was fully supportive of this project and the community spirit certainly showed on the sinking weekend of June 20th, 1996. A barge with a grandstand was towed to the site, about 9 miles north of the town and was filled to capacity for the sinking. A piper played "Amazing Grace" during the final topside minutes of Columbia. In addition to the explosives used to sink the ship, the crowd was treated to a spectacular display of special effect pyrotechnics that lit the guns of *HMCS Columbia* as a final salute to her tour of duty. She sank to the bottom in 3 minutes and forty-five seconds, bow first, quite similar to the *HMCS Mackenzie* sinking.

HMCS Columbia sits on a rock bottom near Maud Island, not far from Discovery Passage. Maude Island provides excellent protection from the swift currents of the nearby waterways allowing for a spectacular second dive site after timing a slack tide dive at nearby current swept dive sites.

History
The sixth of her class, *HMCS Columbia* was built by Burrard Drydock Co., Ltd., North Vancouver. She was commissioned on 7 November 1959 and soon afterward left for service on the East Coast. On 9 September 1960, Columbia sailed from Halifax to represent Canada at Nigerian independence celebrations. She returned to Halifax on 25 October after steaming 10,500 miles and visiting a number of African ports. In March 1967, she departed Halifax in company with Crescent and Algonquin en route to Esquimalt for duty with Pacific Command.

Decommissioned on 18 February 1974, Columbia served as a stationary training ship in Esquimalt, her propellers replaced with no-thrust "wheels" so that her engines might be run without leaving dockside. In June 1996, she was sunk by the Artificial Reef Society of BC and local Campbell River ARS supporters near Campbell River.

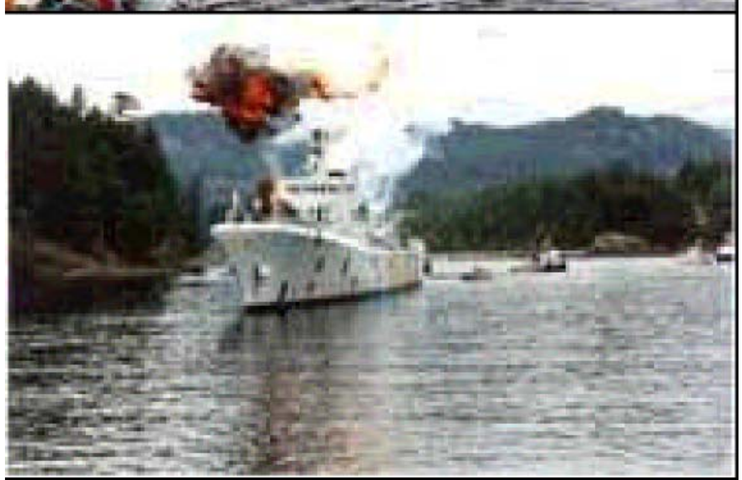
APPENDIX 8. Additional information about the HMCS Columbia and its artificial reef

Source: http://oberon.ark.com/~abyssal/wrecks.html

Our largest wreck, *HMCS Columbia* is a 366-ft. long decommissioned Canadian destroyer that after over a year of preparations was sunk on June 22, 1996.

Now over four years later, the *HMCS Columbia* is well on its way to becoming a thriving artificial reef. Due to the rock bottom the bow of the 2800 tonne ship crumpled like an accordion when it hit the bottom. Many access holes have been cut to open up most of the interior's six decks to properly trained and equipped wreck divers.

Due to shifting debris within the ship we do not recommend penetration. Although the interior may be brightly lit with lots of ambient light when you first arrive, sediment and silt will be lifting and reducing the visibility around you to zero. This is just one of many mistakes that get made around wrecks by novice and "experienced" divers alike. Please respect this warning.



The bow rests at 115-ft and the depth below the stern is 95-ft, the main deck is at about 70-ft, and the top of the super structure comes up to 45-ft. This allows dive profiles to match your skill and comfort level. Although it has a minimal amount of life on it at present, (55 species of plant and animal life) it is increasing daily and will definitely be one of the largest and most intact vessels you will ever see under water! Unlike our other sites it is sheltered from the main current flow to allow dives at any time of day.

In addition we regularly visit a scuttled BC Ferry that has been down about 10 years in less than 50 feet of water and it has a significant amount of life on it.

APPENDIX 9. Photographs and information about the HMCS Mackenzie and its artificial reef

Source: http://www.shalloncharters.com/mackenzie.htm

Named after the Mackenzie River in the Northwest Territories, the *HMCS Mackenzie* was built 1961 at Canadian Vickers Ltd. in Montreal. Commissioned in October 1962, she served as a post war destroyer escort designed for anti-submarine warfare until decommissioned from active service in early 1984. After 1984 she served as a naval officers' training vessel. During her service to Canada the *Mackenzie* steamed over 850,000 miles equal to about 24 times around the earth.

Source: http://www.artificialreef.bc.ca/dive_sites/

Sunk: September 16, 1995 about 150 yards north of Gooch Island (48 40.094 N, 123 17.170 W) located 4 miles (6.4-km) east of Sidney, B.C., in about 100 feet of water. It is an area of sometimes strong current, and visibility averages 25-ft.

The sinking was the largest gathering of watercraft in B.C. History! *HMCS Mackenzie* was sunk on a brilliant September day in 1995 surrounded by more than 1,200 watercraft, aircraft and thousands of well-wishers. She was the second naval destroyer project for the ARSBC and the previous experience from *HMCS Chaudiere* paid off in many ways. The Royal Canadian Navy sent a contingent of ships to mark the occasion and also provided a tender to assist in the final placement of the ship. Six former Commanding Officer's of *HMCS Mackenzie* came aboard the ship prior to the sinking for a final inspection and a toast to the end of her successful 34 year career. As the final ceremony came to a close the flags for Bravo Zulu -- signal shorthand for "well done" were raised to the top of the mast. An old corn broom used in the cleanup of the ship was also fastened to the mast -- a navy tradition to signal a clean sweep.

At approximately 4:30pm the sinking was accomplished in three minutes, forty-five seconds. Four 4 x 6 ft holes had been cut out under the waterline using special explosives placed by members of the Royal Canadian Mounted Police Bomb Disposal unit. The ship landed on the bottom and settled with a 20 degree list to Port. The stern sits on the bottom at 110 feet of water, the bow at 90-ft. Three marker buoys are attached to the bow, bridge and stern of the ship for direct access to the ship from the surface. Moorage buoys are also maintained by the local diving community for private and charter boats to tie up. The site is just north of the USA - Canadian border and about a 30 minute run from the numerous marinas and docks of Sidney, B.C. on Vancouver Island.

APPENDIX 10. Photograph of the sinking of HMCS Mackenzie showing detonation of underwater explosive charges along the waterline and pyrotechnic display on the desks

Source: http://www.shalloncharters.com/mackenzie.htm

APPENDIX 11. Additional photographs of sinking the HMCS Mackenzie

Source: http://www.artificialreef.bc.ca/261_mackenzie/261_sinking.html

APPENDIX 12. Photographs and information about the HMCS Saskatchewan and its artificial reef

Source: http://www.artificialreef.bc.ca/dive_sites/)

Sunk: June 14, 1997 off Snake Island near Nanaimo, B.C. (49 12.96 N, 123 53.070 W) 366', 2900 ton Mackenzie Class Destroyer Escort

HMCS Saskatchewan, the fourth destroyer project and the fifth ship sunk as an artificial reef by the ARSBC was the subject of a International contest to "push the button" and sink the ship. The renowned Cousteau Society sponsored the contest as a fund-raiser to replace its former ship *Calypso* which sank unexpectedly two years earlier in Singapore harbour. *HMCS Saskatchewan* was moored at a Nanaimo pier for two weeks prior to the sinking and was open to tours by the public for a last look prior to being put "into the arms of the sea".

HMCS Saskatchewan was sunk in two steps. On the day prior to the sinking, the engine room was flooded in an attempt to lower the ship's center of gravity. The engine room had been opened up for diver access for the first time of any of the artificial reef projects completed by the ARSBC. Other preparatory work had been completed to reduce the instability caused by air trapped below decks during the sinking. At 10:30am on June 14, 1997 the final holes were cut by members of the Royal Canadian Mounted Police bomb disposal unit -- *HMCS Saskatchewan* sank to the bottom in only 2 minutes and 45 seconds and ended upright with minimal list.

Snake Island is an easy run from Nanaimo and can be easily seen on the approach to Nanaimo from the decks of the BC Ferries which pass near the site. The site has mooring buoys adjacent to the ship and marker buoys attached at the bow, bridge and stern of *HMCS Saskatchewan.*

History

The *Saskatchewan* was launched by the Victoria Machinery Depot Company (hull and superstructure,) and completed by Yarrow Ltd. Esquimalt. She was commissioned on 16 February 1963, at Esquimalt, the second of the Mackenzie class to enter service. She transited the Panama Canal on 30 April, 1963, en route to Halifax where she arrive on 3 June, but left again for the west coast on 20 October, arriving at Esquimalt on 29 November. It had been a busy year for Saskatchewan, with two transits of the Panama Canal, four Atlantic crossings and participation in a major NATO exercise. Late in 1965, she was fitted with an eight-foot square bridge (made of aluminum and glass) atop her regular bridge, as part of an investigation into improved ways of conning a ship. In February 1970, she returned to Atlantic command with the crew of Kootenay, relieving Nipigon as flagship of the (NATO) Standing Naval Force Atlantic. Mike Young, her executive officer during this period, recalls a social gaffe when the pre-wetting system was inadvertently turned on during a quarterdeck cocktail party in St. John's!

The *Saskatchewan* returned to the West Coast in 1973. She commenced her DELEX (Destroyer Life Extension) refit on 27 May 1985 and returned to service on 17 June 1986. That August she was part of a Canadian squadron, which visited Australia for the RAN's 75th birthday celebrations. In her final years, the *Saskatchewan* was a member of Training Group Pacific, instructing as many as 40 officer cadets at a time in the finer point of ship-handling, navigation, and marine and combat systems engineering. The ship completed a minor refit in 1990, which included the installation of an environmentally safe black-water system designed to reduce ship-generated pollution. She was decommissioned on 28 March 1994.

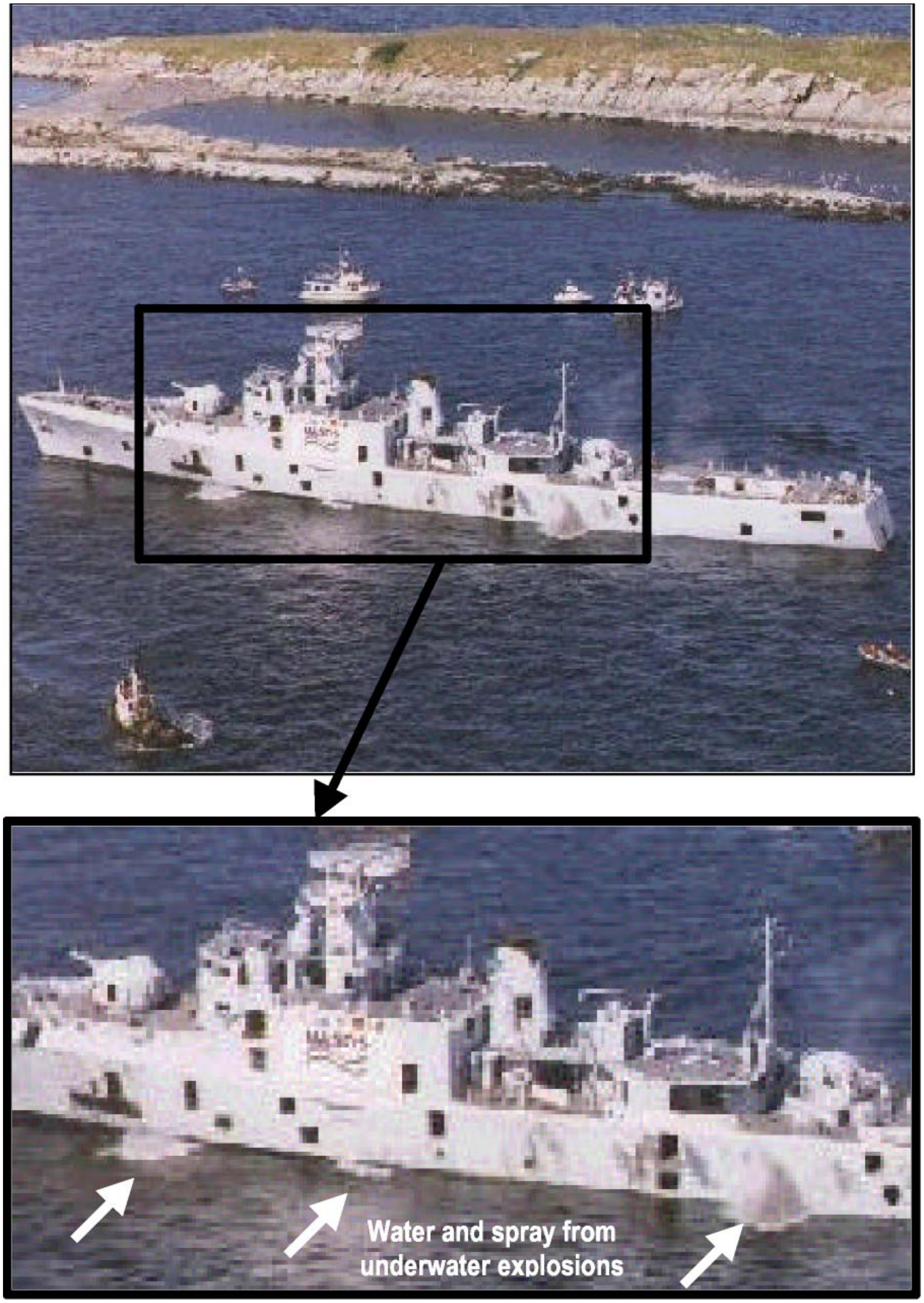
APPENDIX 13. Additional photographs of sinking the HMCS Saskatchewan artificial reef

Source: http://www.oceanexplorersdiving.com/hmcsask.html

Source: http://www.artificialreef.bc.ca/262_saskatchewan/262_sinkday.html

APPENDIX 14. Photographs showing the underwater explosions used to sink the HMCS Saskatchewan

Source: http://www.oceanexplorersdiving.com/hmcsask.html



APPENDIX 15. Photographs and information about the HMCS Cape Breton and its artificial reef

Source: http://www.artificialreef.bc.ca/news.html Breton

Site Selection for the sinking of *HMCS Cape* announced.

VANCOUVER and NANAIMO, BC – The partnership of The Artificial Reef Society of British Columbia, the Nanaimo Dive Association, and Tourism Nanaimo today announced British Columbia's next artificial reef will be placed Saturday, October 20th, 2001 off Nanaimo, BC. The Society has obtained the former Canadian Navy Victory ship, *HMCS Cape Breton*, for use as an artificial reef in British Columbia.

The artificial reef *HMCS Cape Breton* will be located at Snake Island, 3 kilometers east of Departure Bay in Nanaimo. The target depth for the deck of HMCS Cape Breton is 60 to 65 feet making it more accessible to divers' at shallower depths. Two sites were considered: Snake Island and Tinson Point off Gabriola Island.

HMCS Cape Breton was constructed at the Burrard Dry-Dock in North Vancouver, in 1944, measuring over 440 feet in length and more that 55 feet across. The ship displaces more than 10,000 tones.

"HMCS Cape Breton will be one of the world's largest artificial reef," commented James Straith, President of the Artificial Reef Society of British Columbia. "The *Cape Breton* project crowns a program begun 10 years ago in British Columbia waters."

"HMCS Cape Breton will confirm Nanaimo as the premier wreck dive site in North America," said Ian Hall, President of the Nanaimo Dive Association. "We look forward to welcoming the world to our ocean."

"While the actual sinking will be a memorable event, it's the long term marketing opportunities that are important to tourism," said Dave Ilyn, President of Tourism Nanaimo. "Over the last four years, the marketing partnership between Tourism Nanaimo and the Nanaimo Dive Association has proved very successful. Divers are visiting Nanaimo from around the world, and the external media attention has been considerable" adds Ilyn.

Scuba tourism is a growing industry in British Columbia. Christened "the Emerald Sea," by Captain Jacques Cousteau, the Straight of Georgia is home to five purpose placed ARSBC projects including *HMCS Chaudiere* near Sechelt, *HMCS Columbia* near Campbell River, *HMCS Mackenzie* and the *G.B. Church* near Sidney, and *HMCS Saskatchewan* near Nanaimo.

APPENDIX 16. Additional information about the HMCS Cape Breton

Source: www.artificialreef.bc.ca/news.html

Cutting up our heritage: Cape Breton pieces will remind the future of Canada's wartime past

Jan-Christian Sorensen *jsorensen@nsnews.com*

The Artificial Reef Society of B.C. (ARSBC) is preserving a piece of Lower Lonsdale history by tearing it apart. The wartime Victory ship *HMS Flamborough Head* -- later *HMCS Cape Breton* -- was completed at the old Versatile Shipyard site in 1944-45. In a daunting project led by the ARSBC, the stern of the 441-foot vessel will be separated from the ship and affixed to the front of the former Versatile machine shop. It'll be the cornerstone of the redevelopment proj ect planned for the yard -- a hands-on exhibit in honour of the shipbuilders who constructed the vessels and the soldiers who served on them. Patrons will be able to tour the cross-section's five levels and stroll out on the deck of the ship, which will offer a breathtaking view of the Inlet and downtown Vancouver.

The remaining bulk of the ship will be cleaned up and then sunk as an artificial reef for divers off either Snake Island or at Tinsom Point off Gabriola. The aft-end of the ship will be transported to Nanaimo this summer and then sunk later in October. Crews were hard at work this week separating the two sections of the ship. During a media tour led by ARSBC president Jay Straith and North Vancouver Museum and Archives director Robin Inglis on Wednesday, workers had fully sliced through most of the ship and only a few I-beams secured the two halves. The stern section was expected to be moved late this week.

The ships were constructed as part of a massive shipbuilding effort to supply a convoy system to break through Hitler's U-boat campaign against Allied supply routes. During the war, Canada constructed 402 of the merchant type vessels, 253 of which were built on the West Coast. During the war, Burrard Dry Dock had two yards -- one on the north and one on the south side of the Inlet, where 109 vessels were assembled and launched. North Van Ship Repairs built 55 on the site where Lonsdale Quay now stands and another 54 were constructed by West Coast Shipbuilders in False Creek. Over 12,000 men and women worked at the Versatile yards during the height of the war effort.

Only four Victory ships have been saved: The *Cape Breton*, the *SS Jeremiah O'Brien* and *SS John W. Brown* in the U.S. and the *HMS Rame Head* in England. From 1945 to 1951 *HMS Flamborough Head* served as a Royal Navy fleet maintenance and repair ship, after which it was transferred to the Royal Canadian Navy as *HMCS Cape Breton.* Until it was retired from naval service in 1994, it was used primarily as an escort maintenance vessel and training ship out of Halifax, N.S. and Esquimalt, B.C. The *Cape Breton* would have likely become "razor blades," says Straith. That was until his organization purchased the vessel for $20,000.

"In a perfect world there would have been the financial resources to preserve this as a working ship," said Straith. "But that would have cost about 17 million dollars. This is part of Canada's marine heritage which has been lost and a reminder of the past of the West Coast Shipping industry -- the contribution it made to this country and the world and hopefully a good reminder of where it should go in the future." Straith himself has become quite well-acquainted with the history of the Victory ships, and specifically the *Cape Breton.* "I sort of figure I've become the Bob Vila of old warships," joked Straith. "Except Bob Vila doesn't sink his houses."

The most impressive feature of the vessel, though, is the three-cylinder, triple expansion steam engine -- which will become a working centrepiece of the public concourse within the Machine Shop. The direct drive engine is a mammoth piece of machinery; an imposing behemoth with two-foot-diameter piston rods and a height of two-and-ahalf storeys.

"We felt it would have been criminal to sink this ship with this engine in it. It's an important piece of heritage," said Straith.

The engine will be lifted out by crane this week and transported by barge to the site. Straith said the ARSBC has plans to erect two statues on the separate pieces -- one on the landlocked stern to commemorate the soldiers and shipbuilders and one on the sunken portion to honour the dead who served on the ships.

Quoted from the North Shore News, North Vancouver BC

APPENDIX 17. Photographs of the sinking the HMCS Cape Breton

Source: http://www.artificialreef.bc.ca/Ships/100_CapeBreton/100_SinkingDay.htm

Note: The arrows point to visible effects of underwater explosions used to sink the ship.

(Source: Courtesy of B. Smiley DFO)

APPENDIX 18. Information about the Nakaya artificial reef within the Porteau Cove complex near Vancouver, BC

Source: http://www.diveandsea.com/pollier_pass.htm

The Nakaya is at the northern edge of Porteau Cove Provincial Park in northern Howe Sound. It is marked by a square wooden float with a wooden dive flag fixed to one corner. Divers can enter from the lower parking lot at the provincial park and snorkel about 200-m to the wreck or park in the pull out on the east side of Hwy 99 just north of the park, gear up, carefully cross the hwy, climb very carefully down the steep rocky embankment, and then snorkel 25 meters to the wreck. Descend the float chain to 35-ft, where it branches in 3 directions. Drop straight at this point for 20 - 30 feet and you are now on the aft section of the wreck, or follow the thin yellow line from the chain to the aft section of the wheel house.

The Nakaya is a wooden 125 foot long former mine sweeper that saw service as a fish packer and floating bunkhouse for tree planters. It was scuttled in 1985 as an artificial reef for divers. It lies on a north/south line slightly on its side, with the bow in 95-ft and the stern in 50-ft at low tides. The hull is still intact, although sections of the starboard side and most of the stern decking are noticeably eaten away and decay is evident in other areas. The vessel is an eerie site in the dark muddy world under the waves.

A tour of the Nakaya can be accomplished on one tank, although the depth makes it a quick tour. Some fittings remain on the upper deck, particularly on the bow section, and steering gear is visible through the decaying aft decking. The rudders are partially buried in the muddy bottom of the cove. On the port side aft is a small workstation, part of which has fallen into the mud off the port side. The bridge accommodation spaces, work spaces, and breezeways remain intact, but penetration below decks is not advised because of the instability caused by years underwater. With a powerful lights, divers can see all the spaces with the wreck from the outside. The Nakaya is dangerous to enter without proper training and equipment.

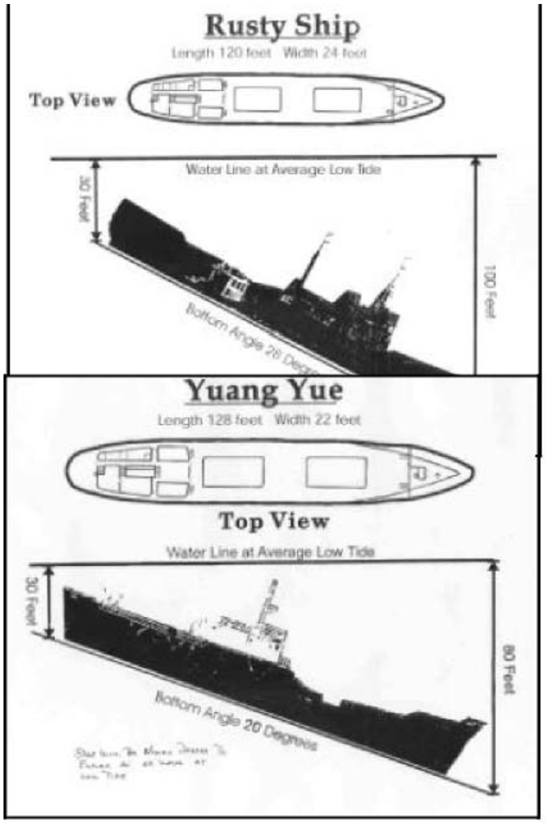
A small variety of marine life lives on the Nakaya. Calcareous tube worms coat the sides. Shrimp and galathaeid crabs hop about the decks. An occasional long ray star or plumose anemone can be spotted. Rockfish and lingcod drift lazily over the decks.

Porteau Cove is a Provincial Marine Park located north of Lions Bay on Hwy #99. This is a great site for diving and is known for the shipwrecks it has to offer. One wooden wreck called the Nakaya is great to dive on and has many lingcod which call the old timbers home.

APPENDIX 19. Photographs and information about the migrant Chinese vessels at Port Alberni, British Columbia

Source: http://www.usbc.org/info/canada/0200reefs.htm

Rusted ships used by illegal migrants to reach B.C. to become tourist and diving attractions as artificial reefs February 22, 2000.



VICTORIA (CP) - The rusted ships that brought hundreds of Chinese migrants to Canada looking for a new life will themselves have a new existence as a tourist and diving attraction. The Restigouche Reef Society of Port Alberni, B.C., paid $1,000, plus taxes, for the four dilapidated hulks that will eventually be sunk as artificial reefs, society spokesman Brooke George said Monday. The four ships brought almost 600 migrants, most from the Fujian province in China, to the B.C. coast last summer and fall. The ships were seized by the Immigration Department and were declared forfeited when their owners did not come forward. They were put up for sale by the federal Public Works Department as surplus assets, which are offered for sale first to non-profit organizations. The successful bidder had to met with stringent provincial and federal environment regulations.

The only other bidder was the Artificial Reef Society, a non-profit society based in New Westminster, B.C., that has become the unofficial North American expert on the sinking of ships. The Artificial Reef Society told the federal government that it would have to be paid to take the ships off the government's hands. "We took a look at the environmental liabilities of the ships and we felt the government would have to pay us to take them," said society president Jay Straith. He estimated it will cost $20,000 to $25,000 to clean up each ship to meet the stringent federal and provincial environment regulations that govern responsible sinking of such vessels.

The Artificial Reef Society has sunk five destroyers and five other ships in British Columbia and has also acted as consultants to several other countries. George acknowledged that the Restigouche society hasn't sunk a ship of such a large size, but said the guidelines are clear and the society feels it can meet them. There are significant economic spinoffs to having the boats sunk as artificial reefs, he said.

“A ship sunk off Nanaimo, B.C. has had 25,000 dives on it in three years”, George said. He said the society has some tentative sites picked out, but they have to be approved through a public process that gathers input from user groups. "We're thinking of sinking three in the confines of the Alberni Inlet," he said. The fourth may be put in the Sechart Channel, in the middle of Barkley Sound, George said. Three of the ships are about 38 metres long and were fishing vessels. The fourth is 64 metres and was a catcher boat, which would take product in from the fishing vessels.

APPENDIX 20 Additional information about the migrant Chinese vessels scuttled as reefs

From: Taylor Paterson [mailto:whosonfirst@telus.net]
Sent: Wednesday, May 16, 2001 1:30 PM
To: To All My Clients & Friends
Subject: June 10, A SPECTACULAR CHINESE TWO SHIP SINKING CEREMONY IN CHINA CREEK, Vancouver Island, Canada

Hello to all,
This is . . . a once in a lifetime event. Two of the four captured Chinese immigrant ships, "Big Red" & "Babe" nicknamed for their "RUSTACULAR" COLORS are scheduled to be sunk as artificial reefs, June 10th, by the Alberni Reef Society. Please spread the word to as many friends as possible. Local, national & international media too. These two sister ships & their unique stories *were* going to be quietly sunk with little fanfare. Between Sven, myself, our circle of friends, and your circle of friends, we can all, make this little known piece of paradise. An Event for everyone to come to be. A part of a fond farewell to these Far Eastern Ladies of the Sea. Come & share in this once in a lifetime ceremony. It's only one of the many Secrets & Treasures of Port Alberni . . . "Portico to the Pacific Rim"

Please contact myself or Sven at (250) 723-3057 fax 723-6817 or divectr@cedar.alberni.net for any questions, suggestions, participation, accommodations, transportation, interviews, press releases, pictures etc. Please read this attachment for more details …Taylor Paterson

"BIG RED" & "BABE" ready to R.I.P June 10
China Creek, just 15 minutes from Port Alberni, will be the final resting place for two travel weary fishing trawlers. How they made it here is unbelievable. The hulls are paper thin, almost transparent. You should really see for yourself. The first time I saw them, I coudn't figure out how or why they were still floating. These two Far Eastern ladies performed their last swan song of dedicated service in 1998. It's a mixed story of courage, sorrow, & anger. All in the hope for a better life. Somehow, bordering on the miraculous, each delivered over 130 hopeful "new" Canadians crammed into cargo holds. No one is sure of the number of people who didn't complete this desparate journey for freedom.

Sven Juthans, Vice President of the Alberni Reef Society informed me, "The sinking of these two ships is a ceremony of "Giving Back to the Sea", a celebration of thanks for all the gifts & treasures she shares with everyone who comes to enjoy her emerald waters." "Everything is in place for the sinking of vessels, we're just waiting for the final inspection (expected in the next few days). Once the OK is received, Port Alberni, "Portico to the Pacific Rim", will be the only shore access Artificial Reef Wreck Dive Site with these unique services, in the Emerald Seas of BC!"

Affectionately renamed by the locals for their vibrant colors, "Big Red" was built in 1950 (presumed Russia) is a 120-ft long, 24-ft beam & 165-ton trawler with large aftdeck cargo holds. "Babe" renamed for her bright, baby blue color and after Paul Bunyon's Ox weighs in at 184 tons, 128-ft long and 22-ft beam, was built in China in 1963 with large cargo holds on the foredeck. Both boast easy, comfortable access to the wheelhouses, cabin, galley and engine rooms. "They will be an awesome addition to an already great, little known, shore dive ", beams Sven.

China Creek is already home to a tug, sailboat, a telephone booth (quarters only) and a great wall dive, all around 50-ft deep. A fantastic spot for night dives. Shining, peeping prawns come up nightly to 30-ft. If you're paranoid of always being watched . . . don't go here. Visibility averages 60-ft plus year round, with little or no current. A huge variety of creatures, swimming scallops, baby to 12-ft+ octopus, six gills, grunt sculpins, decorated war bonnets, kelp greenlings, rockfish and juvenile wolfeels lay claim to this watery wonderland.

The vessels will be laid to rest 600-ft apart, approximately 150-ft from shore, gently sloped with the bows at 40-ft and sterns at 75-ft depth levels. "The shallow resting places will allow great light penetration in the wrecks and provide peeks for snorklers, kayakers and the like.

Hopefully it will entice people to take up scuba diving while promoting the industry as an active participant in the preservation and protection of the environment. It allows easy, affordable access for every level of diver" Sven goes on to say, "With the addition of "Big Red" and "Babe" to China Creek, the area will give the diver at least five fantastic, diverse dives! All within a stones throw from the beach! That's one full weekend!"

APPENDIX 21. Photographs of the pyrotechnic display and underwater explosions during the sinking of the decommissioned military vessel Swan in Australia.

Source: www.members.ozemail.com.au/~diving/articles/hmasswan.htm