COSEWIC
Assessment and Update Status Report

on the

Northern Abalone
Haliotis kamtschatkana

in Canada

ENDANGERED
2009

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-953-3215
Fax: 819-994-3684
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

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COSEWIC
Assessment Summary

Assessment Summary – April 2009

Common name
Northern Abalone

Scientific name
Haliotis kamtschatkana

Status
Endangered

Reason for designation
Highly valued for its meat, this marine mollusc is patchily distributed along the west coast of Canada. Despite a total moratorium on harvest in 1990, the species was designated as Threatened in 2000. Poaching is the most serious threat and continues to reduce population abundance, particularly the larger, more fecund component; however, all size classes have declined significantly over the past three generations (i.e. since 1978) with mature individuals declining an estimated 88-89%. Low densities may further exacerbate the problem by reducing fertilization success in this broadcast spawner (the Allee effect). Although predators such as the recovering Sea Otter population are not responsible for recently observed declines, they may ultimately influence future abundance of abalone populations.

Occurrence
Pacific Ocean

Status history
Designated Threatened in April 1999. Status re-examined and confirmed in May 2000. Status re-examined and designated Endangered in April 2009. Last assessment based on an update status report.

COSEWIC
Executive Summary

Northern Abalone
Haliotis kamtschatkana

Species information

The Northern Abalone, *Haliotis kamtschatkana* Jonas 1845, is the only species of abalone commonly occurring in Canada. There is only one genetically uniform population along the coast of British Columbia. Northern Abalone are recognized by their low ear-shaped shell with irregular lumps and 3-6 respiratory holes on projections. A groove usually parallels the line of holes. The exterior shell colour is usually mottled reddish or greenish with areas of white and blue. The interior of the shell is pearly white with faint iridescence of pink and green without a muscle scar. The large foot is usually tan surrounded by an epipodium (a sensory structure and extension of the foot that bears tentacles) that is somewhat vertically striped and has a delicate lacy appearance.

Distribution

The Northern Abalone is found off the west coast of North America along exposed and semi-exposed rocky coastlines from Sitka Sound, Alaska, to Turtle Bay, Baja California. In Canada, this species can occur on all coastal areas of British Columbia where appropriate habitat is available.

Habitat

Northern Abalone occur in a wide range of habitats from fairly sheltered bays to exposed coastlines in a patchy distribution on hard substrate in intertidal and shallow subtidal waters. They require full salinity (>30 ppt) seawater, good water exchange and a source of macro-algae, particularly kelp, as food. The presence of encrusting algae is also important for settlement. Currently, there is ample habitat available for Northern Abalone on the coast of British Columbia.

Biology

Abalone aggregate in shallow depths to release their gametes in the water column; fertilization success depends on the local density of adults. The planktonic phase of the Northern Abalone is short and temperature-dependent (10-14 days at 14-10ºC). Settlement is thought to occur on encrusting algae. Juvenile abalone become sexually mature at shell lengths between 50 and 70 mm which requires 2-5 years of growth. Abalone growth can vary considerably between areas depending on the extent of exposure to wave action and availability and quality of food. As juveniles approach maturity, their diet changes from benthic diatoms and micro-algae to drift macro-algae. The majority of juvenile Northern Abalone (10-70 mm shell length) are found in crevices and other cryptic habitats, whereas the majority of adults (>70 mm shell length) occur on exposed rock surfaces. Major natural predators of Northern Abalone include Sea Otters, crabs, octopus, some fishes and Sea Stars (especially *Pycnopodia helianthoides*).

Population sizes and trends

Surveys have provided a time series of abalone densities and size frequencies from the southeast Queen Charlotte Islands (Haida Gwaii) and the central coast of British Columbia every 3-5 years from 1978 to 2007. Since 1978, abalone densities have declined by 83% on the central coast and by 81% in the Queen Charlotte Islands (approximately 3 generations). The mean total abalone density declined from 2.40 to 0.40 abalone/m^2 for the central coast between 1978 and 2006, and from 2.22 to 0.43 abalone/m^2 for the Queen Charlotte Islands between 1978 and 2007. During the same periods, the mean mature (≥70 mm shell length) density decreased from 2.13 to 0.23 abalone/m^2 for the central coast and from 1.28 to 0.15 for the Queen Charlotte Islands. Immature densities declined from 0.27 to 0.18 abalone/m^2 and from 1.39 to 0.27 abalone/m^2 for the central coast and the Queen Charlotte Islands, respectively. Proportionally, the densities of mature abalone decreased more rapidly than that of small individuals. Other surveyed areas have even lower density estimates. There is no evidence of population recovery in British Columbia since the fishery closed in 1990. It is not known what the natural state of the Northern Abalone population may have been prior to the extirpation of Sea Otters. With the re-introduction and recent expansion of Sea Otter populations, restoration of Northern Abalone populations to the levels seen in the late 1970s will probably not be possible.

Limiting factors and threats

The Northern Abalone is particularly vulnerable to harvest because mature individuals tend to accumulate in shallow water and are easily accessible to harvesters. Continued illegal harvest and low recruitment levels due to reduced spawner densities have had predominant and widespread impacts and are considered to be the most significant threats to recovery.

Special significance of the species

The Northern Abalone is the only species of abalone which commonly occurs in British Columbia and is the most northerly distributed of all abalone species. Abalone were important not only as food to coastal First Nations peoples, but also played an important part in their spiritual and cultural society. The closure of all abalone fisheries resulted in the loss of this resource for First Nations as well as the loss of income for commercial harvesters and recreational opportunities for sport divers.

Existing protection or other status designations

Fisheries and Oceans Canada closed (*Fisheries Act*) all abalone fisheries in December of 1990 due to concerns about low population numbers. Despite the harvest closure, numbers remained low and in 2000 Northern Abalone was designated as 'threatened' by COSEWIC. In June 2003, Northern Abalone was legally listed and protected as threatened under the *Species at Risk Act* (SARA).

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2009)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

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The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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2009

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SPECIES INFORMATION

Name and classification

Abalone are currently grouped into the monogeneric family Haliotidae (Phylum Mollusca, Class Gastropoda, Order Vetigastropoda) (Ponder and Lindberg 1997) consisting of 55 described species with a world-wide distribution in tropical and temperate waters of both hemispheres (Geiger 1999). Along coastal regions of the eastern North Pacific Ocean, from Baja California to Alaska, there are seven *Haliotis* species, many of which coexist in the waters off California and northern Mexico. The Northern Abalone, *Haliotis kamtschatkana* Jonas 1845, is the only species of abalone commonly found in Canada. Very rarely, specimens of red abalone, *H. rufescens*, have been found off the coast of western Canada (Campbell pers. comm. 2008). Cox (1962) and Haaker *et al*. (1986) also list the flat abalone, *H. walallensis*, as occurring in Canada, but Geiger (1999) lists no such records in his review of abalone taxonomy.

The term ‘northern’ is used as the species is the most northerly distributed of all abalone species (McLean 1966). In the western United States, the species is known as ‘Pinto’ Abalone. The French name is ‘Haliotide pie’ under the SARA (*Species at Risk Act*) Public Registry. While Montfort (1810) originally used the term ‘haliotide’, the more appropriate name is ‘ormeau nordique’ (plural: ‘ormeaux nordiques’) which is similar to the appellation used in France (Clavier and Richard 1986; Foucher and Cochard 2005). ‘Ormeau’ is used in most, if not all, Fisheries and Oceans Canada translations (e.g., Campbell 2000b; Withler *et al*. 2001). Several Aboriginal names for abalone were gathered from the published literature and Abalone Recovery Implementation Group (AbRIG) meetings (Table 1).

Table 1. First Nations names for Northern Abalone in British Columbia.

First Nation	Name	Reference
Haida	G̲álg̲alh iiyán	Ellis and Wilson 1981
Huu-ay-aht	ʕapsy’in	BMSC 2007
Heiltsuk	Ǧatǧ’ni’q	Carpenter pers. comm. 2007
Manhousat	7̲apts7̲in	Ellis and Swan 1981
Nisga’a	Bilaa	Stewart pers. comm. 2007
Tsimshian*	Bilhaa	Sm’algyax Language Committee 2005

*Tsimshian Nation includes Kitasoo/Xai Xais (Klemtu), Gitga’at (Hartley Bay), Kitkatla, Metlakatla, Allied Tribes of Lax Kwa’laams, Kitselas and Kitsumkalulm First Nations

McLean (1966) and Geiger (1999) recognized two subspecies: Northern or Pinto Abalone, *H. kamtschatkana kamtschatkana,* and Threaded Abalone, *H. k. assimilis* Dall 1878 (see **Global range** for distribution of these two forms). Conversely, Cox (1962) considered them separate species, *H. kamtschatkana* and *H. assimilis,* respectively. Regardless, current taxonomists regard the two subspecies as geographic extremes of a single species (Geiger and Poppe 2000).

Morphological description

Like all *Haliotis* species, Northern Abalone has an ear-shaped shell with a large body whorl, small spire and a row of shell perforations above the respiratory cavity (Figure 1) (McLean 1966; Haaker *et al*. 1986; Fisheries and Oceans Canada 2007). The exterior shell colour is usually mottled reddish or greenish with areas of white and blue. An orange shell variant is sometimes encountered. There are 3-6 open holes on tubular projections. A groove usually parallels the line of holes. Irregular lumps are superimposed over a spiral sculpture of broad ribs with weak spiral ribs in interspaces. The interior of the shell is pearly white with faint iridescence of pink and green without a muscle scar. The large foot is usually tan. The epipodium (a sensory structure and extension of the foot that bears tentacles) is a mottled pale yellow to dark brown colour, with a pebbly appearing surface and lacy edge. The epipodium tentacles are yellowish brown, or occasionally green, and thin (Figure 2). The Northern Abalone has a flat, elongate shell with rugose surface, while the Threaded Abalone has a high, rounded shell with little rugose sculpture. There is some indication that shell form is partially dependent upon temperature conditions (McLean 1966).

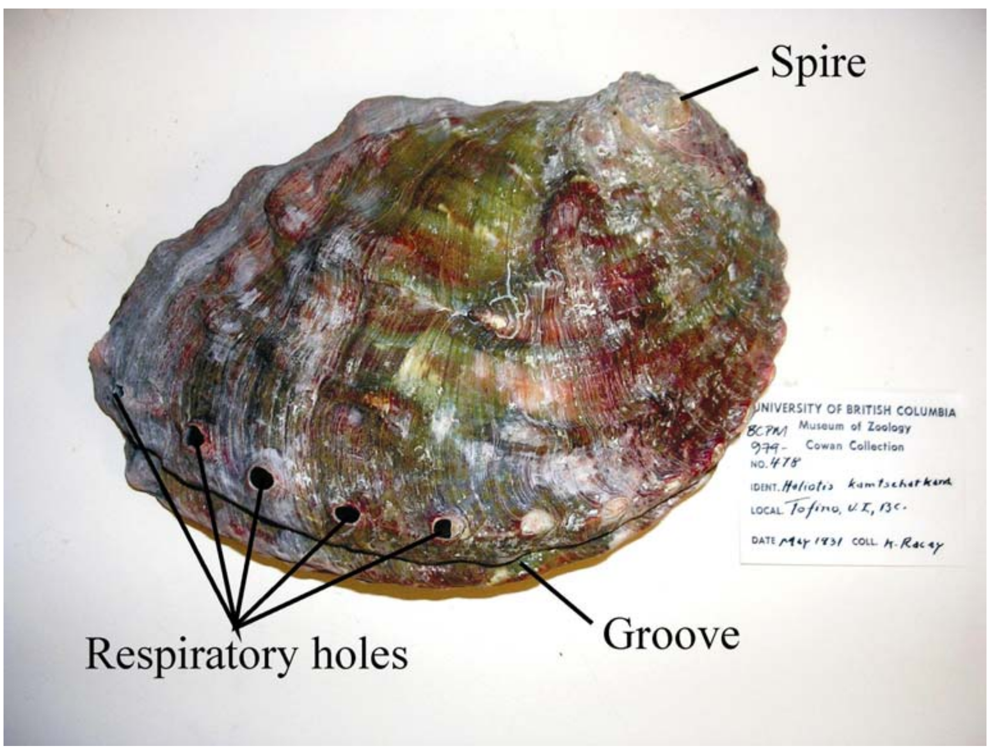

Figure 1. Northern Abalone, *H. kamtschatkana*, shell specimen from the Royal British Columbia Museum. (Photo by L. Kirkendale, RBCM, Victoria.)

Figure 2. Northern Abalone, *H. kamtschatkana*. (Photo by D. Bureau, Fisheries and Oceans Canada, Nanaimo.)

Northern Abalone which feed only on kelp have a mottled pale green shell colour (Figure 3) while shell colour is darker and with more red when they feed on other types of algae and diatoms (Figures 1-2). Switching diet in captivity produces clearly discernable lines of different colours on the shell (feed-marking).

Figure 3. Northern Abalone fed only with kelp; cultured by the Bamfield Huu-ay-aht Community Abalone Project, Bamfield, west coast of Vancouver Island. An orange variant is in the foreground (usually darker in its natural environment). (Photo by L. Convey, Fisheries and Oceans Canada, Nanaimo.)

Genetic description

Variation in 12 abalone DNA microsatellite loci from 18 sites in British Columbia (BC) and one site from Alaska showed that 99.6% of genetic variation was contained within any sample (site) and only 0.4% among samples (Withler *et al*. 2001). There was a small division (0.2%) among abalone samples from the Queen Charlotte Islands and Alaska and those found in central and southern BC. The remaining 0.2% was due to differences among samples within each of those two regions. These results suggest that historical and/or current gene flow is sufficient to maintain a high level of diversity and to prevent population subdivision. Withler *et al*. (2001) could not detect any disruption of gene flow caused by recent low abundance levels. The high level of heterozygosity (H = 0.64-0.74) they found in all samples resulted in a large estimated effective population size for Northern Abalone of 420,000, as well as a high estimate for the average number of migrants entering breeding aggregations in each generation (~20).

As a result of the high microsatellite heterozygosity, it is possible to identify parents of Northern Abalone progeny provided the genetic make-up of the parents is known (Withler pers. comm. 2008). However, current aquaculture abalone stocks, mainly 1st generation (F1) and some 2nd generation (F2) abalone, have the same allele combinations as wild stock and have not yet diverged enough to enable enforcement agencies to distinguish between cultured and wild stocks. Without prior knowledge of the parents and the time-consuming process involved, current aquaculture progeny cannot be genetically differentiated from wild stock at this time.

Northern Abalone can be differentiated from other Pacific species using sperm lysin (Lee and Vacquier 1995) as well as allozymes (Withler 2000). However, it appears that *H. kamtschatkana* subspecies cannot be genetically distinguished using molecular genetic tools applied to date. Geiger (1998) subdivided the species based on morphology according to McLean (1966). Gruenthal and Burton (2005) could not separate the two subspecies using mitochondrial cytochrome oxydase subunit 1 and cytochrome *b* as well as DNA coding of VERL (egg vitelline envelope receptor for sperm lysin). Recent studies using DNA microsatellites indicated that all alleles found in a sample of ten *H. k. assimilis* from central California were present in BC (Withler pers. comm. 2008).

Designatable units

Northern Abalone represents a complex situation where various human-mediated activities have manipulated components of the total population, thus potentially affecting eligibility for status assessment. The genetic and distribution data suggest that, all other things being equal, Northern Abalone should be assessed as a single designatable unit (DU). Lack of molecular genetic variation among sample sites indicates that gene flow is high and, while the species' distribution on the Pacific coast is not uniform, no major disjunctions in geographical range are evident.

While the large majority of abalone occurs in the wild environment, a captive breeding facility supports the production of abalone for both recovery and commercial purposes. In addition, wild individuals have been transplanted to other wild sites to increase the reproductive potential at these sites. For the purposes of this status assessment, all abalone are considered eligible for inclusion as part of the species being assessed, but only abalone in the wild environment will be included in evaluations of distribution, abundance and trends.

DISTRIBUTION

Global range

The species *H. kamtschatkana* is found off the west coast of North America in shallow subtidal waters along exposed and semi-exposed rocky coastlines from Sitka Sound, Alaska, to Turtle Bay, Baja California (McLean 1966; Geiger 1999) (Figure 4). While there are no records of this species in Oregon State (Geiger 1999) it most likely does occur there although virtually no abalone surveys are conducted. O'Clair and O'Clair (1998) report the distribution as extending further north to Yakutat, Alaska, but no record could be located to confirm abalone presence in that region (Foster pers. comm. 2008; O'Clair pers. comm. 2008; Wing pers. comm. 2008). Geiger (1999) reviewed the taxonomy of all abalone species and consulted several important museum collections from Europe and the United States. While published and museum records exist for Northern Abalone in Cook Inlet and even in the Aleutian Archipelago, Geiger (1999) dismissed these records as erroneous. The northern form, *H. k. kamtschatkana*, is distributed from Alaska south to Point Conception in central California. The southern form, *H. k. assimilis*, is distributed from central California to Turtle Bay in Baja California (McLean 1966; Geiger 1999).

In Alaska, Sea Otter, *Enhydra lutris*, populations have continued to expand in areas where Northern Abalone are present (Woodby *et al*. 2000). Woodby *et al.* (2000) saw abalone densities decrease considerably over 10 years of dive surveys (1988/89-1998/99). However, pockets remained and samples taken in 1998 indicated recent recruitment around Sitka Island at the northern end of their distribution. In Washington, Northern Abalone are in decline and exhibit recruitment failure despite closure of the fishery (Rogers-Bennett 2007; Rothaus *et al.* 2008). They have also declined 10-fold in northern California in the absence of legal fishing pressure (Rogers-Bennett 2007). In southern and central California, Northern Abalone are now extremely rare (Rogers-Bennett 2007). The Threaded Abalone never sustained a commercial catch in Baja California and very few individuals were present in the commercial catch (del Rio-Portilla pers. comm. 2008). Only one or two Threaded Abalone were encountered in surveys conducted in the early 1980s and no individuals were observed in surveys in the 1990s. It is unknown if any live individuals of *H. kamtschatkana assimilis* still exist in Mexico (del Rio-Portilla pers. comm. 2008). While a range contraction of the Threaded Abalone subspecies may have occurred in its southern range, there has been no known range contraction of *H. kamtschatkana kamtschatkana* despite significant declines at the extremities of its distribution.

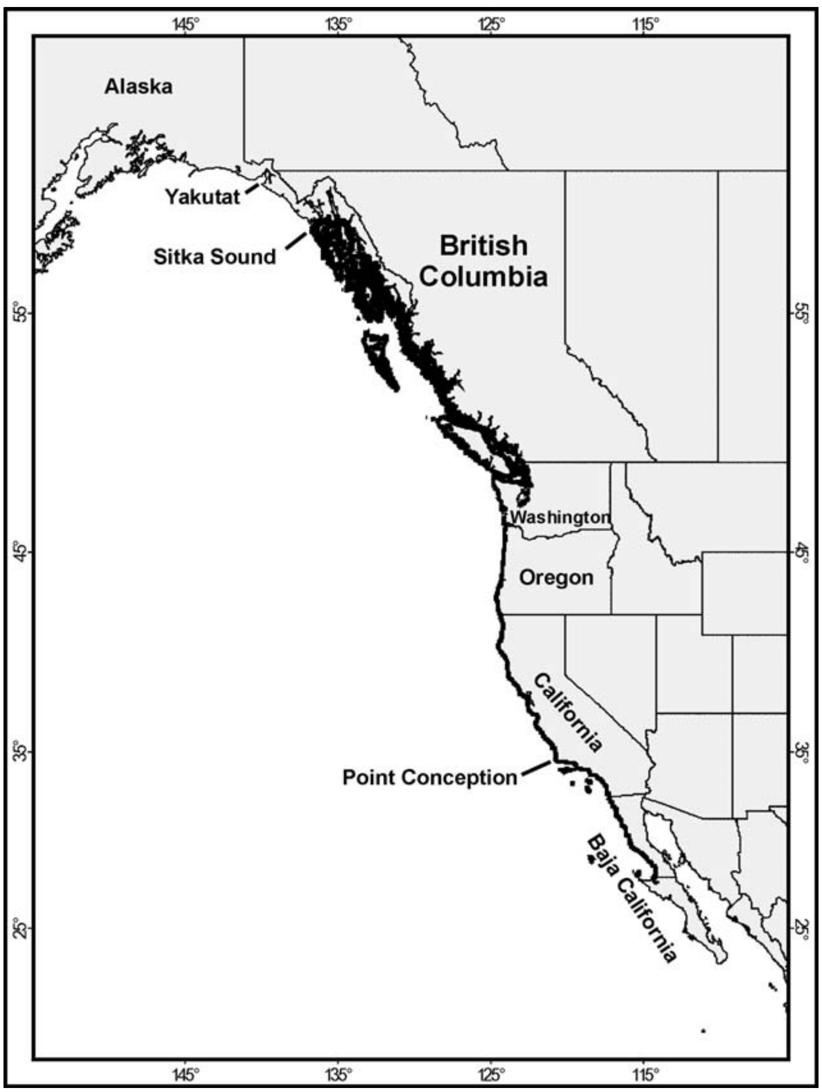

Figure 4. Global *H. kamtschatkana* distribution (bold coastline indicates possible distribution).

Canadian range

In Canada, Northern Abalone occur only on the Pacific coast of British Columbia, in a patchy distribution on hard substrate in the intertidal and shallow subtidal zones. Abalone can occur on all BC coastal areas where appropriate habitat is available (Figures 5 and 6). Their distribution is usually aggregated (not uniform over the available habitat). Some localized depletions are known to have occurred (e.g., Cumshewa Inlet, Queen Charlotte Islands; Hankewich *et al*. 2008). Thomson (1914) could not find abalone in the Georgia Strait, yet abalone are present at several locations in this region today (Wallace 1999; Lucas *et al*. 2002; anecdotal information from members of the Abalone Recovery Implementation Group (AbRIG) and the recreational dive community). Some known locations that have been used in the past for Aboriginal harvest are now depleted of abalone (anecdotal information from AbRIG members). Several First Nations communities have reported that, even before the abalone fisheries closure, abalone were disappearing from the intertidal zone and could no longer be harvested as most First Nations collected only abalone exposed by low tides (anecdotal information from AbRIG members).

The extent of occurrence (EO) in Canada has been calculated as 207,478 km^2 (Filion pers comm. 2008). The EO is an area (polygon) which encompasses all known, inferred or projected sites of present occurrence of the species. As such, the extent of occurrence for Northern Abalone includes land and deep waters. Whereas many locations are known for current and past abalone presence, not all locations where abalone occur have been identified and/or mapped. Northern Abalone are widely distributed in BC and it would be impossible to survey all locations where abalone may exist. The nearshore environment is dynamic, highly variable, and difficult to access, making data collection difficult and expensive. No comprehensive data set exists that would enable the identification or modelling of all abalone habitat in BC. Jamieson *et al*. (2004) created a model based on the few available physical and biological mapped data to determine areas of suitability for abalone habitat around the Queen Charlotte Islands and on the west coast of Vancouver Island. While the model showed promise in areas where mapped data resolution was high, there were problems in areas of low resolution. Additionally, the model has not been verified by surveys or extrapolated to all of coastal BC. Consequently, there are no area estimates of abalone habitat for the BC coast and, therefore, the area of occupancy (AO; the area within the extent of occurrence that is occupied by the species) cannot be calculated. In any case, the AO for Northern Abalone will be larger than 2,000 km^2 once calculated.

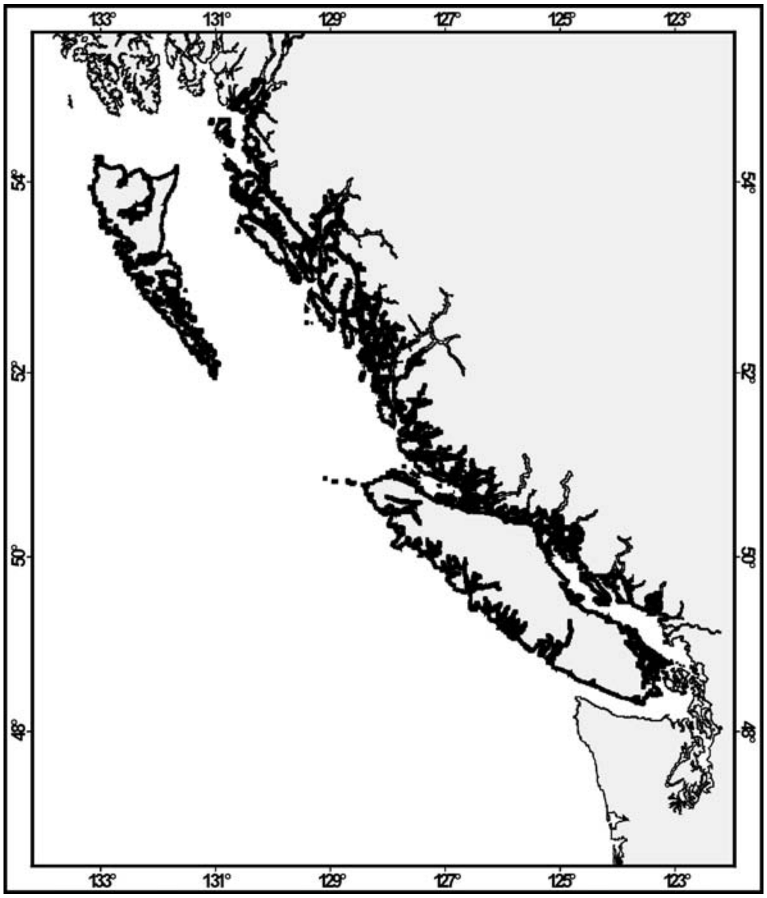

Figure 5. Northern Abalone, *H. kamtschatkana*, distribution in Canada (bold coastline indicates possible distribution).

HABITAT

Habitat requirements

Northern Abalone occur in a wide range of habitats from fairly sheltered bays to exposed coastlines, from the low intertidal zone to shallow subtidal depth (Fisheries and Oceans Canada 2007). For practical purposes, abalone habitat in BC has been defined using the following parameters (Lessard *et al*. 2007b):

<u>Physical parameters</u>

i. Primary substrate: bedrock and/or boulders
ii. Normal seawater salinity (> 30 ppt; not low salinity as found close to river run off)
iii. Depth: ≤10m depth (chart datum)
iv. Good water exchange (tidal current or wave action present)
v. Secondary substrate: some cobble may be present but little or no gravel, sediment, sand, mud, or shell present.

Biological parameters

i. Presence of encrusting coralline algae (e.g. *Lithothamnium*)
ii. Presence of Sea Urchins *Strongylocentrotus franciscanus* and/or *S. droebachiensis, Lithopoma gibberosum (= Astraea gibberosa)*, Sea Stars
iii. Presence of kelp in surrounding area (e.g., *Nereocystis, Macrocystis, Pterygophora*)
iv. Presence of abalone

Physical and biological parameters are listed in order of importance. This is considered a broad definition of habitat because not all habitats support high abalone densities. In addition to the inherent difficulty in identifying the parameters affecting abalone distribution (Sloan and Breen 1988; Lessard and Campbell 2007), commercial harvest (legal historical and illegal) as well as the decline in abundance from all causes may have altered remaining distribution patterns (Shackell *et al*. 2005).

Several studies in BC have determined that while Northern Abalone density increases with relative wave exposure, mean shell length (SL) decreases (Breen and Adkins 1979; Tomascik and Holmes 2003; Lessard and Campbell 2007). In general, abalone densities are low in *Macrocystis integrifolia* forests and highest in *Pterygophora californica* forests without surface canopy; densities in *Nereocystis luetkeana* forests are between these two extremes (Breen and Adkins 1979; Lessard and Campbell 2007). In BC, transplanting slow growing Northern Abalone from high wave exposure areas (referred as “surf abalone”) to sheltered locations increases individual growth rates in both the Queen Charlotte Islands (Breen 1986) and Barkley Sound (Emmett and Jamieson 1988; Lessard pers. comm. 2008).

Abalone larval settlement is thought to occur on encrusting coralline algae (Roberts 2001) which is usually present at sites where abalone already to exist. The layer of encrusting algae may be maintained by Sea Urchins and probably other herbivores which by grazing prevent the growth and settlement of algae and sessile invertebrates (Steneck 1986; Tegner 2000; Tomascik and Holmes 2003).

Habitat trends

Currently, there is ample habitat available for the Northern Abalone population on the coast of BC. Although the abalone population has declined, there has been no known reduction in available habitat.

Habitat protection/ownership

The Northern Abalone is under the jurisdiction of Fisheries and Oceans Canada and is protected under the *Fisheries Act* and the *Species at Risk Act* (SARA) although critical habitat has not yet been determined (Fisheries and Oceans Canada 2007). Portions of the *Fisheries Act* are also enforced by the Department of the Environment, the Department of Indian Affairs and Northern Development, and in BC, the provincial Ministry of the Environment.

BIOLOGY

The biology of Northern Abalone was reviewed by Sloan and Breen (1988). In BC, the bulk of the research efforts since that work was published have focused on monitoring the abalone population and rebuilding methods. Recently, a stock-recruitment model was developed for Northern Abalone (Zhang *et al*. 2007). The results of this model, including the population projections enabled by the model, are an integral part of this Northern Abalone status assessment. The relevant results are described in **Population stock-recruitment and mortality estimates from abalone surveys**, as well as in other appropriate sections.

Life cycle and reproduction

Northern Abalone spawn synchronously, with groups of males and females in close proximity to each other in shallow depths broadcasting their gametes into the water column (Breen and Adkins 1980b). Abalone can have ripe gonads throughout the year, but more spent gonads were found between April and June near Tofino (Quayle 1971); gonad indices were at their highest in Barkley Sound between June and August (Emmett and Jamieson 1988). Based on field and laboratory observations, Northern Abalone are thought to aggregate on a high spot such as a boulder and/or stack on top of each other to spawn (Quayle 1971; Breen and Adkins 1980b).

In BC, Northern Abalone become sexually mature at a shell length (SL) of about 50 mm and all are mature at 70 mm SL (Quayle 1971; Campbell *et al*. 1992). Fecundity ranges from 156,985 eggs for a 57 mm SL abalone to 11.56 million eggs in a 139 mm SL female (Campbell *et al*. 1992). From cumulative size frequency data of abalone surveyed off the southeast Queen Charlotte Islands during June 1990 (Thomas *et al*. 1990), Campbell *et al*. (1992) estimated that 50% of the total potential eggs could be produced by mature females <100 mm SL, which constituted 80% of the total population surveyed. The remaining 20% of mature females in the 100-152 mm SL size group could produce about 50% of the total potential egg production. Thus large females make important contributions to the total potential egg production.

Fertilized eggs hatch within 1-2 days into planktonic larvae. The planktonic phase of Northern Abalone is short, greatly limiting dispersal capability, and temperature dependent (10-14 days at 14-10ºC) (Sloan and Breen 1988; Pearce *et al*. 2003). Settlement in many abalone species occurs on encrusting algae (Morse and Morse 1984; McShane 1992; Roberts 2001). Encrusting algae are usually more abundant at greater depths than kelp and other foliose algae, therefore settlement may take place deeper than where adult abalone are more abundant (Breen 1980b; Sloan and Breen 1988) or where there is Sea Urchin grazing.

Juvenile Northern Abalone (<70 mm SL) are typically cryptic and often found under rocks or in crevices, whereas the majority of adults (≥70 mm SL) are found on exposed rock surfaces (Boutillier *et al*. 1985; Campbell and Cripps 1998; Zhang *et al*. 2007). As juveniles mature, their diet changes from benthic diatoms and micro-algae to drift macro-algae. In captivity, diatoms were eaten by all Northern Abalone tested (Paul *et al*. 1977), but, given choices, abalone preferred *Macrocystis integrifolia* and *Nereocystis luetkeana* (Sloan and Breen 1988).

Abalone growth can vary considerably among areas, depending on the extent of exposure to wave action and availability and quality of food. In BC, estimates of the age at which abalone reach 50 mm SL and 100 mm SL are 2 to 5 years and between 6 to 9 years (or more), respectively (Sloan and Breen 1988). The largest shell length of Northern Abalone ever recorded was 165 mm (Breen 1980b). Growth of adults tends to be stunted in highly exposed outer coastal areas due to reduced opportunities for abalone to catch and feed on drift algae in strong wave action and water currents. Abalone growth is more rapid in moderately exposed areas with Giant Kelp, *Macrocystis integrifolia*, or Bull Kelp, *Nereocystis luetkeana*, forests than at highly exposed areas with *Pterygophora californica* kelp forests (Sloan and Breen 1988). Breen (1980b) speculated that ages of 50 years or more were not improbable, based on shell appearances and extrapolation from other invertebrate species present on abalone shells. However, longevity of 15-20 years for Northern Abalone seems more likely based on age determined by spire growth rings (Shepherd *et al*. 2000), observed sizes taken with growth curves (Quayle 1971; Sloan and Breen 1988), and animals kept in captivity (Paul and Paul 2000).

Thus, an estimate of natural generation time would be approximately 10 years (average age of the parents in the population). However, as large individuals are now rare (see **POPULATION SIZES AND TRENDS**), generation time has probably decreased in the last 10 or 30 years. In areas where Sea Otters are present, generation time may even be close to age at maturity, 2-5 years old (see paragraph above and **Interspecific interactions** and **Limiting factor: Sea Otter predation**).

Population stock-recruitment and mortality estimates from abalone surveys

Northern Abalone stock-recruitment (SR) relationships and mortality rates were estimated using two abalone index site survey time series (see **POPULATION SIZES AND TRENDS** for description of the time series) and established growth models (Zhang *et al*. 2007). The fitted SR curves were flat and close to linearity, indicating low productivity for the abalone stocks. At low spawning biomass (<0.05 kg/m^2) the SR relationships seemed to be density independent (i.e., no Allee effect was detected). There were considerable variations in the SR relationships, and variation in recruitment increased with increasing spawning biomass. The maximum mean recruitment was estimated to be 0.62 abalone/m^2.

From the two survey time series, excluding surveys when the abalone fishery was opened, adult instantaneous annual mortality rates (Z) were estimated to be 0.29 ± 0.05SE (standard error) (or 25 ± 5%/y) on the central coast and 0.36 ± 0.07SE (or 30 ± 7%/y) on southeast Queen Charlotte Islands (Zhang *et al.* 2007), which included natural mortality and illegal fishing rates (see **Threat: Illegal harvest** for further discussion of natural and fishing mortality rates). Simulation results using these mortality rates and SR functions agreed with the observed data reasonably well; the majority of observed mean densities were within the 90% confidence intervals of the simulated results. With these estimated mortality rates (Zhang *et al.* 2007), modelled population trajectories showed that abalone stocks would continue to decrease in both areas, and extinctions (defined as densities <0.001 abalone/m^2) would occur in approximately 270 years (Lessard *et al*. 2007b).

In areas without Sea Otters, the long-term recovery target was set as 1 spawner/m^2 (1 mature abalone ≥70mm SL/m^2) based on the SR model (Zhang *et al.* 2007). No data are available to model areas with Sea Otters. The SR relationships showed that at this level, an increase in spawning biomass did not correspond to a comparable increase in the number of recruits and therefore the benefit of further increasing the number of spawners decreased. The mortality rate would have to decrease to at least 0.15 (or 14%/y) to recover abalone to the 1 mature abalone/m^2 level within 70 years (Lessard *et al*. 2007b).

Predation

Abalone are prey for Sea Otter, *Enhydra lutris*; River Otter, *Lontra canadensis*; Mink, *Mustela vison*; crab, *Cancer* spp.; Sea Stars, *Pycnopodia helianthoides*; Octopus, *Enteroctopus dofleini*; Wolf Eel, *Anarrhichthys ocellatus*; Cabezon, *Scorpaenichthys marmoratus*; and other fish species. See also **Limiting factor: Sea Otter predation**.

Physiology

Important physiological tolerances are described under **Adaptability** below.

Dispersal/migration

As larvae of abalone species are generally non-feeding and poor swimmers, many authors have suggested that larval dispersal is minimal and that recruitment is from local reproductive populations (Tegner and Butler 1985; Prince *et al*. 1987; McShane *et al*. 1988; McShane 1992; Shepherd and Brown 1993; Tegner 1993; McShane 1995a,b). Nevertheless, larval dispersal probably does occur in several abalone species, including Northern Abalone, as genetic studies have found high genetic variation which indicates gene flow over large areas with little population subdivision (Brown 1991; Brown and Murray 1992; Shepherd and Brown 1993; Burton and Tegner 2000; Withler *et al*. 2003).

While adult and juvenile abalone can move several metres during a day, they are usually considered sedentary and probably spend their lifetime close to their settlement place (Sloan and Breen 1988). Some adult abalone even show home scars (bare rock underneath an abalone matching the shape of the shell), indicating that their movement is minimal (Breen 1980b). Quayle (1971) found little vertical or lateral movement, <50 m annually, from tagged abalone. The maximum recorded movement was 125 m in one year (Emmett and Jamieson 1988).

Interspecific interactions

Within the nearshore exposed or semi-exposed coastal waters, Northern Abalone play the role of herbivore and are the prey of many species. Food for juvenile and adult abalone includes macro-algae and kelp, often in the form of drift algae. Recovery of abalone may be related to the abundance and health of kelp forests in certain areas. Northern Abalone also compete with other species (e.g., Red Sea Urchins, *Strongylocentrotus franciscanus*) for food.

The role of Sea Otters in shaping the nearshore kelp forest ecosystem likely has a significant impact on the structure of the Northern Abalone population where the two species co-exist. Studies have shown that in areas where Sea Otters are present abalone are smaller and are restricted to crevices and other cryptic habitats where they are inaccessible to, or hidden from, Sea Otters (Lowry and Pearse 1973; Cooper *et al.* 1977; Breen *et al*. 1982b; Pollard 1992; Watson 1993, 2000; Fanshawe *et al.* 2003). It is unclear whether abalone inhabit crevices as a direct result of Sea Otter predation or because the abundant supply of food (perhaps as a result of Sea Otter predation on herbivores) reduces their foraging activity (Lowry and Pearse 1973).

Adaptability

Northern Abalone live in a wide range of habitats and have a large distribution from Alaska to Baja California. They also have a wide range of temperature tolerance. When exposed to temperatures between 2ºC and 24ºC in the laboratory, there was no mortality or evidence of respiratory stress (Paul and Paul 1998). McLean (1966) speculated that temperature tolerance accounted for differences in depth distribution at the extreme of *H. kamtschatkana* geographical range, from the lower intertidal zone to approximately 10 m depth in their northern range and strictly subtidal in the southern portion of their range.

Northern Abalone can survive, grow and reproduce in aquaculture settings (Paul and Paul 2000; Pearce *et al*. 2003). Outplanting of juveniles and larvae from aquaculture into natural habitats has taken place in BC. However, no published results on survival are available at this time. In New Zealand, Australia, South Africa and the United States, there is short-term evidence that outplanting juveniles can be successful in some cases (Schield 1993; Rogers-Bennett and Pearse 1998; Tegner 2000; De Waal and Cook 2001; Dixon *et al*. 2006). However, the only long-term results are from Japan where outplanting of large juveniles (> 30 mm SL) has maintained the abalone fishery, but has not contributed to wild production (Tegner 2000; Uchino *et al*. 2004). Releasing hatchery-reared abalone larvae has met with limited success, with most studies concluding that larval release is not suitable for large scale restocking (reviewed in Roberts *et al*. 1999). Thus, survival of outplanted juveniles has been shown in other abalone species, but has not yet been proven with Northern Abalone.

In Barkley Sound, wild-to-wild translocation of Northern Abalone from exposed to more sheltered habitat enhances individual growth rates (Emmett and Jamieson 1988). In 2002, a study was initiated in Barkley Sound to evaluate wild-to-wild translocation (adult aggregation) as a rebuilding method for Northern Abalone. Preliminary results indicate that a good proportion of the translocated adult abalone stayed within their new habitat and probably contributed to the subsequent increase in juvenile densities (Lessard pers. comm. 2008). The Kitasoo and Haida Habitat Stewardship Projects conducted comparable experiments on the central coast and Queen Charlotte Islands and reported similar results (DeFrietas pers. comm. 2007; Harding pers. comm. 2007). Thus, Northern Abalone may be able to survive, grow and reproduce after wild-to-wild translocations.

POPULATION SIZES AND TRENDS

Search effort

Since 1978, index site surveys have provided a time series of abalone densities and size frequencies from the Queen Charlotte Islands and the central coast of BC, every 3–5 years (Figure 6) (Breen *et al*. 1978b; Adkins and Stefanson 1979; Breen and Adkins 1979, 1980a, 1981; Breen *et al*. 1982a; Boutillier *et al*. 1984, 1985; Farlinger and Bates 1986; Carolsfeld *et al*. 1988; Thomas *et al*. 1990; Farlinger *et al*. 1991; Winther *et al*. 1995; Thomas and Campbell 1996; Campbell *et al*. 1998, 2000; Atkins *et al*. 2004; Lessard *et al*. 2007a; Hankewich and Lessard 2008; Hankewich *et al*. 2008). Index site surveys have consistently used the standard ('Breen') method developed by Breen and Adkins (1979). Although there are a few published Northern Abalone surveys for southern BC (Quayle 1971; Breen *et al*. 1978a; Adkins 1996; Wallace 1999; Atkins and Lessard 2004; Davies *et al*. 2006) they did not provide the extended coverage and the time series compared to the surveys in the northern half of BC. Most surveys were conducted in northern BC where the bulk of BC historical commercial abalone harvest occurred and where abalone were considered most abundant (Sloan and Breen 1988). In addition to the time series, several other surveys using other methods have been completed or are ongoing in BC. However, none of these surveys have the time series or the method consistency that the index site surveys have provided. Consequently, the results from time series in northern BC have been used to make management decisions. It should be noted that the majority of the time series took place in areas without Sea Otters (either spatial or temporal).

In 1978-1983, the surveyed sites were selected because of harvestable commercial abalone abundances. Index sites subsequently added were selected because of good abalone abundances. In areas without time series (Queen Charlotte and Johnstone Straits, west coast of Vancouver Island and Georgia Strait), sites were randomly selected prior to the survey and only those sites largely composed of abalone habitat were included in the analysis. During each survey, site positions were located from previous chart records, written descriptions, photographs and GPS positions. Once each site was located, divers placed a 1 m^2 quadrat at the top of the abalone habitat zone and then sampled 16 quadrats which were arranged in four transects, each 4 m apart, and each of the four quadrats within a transect were 1 m apart. For each quadrat, exposed abalone were measured and, in recent years, several habitat characteristics were recorded (algae cover and species composition, number of urchins, species and relative size of predators, depth and substrate). Only exposed abalone are included in the density estimates given in this report as cryptic searches (where divers turned boulders and rocks) were not conducted in all survey years. Survey methods exist where the majority of small abalone are sampled (e.g., night surveys and cryptic searches), but, as mentioned before, these have not been consistently used over many years and are either logistically difficult or time consuming. Using the Queen Charlotte Islands time series data, Zhang *et al*. (2007) determined the percentage of cryptic abalone to be almost 100% for abalone <20 mm SL decreasing progressively to approximately 20% for 70 mm SL abalone. However, during more recent surveys, abalone <20 mm SL have been regularly seen exposed (Lessard pers. comm. 2008). While not all immatures are sampled during index site surveys, a significant portion are exposed and available for sampling. Consequently, immature densities calculated from the two time series are used as an index of recruitment in the current assessment.

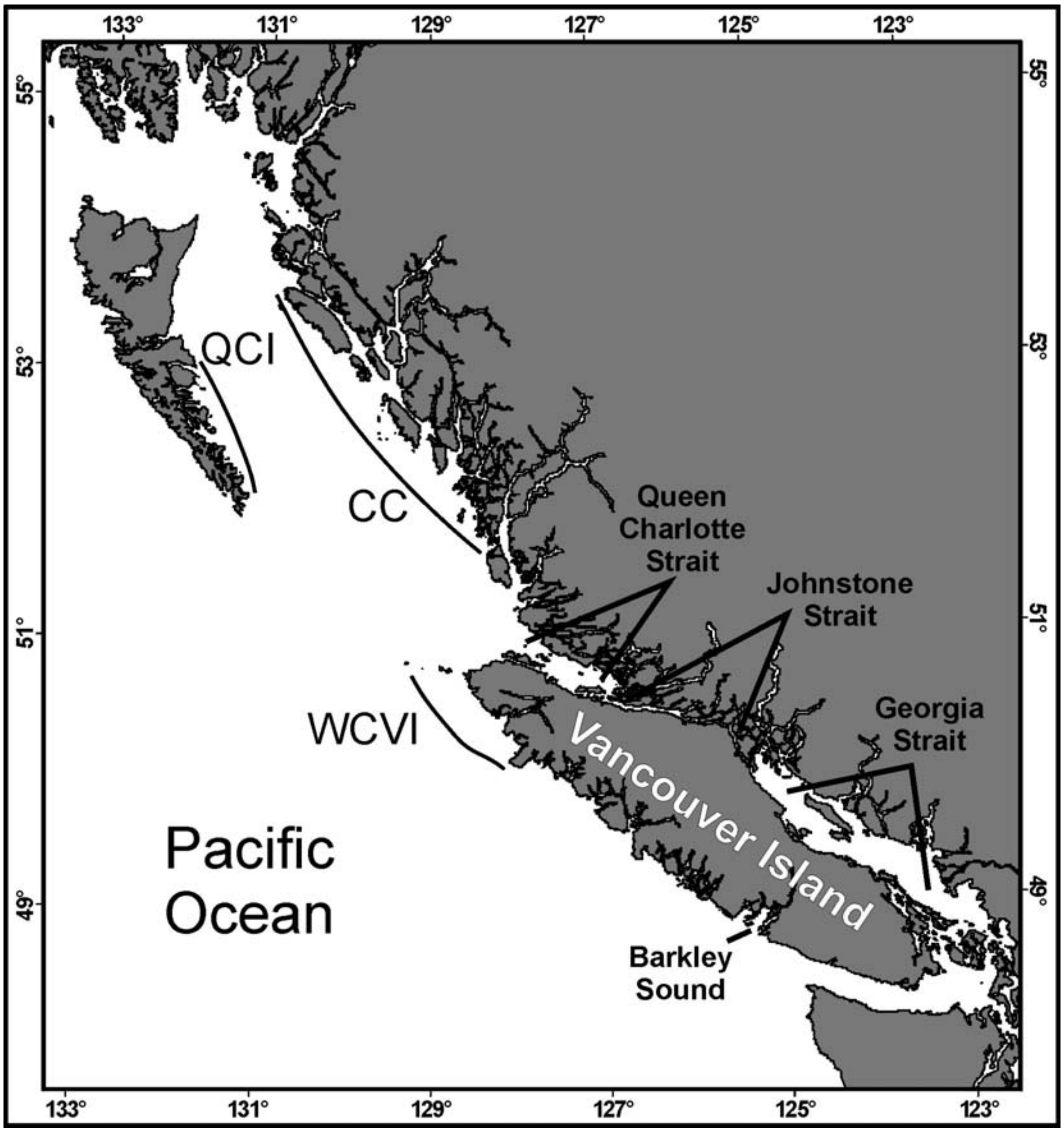

Figure 6. Map of BC showing several locations described in the text as well as extent of areas surveyed to monitor abalone in BC for: Queen Charlotte Islands (QCI), central coast (CC), and west coast of Vancouver Island (WCVI).

Abundance

Based on microsatellite heterozygosity, the estimated effective population size (the population contributing to the next generation) for Northern Abalone is 420,000 (Withler *et al*. 2001; see also **Genetic description**); this is the only estimate of abundance for Northern Abalone and reflects more the long-term historical than contemporary effective population size. Although habitat characteristics are fairly well defined, not all abalone habitat locations are known due to knowledge gaps in shoreline composition, and therefore there is no estimate for AO. Consequently, the index site survey time series have provided an 'index' of abundance as opposed to a total number of individuals (population number).

The mean total abalone density[1] at index sites declined from 2.40 to 0.40 abalone/m^2 for the central coast, between 1978 and 2006 (Table 2, Figure 7), and from 2.22 to 0.43 abalone/m^2 for the Queen Charlotte Islands between 1978 and 2007 (Table 3, Figure 8). During the same periods, the mean mature (≥70 mm SL) density decreased from 2.13 to 0.23 abalone/m^2 for the central coast and from 1.28 to 0.15 for the Queen Charlotte Islands. Immature densities declined from 0.27 to 0.18 abalone/m^2 and from 1.39 to 0.27 abalone/m^2 for the central coast and the Queen Charlotte Islands, respectively. Proportionally, the densities of mature and large abalone decreased more rapidly than that for small individuals (Atkins *et al*. 2004; Lessard *et al*. 2007a). The declines in density estimates for all size categories were statistically significant between the latest surveys and those completed in 1978 (about three generations). However, only the mature and large abalone density estimates from the 2006 or 2007 surveys were significantly lower when compared to the 1989 or 1990 surveys-just before the fisheries closed. The cryptic nature of the juveniles and possible changes in how they were sampled and became exposed over time suggest that trend analyses for the immature group may be affected by other factors (e.g., search efficacy improves with increased understanding of cryptic juvenile habitats).

Table 2. Mean exposed abalone density estimates (number/m^2) by year and size category from index site surveys on the central coast. Values in brackets are the standard errors of the means.

	Year									
	1978	**1979**	**1980**	**1983**	**1985**	**1989**	**1993**	**1997**	**2001**	**2006**
Number of sites sampled	12	14	19	42	28	26	33	47	55	68
All sizes	2.40	2.94	3.09	1.58	1.50	0.55	0.46	0.42	0.27	0.40
	(0.43)	(0.66)	(0.49)	(0.26)	(0.18)	(0.11)	(0.07)	(0.07)	(0.04)	(0.06)
Immature	0.27	0.59	1.40	0.37	0.32	0.14	0.15	0.12	0.10	0.18
(<70 mm SL)	(0.08)	(0.13)	(0.31)	(0.08)	(0.07)	(0.05)	(0.02)	(0.03)	(0.02)	(0.03)
Mature	2.13	2.35	1.68	1.22	1.18	0.41	0.32	0.30	0.17	0.23
(≥70 mm SL)	(0.38)	(0.61)	(0.30)	(0.21)	(0.03)	(0.08)	(0.06)	(0.06)	(0.03)	(0.04)
Large adult	1.10	0.62	0.26	0.24	0.33	0.10	0.08	0.10	0.04	0.02
(≥100 mm SL)	(0.22)	(0.17)	(0.09)	(0.04)	(0.07)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)

[1] unless otherwise stated, all densities are of emergent/exposed abalone

Table 3. Mean exposed abalone density estimates (number/m^2) by year and by size category from index site surveys in southeast Queen Charlotte Islands. Values in brackets are the standard errors of the mean. *only 51 sites used for density estimates of immature and mature size categories.

	Year								
	1978	**1979**	**1984**	**1987**	**1990**	**1994**	**1998**	**2002**	**2007**
Number of sites sampled	108*	10	70	70	69	70	115	68	82
All sizes	2.22 (0.24)	2.34 (0.52)	0.53 (0.06)	0.65 (0.08)	0.46 (0.06)	0.29 (0.04)	0.56 (0.05)	0.34 (0.06)	0.43 (0.05)
Immature (<70 mm SL)	1.39 (0.27)	0.64 (0.22)	0.22 (0.05)	0.24 (0.06)	0.20 (0.03)	0.12 (0.02)	0.22 (0.03)	0.18 (0.04)	0.27 (0.04)
Mature (≥70 mm SL)	1.28 (0.24)	1.70 (0.39)	0.30 (0.05)	0.40 (0.05)	0.27 (0.04)	0.17 (0.17)	0.34 (0.04)	0.15 (0.03)	0.15 (0.03)
Large (≥100 mm SL)	0.36 (0.05)	0.55 (0.18)	0.09 (0.02)	0.19 (0.03)	0.10 (0.02)	0.06 (0.01)	0.11 (0.02)	0.04 (0.01)	0.03 (0.01)

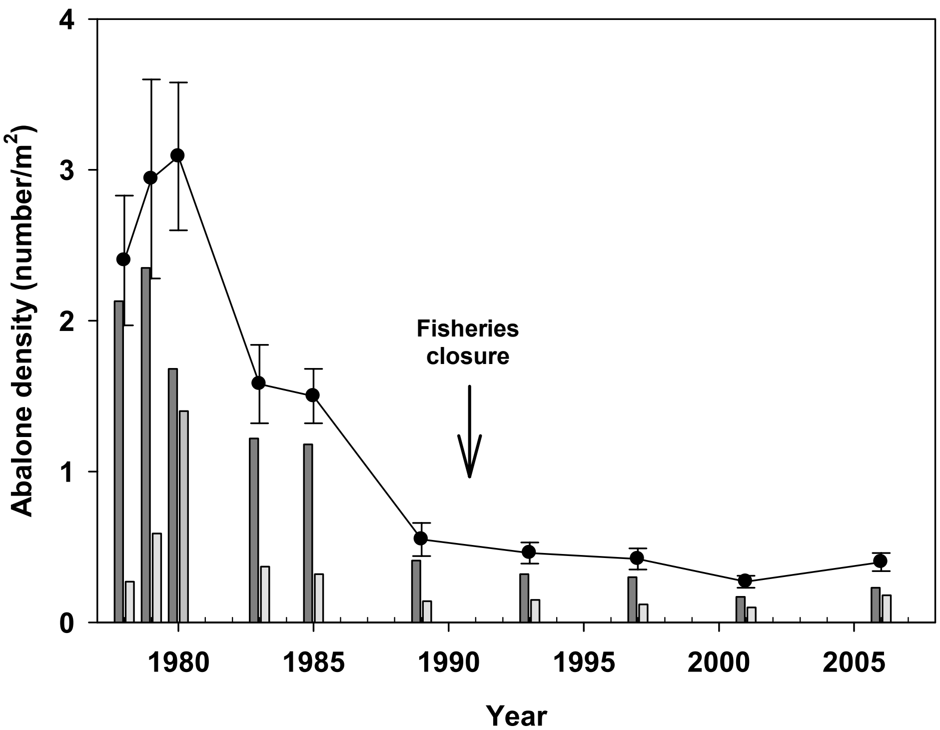

Figure 7. Abalone total (circle and line), mature (≥70mm SL) (dark grey bars) and immature (<70mm SL) (light grey bars) density estimates for the central coast survey time series.

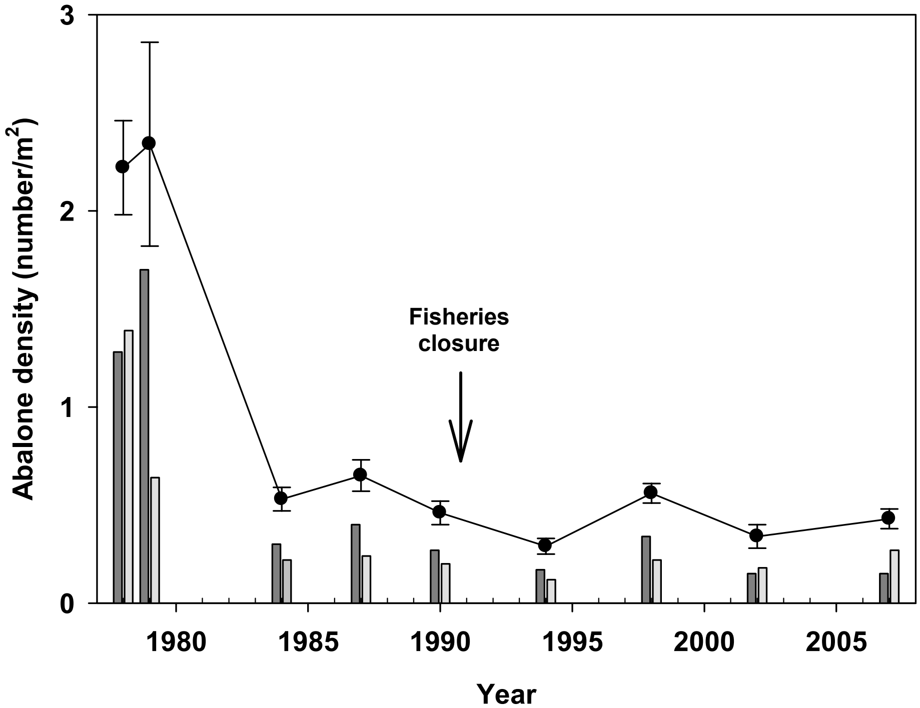

Figure 8. Abalone total (circle and line), mature (≥70mm SL) (dark grey bars) and immature (<70mm SL) (light grey bars) density estimates for the Queen Charlotte Islands survey time series.

The mean size of abalone measured on the central coast in 2006 (69.4 mm SL) was significantly smaller than in every other survey year since 1978, with the exception of 1980 (68.2 mm SL) (Hankewich and Lessard 2008). Similarly, the mean size of the Queen Charlotte Islands abalone in 2007 (61.5mm SL) was significantly smaller than estimates from every other survey year, with the exception of 2002 (67.0 mm SL) (Hankewich *et al*. 2008). These decreases in mean size were the result of a greater proportion of small individuals combined with a decrease in maximum shell length.

The large decrease in mature abalone densities combined with the decline in mean SL since the fisheries closure suggest size-selective fishing (poaching) mortality. Sea Otters were present in only a small portion of the central coast surveyed areas, and were absent from the Queen Charlotte Islands (Nichol *et al*. 2005). Therefore, Sea Otter predation could not explain these reductions in density and mean size estimates. Other sources of mortality, including disease and/or seastar predation, would also affect smaller individuals (<70 mm SL). Currently, abalone populations in the Queen Charlotte Islands are skewed towards higher densities of immature individuals (Figure 8). This trend was also observed in the central coast abalone in 2006, though not to the same extent (Figure 7). Oceanic conditions appear to have been favourable for abalone reproduction and recruitment over the last few years; the densities of immature abalone in 2006-2007 were the highest since the harvest ban in 1990. Yet, the densities of mature abalone are not increasing correspondingly. Obviously, abalone in BC are either experiencing mortality before reaching maturity, or their addition to the mature cohort is being offset by mortality of existing mature abalone. The accumulation of large individuals expected for this long-lived species in the absence of harvest and Sea Otter predation, as was seen prior to the expansion of the commercial fishery in the late 1970s (Breen 1986), has not taken place. Large adult abalone (≥100 mm SL; former legal minimum size) were at their lowest recorded levels during the most recent surveys in both regions (Tables 2-3).

New index site surveys were initiated on the west coast of Vancouver Island (WCVI) in 2003 (Atkins and Lessard 2004) and in Queen Charlotte and Johnstone Straits in 2004 (Davies *et al*. 2006) using the Breen survey method. The mean total density estimates were 0.06 abalone/m^2 in Queen Charlotte Strait and 0.02 abalone/m^2 in Johnstone Strait. Previous surveys done in one particular location in Johnstone Strait indicated high abalone density, up to 10 abalone/m^2, based on timed-swims in 1977 (Breen *et al*. 1978a), and 1.13 abalone/m^2 in 1986 using the Breen method (Adkins 1996). This particular location was the only place in Johnstone Strait where divers observed any abalone at all in 2004, except one individual at another site. Harvest logs confirm that there were commercially harvestable numbers in Queen Charlotte and Johnstone Straits (Harbo 1997), but a survey by Breen *et al*. (1978a) suggested that the fishery was largely confined to the northwest portion of Queen Charlotte Strait, where densities were higher. In Queen Charlotte Strait in 1977, Breen *et al*. (1978a) visually estimated abalone densities to be generally low, 1/m^2 or less, and noted a scarcity of juveniles. Although not directly comparable due to differences in survey designs, abalone densities in Queen Charlotte Strait have certainly decreased since 1977.

In 2003, on the northwest side of the west coast of Vancouver Island, the mean total density was 0.09 abalone/m^2 from all sites sampled, but 0.21 abalone/m^2 from sites in Quatsino Sound where more sheltered abalone habitat was present (Atkins and Lessard 2004). Sea Otters have inhabited the surveyed area of the west coast of Vancouver Island since 1989 and more specifically since 1991 in Quatsino Sound (Watson *et al*. 1997). The Quatsino Sound density estimate was higher than abalone densities estimated by Watson (1993) in areas with Sea Otters despite sampling for exposed abalone only (i.e., not cryptic as no rocks were turned). This may be the result of the relatively low abalone densities which make abalone a scarce food resource for Sea Otters; being scarce may prevent abalone from being selected, as Sea Otters often exploit seasonally abundant food resources (Watson *et al*. 1997). No other abalone surveys exist for the area surveyed in 2003; therefore trends for this area cannot be assessed.

In Georgia Strait, only a small portion on the southern tip of Vancouver Island has recently been surveyed, i.e., in February 2005 (Lessard pers. comm. 2008). Only three individual abalone were found at two (11%) of the 19 sites surveyed. The mean density for all sites surveyed was 0.0098 abalone/m^2. This estimate was drastically lower than density estimates from two previous surveys on the southeast side of Vancouver Island; one in 1982, 0.73 abalone/m^2, and one in 1985, 1.15 abalone/m^2 (Adkins 1996). Abalone stock in these areas has declined by more than 98% since the mid-1980s. Due to access restrictions enforced by a prison, the waters around William Head have been a *de facto* marine reserve since 1958 (Wallace 1999). During a 1996/97 survey at this prison site, divers found 211 abalone in 275 minutes of diving (0.77 abalone/min). At four sites surveyed in proximity of William Head in 2005, only one abalone was found (Lessard pers. comm. 2008). Although a few (<10) more were observed outside of the quadrats (<0.1 abalone/min), the abalone population around William Head seemed to be disappearing. This large decrease could be a result of poaching, but because of the security at this particular location, the most likely reason is simply that the large abalone found during the previous surveys have died and there has been no, or little, recruitment. The sizes of the three sampled abalone during the 2005 survey were 141 mm, 135 mm, and 135 mm SL, well above the historical size limit of 100 mm SL in place during the former fishery. The results from the 2005 survey were similar to surveys conducted in the San Juan Islands by the Washington Department of Fish & Wildlife. The mean density of Northern Abalone in 2006 at the San Juan Islands index sites was 0.04 abalone/m^2 and ranged from 0.082 to 0.000 abalone/m^2, with two sites extirpated (Rothaus *et al*. 2008). All the abalone measured were large, indicating recruitment failure.

Fluctuations and trends

Northern Abalone total and mature densities at index sites have declined by 83% and 89% on the central coast and by 81% and 88% in the Queen Charlotte Islands since 1978 (approximately three generations). Since the fisheries closure in 1990, mature abalone densities have continued to decline, 44% for both time series, but immature density estimates increased and were 29% and 35% above the levels observed during the 1989 central coast and 1990 Queen Charlotte Islands surveys, respectively. Since the fisheries closure, total abalone density estimates have been fluctuating at low levels and there have been no statistically significant changes. However, the mature and large density estimates have declined since 1990. Hence, abalone population rebuilding in BC has not taken place in the absence of legal harvest.

Based on the stock-recruitment model, abalone population growth trajectories were simulated at various mortality levels for the central coast and the Queen Charlotte Islands abalone stocks (Zhang *et al*. 2007). Abalone stocks would be sustainable with adult mortality rates around 0.25 (or 22%/y), and would increase or decrease with lower or higher mortality rates, respectively. Adult mortality rate estimates were >0.25 in areas of northern BC without Sea Otters after the closure to all fisheries in 1990, which likely contributed to low abalone population abundances. Indeed, the prospect of further precipitous abalone population declines must be considered a real possibility with the continued illegal harvest (poaching) by humans and the continued growth and spread of the Sea Otter population in BC.

It is unknown what the natural state of Northern Abalone populations may have been historically. Abalone populations probably fluctuated even in the absence of commercial fishing. Exploratory surveys conducted in the southeast Queen Charlotte Islands in 1955 (Quayle 1962) suggested that Northern Abalone were less abundant in 1955 than in both 1913 (Thomson 1914) and in the late 1970s (Breen 1980a). The extirpation of Sea Otters had an effect on all invertebrate populations, including Northern Abalone. With the re-introduction and recent expansion of the Sea Otter population, restoration of the Northern Abalone population to the levels seen in the late 1970s will probably not be possible.

Rescue effect

As stocks are lower and declining in Alaska (Woodby *et al*. 2000), Washington (Rothaus *et al.* 2008) and California (Rogers-Bennett 2007), BC has, relatively speaking, a healthier Northern Abalone population. Larvae dispersal may be possible from Washington or Alaska (see **Dispersal/migration**), but the likelihood is small given their low Northern Abalone population abundances. Furthermore, wild introductions and/or supplementation from US sources will not be possible without depleting their stocks.

LIMITING FACTORS AND THREATS

The Northern Abalone is particularly vulnerable to overharvest because mature individuals tend to accumulate in shallow water and are easily accessible to harvesters. Continued illegal harvest and low recruitment levels due to reduced spawner densities have had predominant and widespread impacts and are considered to be the most significant threats to Northern Abalone recovery. Another limiting factor to the rebuilding of Northern Abalone population is Sea Otter predation. Additional considerations of abalone habitat loss and/or degradation, climate change and the presence of abalone in the marketplace also are discussed.

The following threats and limiting factors are listed in order of importance, according to current knowledge and the expert perception of the Abalone Recovery Team (Fisheries and Oceans Canada 2007).

Threat: Illegal harvest

Illegal harvest or poaching of abalone is considered an important source of abalone mortality (Jubinville 2000). The most recent estimates of adult instantaneous annual mortality rates were 0.33 (or 28%/y) for the central coast (Hankewich and Lessard 2008) and 0.32 (or 27%/y) for the Queen Charlotte Islands (Hankewich *et al*. 2008). Both estimates were greater than natural mortality rates, 0.15-0.20 (or 14-18%/y), estimated by Breen (1986). However, these mortality rate estimates were within the range Breen (1986) estimated for areas exposed to the commercial fishery (0.21-0.41 or 19-34%/y). The rates indicate that illegal harvest was probably still ongoing and was a major source of mortality following the fisheries closure.

Between 1997 and 2006, approximately 30 abalone poaching convictions have been made. In some cases, multiple charges were laid and strict sentences imposed on repeat offenders. However, fishery officers suggest that poaching remains a major concern and estimate that only 10-20% of poaching activity is prosecuted (Hume pers. comm. 2006), meaning fishery officers think that 80-90% of poaching is not prosecuted, unknown, or otherwise undetected. There were also 14 reports of suspected poaching in 2004 and 23 in 2005. The majority of reports received were from northern BC (Hume pers. comm. 2006).

Mature Northern Abalone, which tend to accumulate and aggregate in shallow water, are easily accessible to harvesters. The high market value of abalone and the difficulty in enforcing the fisheries closure in large, mostly uninhabited coastal areas has fostered illegal harvesting. Poaching not only depletes the already depressed Northern Abalone population, but also reduces their reproductive potential by removing large mature abalone and leaving the remaining mates too far apart to successfully spawn (see next subsection). This combination seriously hinders rehabilitation through the harvest closures. The mean size of all abalone poached, for which measurements were taken, was 115.1 mm (±0.41SE) with a range of 70-154 mm and only 179 abalone out of 1239 were below the former legal size (Lessard pers. comm. 2008). Therefore, poachers preferentially select larger abalone which are more fecund, thus compounding the problem.

Limiting factor: Low recruitment (due to reduced adult spawner densities)

Low recruitment in an area, over a protracted period of several years, may contribute to further declines in the Northern Abalone population by failing to replenish the reproductive adults that die from natural causes or illegal harvest. Spawning aggregations are believed to enhance reproductive success in many abalone species by increasing the chance of fertilization (Sloan and Breen 1988; Shepherd and Brown 1993; McShane 1995a,b; Shepherd and Partington 1995; Babcock and Keesing 1999; Dowling *et al*. 2004). Recent studies on several abalone species (McShane 1995a,b; Shepherd and Partington 1995; Babcock and Keesing 1999; Dowling *et al*. 2004) and Sea Urchins (Levitan *et al*. 1992; Levitan and Sewell 1998) have pointed to reduced fertilization success caused by dilution of gametes through reduced adult spawner densities, known as the Allee effect (Allee *et al*. 1949).

A critical density below which fertilization is essentially zero has not been determined for Northern Abalone. Shepherd and Brown (1993) observed a 50% decline in the proportion of aggregating adults in *H. laevigata*, an Australian species, when density declined from 1.8 to 0.7/m^2. They reasoned that the loss of reproductive potential is multiplied by a factor related to the ability of abalone to aggregate. In other words, the effective population size declines more rapidly than the true population size as density declines. In the same study, a mean density change from 0.37 to 0.29/m^2 in 13 years was followed by a recruitment failure (Shepherd and Brown 1993).

Minimum thresholds at which the Allee effect becomes significant have been estimated for other abalone species at between 0.15 to 0.33 abalone/m^2 (Shepherd and Partington 1995; Babcock and Keesing 1999). Based on a recent study in the US San Juan Islands, adjacent to the southern tip of Vancouver Island, Rothaus *et al.* (2008) proposed that Northern Abalone may actually have a higher Allee effect threshold than these proposed densities. Estimates of Northern Abalone density for the Queen Charlotte Islands in 2002 and 2007 were below 0.15 mature abalone/m^2 (Table 3), while estimates in the central coast have been below 0.33 mature abalone/m^2 since 1993 (Table 2). Furthermore, all new survey sites on the west coast of Vancouver Island and Georgia Strait were considerably less than 0.15 abalone/m^2 with the exception of the sheltered site in Quastino Sound.

The San Juan Island Study (Rothaus *et al.* 2008) concluded that overharvest may have been responsible for low densities (and possible Allee effect) in the 1990s but Allee effects associated with reduced fertilization success appeared to be responsible for more recent, ongoing recruitment failure. This was supported by an increase in the mean shell size over time coupled with the disproportionate reduction in individuals <90 mm SL. In BC, mean size actually appears to be dropping along with a disproportionately greater decline in larger individuals suggesting that ongoing removal of large abalone continues to be an issue although the Allee effect for some populations may also be contributing to the low densities observed.

Limiting factor: Sea Otter predation

The Sea Otter is an important natural predator of many marine invertebrates, including abalone, and as a consequence can have a significant effect on the nearshore coastal ecosystems of BC (Watson 2000). A massive fur trade occurred from the mid-1700s until 1911 when Sea Otters were protected under the International Fur Seal Treaty. By that time, few populations remained and the last Sea Otter in BC was shot in 1929 resulting in their extirpation in BC. Subsequently, the Sea Otter was reintroduced into BC in three separate translocations from Alaska between 1969 and 1972 and, with the absence of exploitation, the population has grown and continues to spread in BC (Watson *et al*. 1997; Nichol *et al*. 2005). Sea Otters in Canada were designated by COSEWIC as Endangered in 1978, re-examined and confirmed as Endangered in 1986, re-designated as Threatened in 1996, re-examined and confirmed as Threatened in 2000, and re-examined and designated as Special Concern in 2007 (COSEWIC 2007).

Mortality rates of Red Abalone, *H. rufescens*, populations in California in areas occupied by Sea Otters has been estimated at 0.3-1.0 (or 26%-63%/y) (Hines and Pearse 1982 *in* Shepherd and Breen 1992) and 1.3 (or 73%/y) (Deacon 1989 *in* Shepherd and Breen 1992). In BC, there are no estimates of predation mortality by Sea Otters. However, rough estimates of mortality rates were calculated from Watson's (1993, 2000) studies on the effect of Sea Otters on nearshore ecosystems (Lessard *et al*. 2007b). At a permanent site in Kyuquot Bay, the mean number of exposed abalone was 0.97/m^2 in 1988, decreased to 0.36/m^2 the following year and was 0.22/m^2 in 1990

(Watson 1993). At that site, Sea Otters were first observed in November 1988 and foraged sporadically thereafter (Watson 1993). The abalone mortality rates were estimated to be 0.99 and 0.49 (or 63%/y and 39%/y). No legal fishery took place once Sea Otters had occupied the area (Harbo 1997). These mortality rate estimates should be considered carefully as they do not include the number of Sea Otters in the area recently occupied nor do they distinguish between Sea Otter predation and other mortality causes including poaching. Nevertheless, these estimates are similar to those estimated for California.

Abalone populations have been present at low stable abundances in Sea Otter areas in California (Cooper *et al*. 1977; Hines and Pearse 1982; Wendell 1994; Micheli *et al.* 2008). In BC, abalone do co-exist in areas with Sea Otters, but it is not known at this time at what levels they will persist once the Sea Otters' other food items, i.e., Sea Urchins and other shellfish species, are depleted. Sea Otters and abalone co-existed in BC for millennia prior to the extermination of Sea Otters by humans in BC (Watson 2000). However, the exact mechanisms for this coexistence and the survival of abalone at low abundance in BC are not known. Ecosystems are clearly complex, constantly changing in spatial and temporal scales and can foster the development of counter-intuitive population changes (Sinclair and Byrom 2006). Carter *et al*. (2007), using Sea Urchins, have shown that the "sea otter-trophic cascade paradigm" is not applicable in all locations and habitat types. Many factors, such as environmental variability (e.g., storm frequency, climate change) and biological factors (e.g., disease, invertebrate predators and competitors, density dependent effects on growth, reproduction, and survival) may positively or negatively influence abalone density and abundance in an area.

Most of what is known about abalone in BC is based on studying systems without Sea Otters. While Sea Otters are clearly not responsible for the observed declines in the Northern Abalone population over the last few decades, as the range of Sea Otters expands, Northern Abalone may only persist at low levels. In areas where abalone have been severely depleted by natural factors and/or human poaching, subsequent Sea Otter predation may significantly accelerate the decline and contribute to the demise of abalone populations in many areas of BC.

Additional consideration: Habitat loss or degradation

In general, the impacts of works and developments on, in, and under the water (e.g., marinas, loading facilities, aquaculture farms) on abalone populations and their habitat have not been studied. Conversely, while their cumulative impacts are unknown, the areas potentially affected are relatively small where abalone habitat with high suitability is present (wave-exposed areas, mainly northern BC and west coast of Vancouver Island). In order to evaluate the impacts on Northern Abalone and their habitat, a protocol has been developed for authorizing and monitoring works and developments around abalone habitat (Lessard *et al*. 2007b). Continued monitoring and regulation will be necessary to maintain habitat in which the Northern Abalone can be recovered and to prevent losses to important spawning aggregations.

Currently, abalone habitat loss or degradation is listed as a threat in the recovery strategy (Fisheries and Oceans Canada 2007). While there is a great amount of uncertainty (lack of knowledge) regarding the impacts of works and developments on abalone and their habitat, habitat loss and/or degradation from these activities is not considered to be a major concern as long as the protocol of Lessard *et al.* (2007b) continues to be applied.

Additional consideration: Climate change

Anomalous warming of surface water is one of the physical consequences of El Niño (Tabata 1985). The frequency and intensity of El Niño have been increasing since the 1975-76 regime shift in the North Pacific (Vilchis *et al*. 2005). Adult abalone populations are affected by the availability of drift kelp as a food source (Tegner *et al*. 2001). Tegner *et al*. (1996) determined that a >50% reduction in *Macrocystis pyrifera* carrying capacity coincided with the warming trends since 1957. Abalone growth declined during El Niño conditions (Haaker *et al*. 1998) which was probably due to reduced food quality or quantity (Vilchis *et al*. 2005). In Barkley Sound, BC, a study was conducted to assess the effects of the 1997 El Niño on the fish and algae communities within *Macrocystis integrifolia* kelp beds (Lessard pers. comm. 2008). There was a significant decline in the percent cover of algae between 1997 and 1998.

Northern Abalone have a considerable temperature tolerance. Although they may be directly affected by global warming in their southern distribution (Rogers-Bennett 2007), direct effects in Canada are not expected to occur for several years as BC is well within the global distribution of the species. In contrast, abalone food, namely kelp, is expected to be directly affected by climate change as warmer waters are usually nutrient-depleted-which is known to affect kelp growth in California and in BC (Tegner *et al*. 1996; Vilchis *et al*. 2005; Lessard pers. comm. 2008).

Additional consideration: Abalone in the marketplace

Other species of abalone from aquaculture and commercial fisheries in other jurisdictions (including Australia, Mexico, China, Chile, and the United States) are still available in the BC marketplace. Stock laundering through these legitimate sources is possible. While it is feasible to genetically differentiate abalone species, identifying the provenance of *H. kamtschatkana* is problematic because of little population subdivision across its global distribution (see **Genetic description**).

Furthermore, current Northern Abalone aquaculture stocks in BC have not yet been distinguished genetically from wild sources. Tracking protocols for sold individuals are in place to limit the avenues through which wild abalone may be “laundered” as cultured product. Abalone aquaculture stocks are currently included in the SARA listing and require a SARA permit to be transferred to the wild or sold. Optimistically, negative impact to the wild abalone population is not expected to increase if current tracking protocols remain in place.

SPECIAL SIGNIFICANCE OF THE SPECIES

Long harvested by coastal First Nations, abalone (*Haliotis* spp.) meat was consumed as food and the shells or pieces of shell of Northern Abalone or Red Abalone (*H. rufescens*) traded from California were used in BC as fishing lures, in jewellery and as an inlay for carvings (Stewart 1977; Sloan 2003). Abalone buttons on a ceremonial blanket were a sign of wealth to the Tsimshian (Reece 2000). Abalone were important not only as food to coastal First Nations, but played an important part in their spiritual and cultural society. Harvest was generally restricted to the lowest tides, although some, such as the Haida, also used a three-pronged spear to access abalone in subtidal areas (Jones 2000). BC's coastal First Nations express continued concern that the Northern Abalone population is threatened because this situation results in the closure of the food, social and ceremonial fisheries. Interest in food, social and ceremonial fisheries for abalone has provided an incentive for Northern Abalone rebuilding programs in some areas. Some of these programs go beyond the objective of the recovery strategy, but nonetheless support Northern Abalone recovery.

In addition to the concerns of First Nations, the closures of BC's commercial and recreational abalone fisheries represented significant economic and recreational loss to participants, associated industries and coastal communities. While small recreational and commercial fisheries for Northern Abalone occurred in BC as early as 1900, a commercial dive fishery directed on Northern Abalone began in earnest in 1972. Developing through the 1970s, BC's commercial fishery peaked in 1977 with landings of 481 t. The majority of harvest occurred in the north and central coast of BC and in the Queen Charlotte Islands (Harbo 1997; Campbell 2000a). The value of the commercial fishery peaked at $1.86M (landed value) in 1978 (Sloan and Breen 1988). Northern Abalone were also regarded as a gourmet food and recreational divers were known to have had a keen interest in Northern Abalone harvest.

The Northern Abalone (*Haliotis kamtschatkana*) is the only species of abalone commonly occurring in BC and is the most northerly distributed abalone species in North America.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

BC's Northern Abalone fisheries were closed to all users in December 1990 (*Fisheries Act*). The last commercial fishery for Northern Abalone was in Alaska in 1995. Alaska still has a skin-diving (no surface air supply) recreational fishery where the daily and possession limits are five abalone; a licence is required. Washington and Oregon never had commercial fisheries for Northern Abalone and Washington State closed its recreational abalone fishery in 1994. Currently, Oregon has a very limited recreational fishery for abalone: the catch limit is five abalone/year and the minimum size is 8 inches (200 mm) which effectively precludes any harvest of Northern Abalone as the largest shell length of Northern Abalone ever recorded was 165 mm. California also closed all commercial abalone fisheries in 1997. A skin-diving recreational fishery for Red Abalone north of San Francisco is the only remaining abalone fishery in California.

Northern Abalone was designated as Threatened by COSEWIC in 2000 (Campbell 2000a; Jamieson 2001). In June 2003, Northern Abalone was legally listed and protected as Threatened under Schedule 1 of the *Species at Risk Act* (SARA). The listing under SARA includes prohibitions for the killing, harming, harassing, possessing, buying or selling of an individual, or its parts (including shell), of a listed species. The existing listing and protection under SARA does not exclude captive-bred populations and SARA's prohibitions currently apply also to aquaculture-raised abalone.

Several rebuilding projects are currently underway in BC. Adult translocations to increase local density and reproductive potential have been completed on the central coast, southeast Haida Gwaii, and in Barkley Sound, west coast of Vancouver Island. As these studies are ongoing, no published results are available at this time. Juveniles and larvae outplanting from captive-breeding have also taken place in Barkley Sound. As these small animals require several years of growth to be fully available for sampling, results are also pending.

The most effective measure to recover the abalone stock is the maintenance and effective enforcement of the harvest closure. While rebuilding methods, namely outplanting and adult aggregation (wild-to-wild translocations), have shown some promise, their outcomes have often been poor and uncertain (Tegner 2000). In addition, their effects are likely quite localized and are probably not suited for species recovery as a whole.

Northern Abalone is red-listed in BC. Its global and provincial status are G3G4 and S2, respectively (BC Conservation Data Centre 2008).

Pinto (i.e., Northern) Abalone were designated as a 'State Candidate Species' in Washington in 1998 and were listed as a 'Species of Concern' by NOAA Fisheries in 2004 for protection under the federal *Endangered Species Act* (NOAA 2008).

The IUCN Species Survival Commission has listed the global status of *H. kamtschatkana* as endangered (EN A2abd) based on an observed population size reduction of >50% (IUCN 2008). Although the observed declines in BC and Washington showed a population size reduction of >80%, the assessment judged that “the historical elimination of Sea Otters led to abnormally large pre-exploitation level [of abalone]” and accordingly reduced the classification from critically endangered.

TECHNICAL SUMMARY

Haliotis kamtschatkana
Northern Abalone — Ormeau Nordique
Range of Occurrence in Canada : Pacific Ocean (coastal BC)

Demographic Information

Generation time (average age of parents in the population) Age at first reproduction 2-5 years; longevity 15-20 years.	Approximately 10 years
Estimated percent reduction in total number of mature individuals over the last 3 generations. Based on densities for two time series (central coast and Queen Charlotte Islands).	88-89%
Projected percent reduction in total number of mature individuals over the next [10 or 5 years, or 3 or 2 generations].	May continue to decline
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 or 5 years, or 3 or 2 generations] period, over a time period including both the past and the future.	Decline is likely
Are the causes of the decline clearly reversible? Commercial, recreational and First Nations legal fishery closed in 1990, but stocks have not recovered.	No
Are the causes of the decline understood?	Yes
Have the causes of the decline ceased? Commercial, recreational and First Nations legal fishery closed in 1990; illegal harvest (poaching) continues; growth of Sea Otter population (main predator) continues; Allee effect may now be operating.	No
Projected trend in number of populations	No change
Are there extreme fluctuations in number of mature individuals?	Unknown
Are there extreme fluctuations in number of populations?	No (only 1 population)

Extent and Area Information

Estimated extent of occurrence	207,478 km²
[Observed, inferred, or projected] trend in extent of occurrence	Stable
Are there extreme fluctuations in extent of occurrence?	No
Estimated area of occupancy Extent of appropriate habitat is unknown and has not been mapped, but will be larger than 2000 km^2.	IAO > 2000 km²
Inferred trend in area of occupancy	May be declining
Are there extreme fluctuations in area of occupancy?	No
Is the total population severely fragmented? Recruitment is still occurring in most areas.	Probably not
Number of current locations	Unknown (very large)
Trend in number of locations	May be declining
Are there extreme fluctuations in number of locations?	No
Trend in area and/or quality of habitat	Stable

Number of mature individuals in each population

Population	**N Mature Individuals**
Total population Effective population size based on genetic analysis.	420,000
Number of populations Only one population in BC.	1

Quantitative Analysis

Based on population simulation projections if current mortality rates continue (no probability calculated). Probabilities of extinction at 20 years, 5 generations, and 100 years are unavailable.	Extirpation in 270 years

Threats (actual or imminent, to populations or habitats)

Main threats in order of importance: Illegal harvest (actual); Low recruitment due to reduced spawner densities (Allee effect) resulting from mortality of reproductive adults from natural causes and illegal harvest (actual); Sea Otter predation (actual/imminent); Climate change (imminent and indirect, due to impact on kelp which is the primary food source).

Rescue Effect (immigration from an outside source)

Status of outside population(s) USA: N3N4; IUCN Red List Category: Endangered; Global (NatureServe): G3G4; US *Endangered Species Act*: Special Concern; Alaska: S2S3; Oregon: SNR; Washington: SNR (but designated as a State Candidate Species).	
Is immigration known?	Immigration is possible from Washington State and Alaska
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	No, stocks too low

Current Status

COSEWIC: Endangered 2009 SARA: Threatened 2003 (Schedule 1) Canada: N2 BC: S2

Status and Reasons for Designation

Status: Endangered	**Alpha-numeric code:** A2bd
Reasons for Designation: Highly valued for its meat, this marine mollusc is patchily distributed along the west coast of Canada. Despite a total moratorium on harvest in 1990, the species was designated as Threatened in 2000. Poaching is the most serious threat and continues to reduce population abundance, particularly the larger, more fecund component; however, all size classes have declined significantly over the past three generations (i.e. since 1978) with mature individuals declining an estimated 88-89%. Low densities may further exacerbate the problem by reducing fertilization success in this broadcast spawner (the Allee effect). Although predators such as the recovering Sea Otter population are not responsible for recently observed declines, they may ultimately influence future abundance of abalone populations.	

Applicability of Criteria

Criterion A (Declining Total Population): Met Criterion A for Endangered because the reduction in the total number of mature adults over the last 3 generations is estimated to be 88-89%. A2 applies because the reduction, shown by declines in density at index sites monitored regularly over the past 30 years, may not have ceased and may not be reversible (b) and actual or potential levels of exploitation (d) continue. While the main cause of the reduction – the legal fishery – has ceased, the stock has not recovered and is still subject to poaching and increased natural predation from Sea Otters.
Criterion B (Small Distribution, and Decline or Fluctuation): Does not apply because the EO is estimated to be 207,478 km^2 and the IAO is estimated to be > 2,000 km^2.
Criterion C (Small Total Population Size and Decline): Does not apply because the estimated effective population size is 420,000.
Criterion D (Very Small Population or Restricted Distribution): D1 does not apply because the estimated effective population size is 420,000. D2 does not apply because the AO is much larger than 20 km^2 and the number of locations, although not specifically known, is very large.
Criterion E (Quantitative Analysis): Does not apply.

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Aboriginal Traditional Knowledge process and protocol guidelines are being reviewed by Aboriginal Elders and Knowledge Holders for implementation in the COSEWIC species assessment process. Therefore, the ATK Subcommittee was unable to assess the methodology, completeness and accuracy of ATK, but are satisfied with the effort made to collect and incorporate ATK and community knowledge in the Northern Abalone status report (Benoit pers. comm. 2008).

Abalone Recovery Team (2007)

Alan Campbell, Fisheries and Oceans Canada

Laurie Convey (Recovery Team Chair), Fisheries and Oceans Canada, Resource Management South Coast Area, 3225 Stephenson Point Rd., Nanaimo B.C. V9T 1K3.

Ted Down, Ministry of Environment, Government of British Columbia

Rick Harbo, Fisheries and Oceans Canada

Bill Heath, Ministry of Agriculture and Lands, Government of British Columbia

Heather Holmes, Parks Canada Agency, Pacific Rim National Park Reserve

Bryan Jubinville, Fisheries and Oceans Canada

Joanne Lessard, Fisheries and Oceans Canada

Guy Parker, Fisheries and Oceans Canada

Abalone Recovery Implementation Group (2006-7)

William Benyon, Metlakatla Fisheries Program

Julie Carpenter, Heiltsuk Fisheries Program / Heiltsuk Abalone Stewardship Project

Laurie Convey, Fisheries and Oceans Canada

Ernie Cooper, TRAFFIC

Bart DeFreitas, Haida Fisheries Program / Haida Gwaii Abalone Stewards

Mike Featherstone (alternate Tim Joys), Pacific Urchin Harvesters Association

Joel Harding (alternate Ernie Mason), Kitasoo Fisheries Program / Kitasoo Abalone Stewardship Project

Heather Holmes, Parks Canada Agency

Russ Jones, Haida Fisheries Program / Haida Gwaii Abalone Stewards

Bryan Jubinville, Fisheries and Oceans Canada

Lynn Lee, World Wildlife Fund Canada / Haida Gwaii Abalone Stewards

Joanne Lessard, Fisheries and Oceans Canada

Doug McCorquodale, Gwa'sala-'Nakwaxda'xw Nation and Kwakiutl Fisheries Program

John Richards, Bamfield Huu-ay-aht Community Abalone Project

Mike Ridsdale, Gitxaala Fisheries Program

Anne Stewart, Bamfield Marine Sciences Centre

Blair Stewart, Nisga'a Fisheries Program

Tomas Tomascik, Parks Canada Agency

Marty Weinstein, Namgis Fisheries Program

Guy Whyte, Pacific Trident Fishing

Ross Wilson, Heiltsuk Fisheries Program / Heiltsuk Abalone Stewardship Project

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Joanne Lessard has worked exclusively as the abalone research biologist for the department of Fisheries and Oceans Canada since September 2002. She sits on the Abalone Recovery Team which now assumes a more administrative function as the implementation of the recovery strategy and action plan are now overseen by the Abalone Implementation Group for which she is the Fisheries and Oceans Canada Science representative. She is also chair of the Northern Abalone research and recovery sub-group of the recently formed Transboundary Recovery Abalone Group, which strives to support collaboration and information sharing throughout the global range of Northern Abalone. As the Fisheries and Oceans Canada abalone biologist she develops, plans and participates in field research as well as provides science support for community-based rebuilding projects. She has authored and co-authored several primary publications on Northern Abalone biology as well as overseen the publication of all the recent survey results. Prior to September 2002, she worked on the stock assessment and habitat of several marine invertebrate species in the Pacific Region, notably Red Sea Urchins which share similar habitats as Northern Abalone. She has an M.Sc. in Zoology from the University of British Columbia and completed her B.Sc. in Biology in 1991 at the Université Laval, Québec.

COLLECTIONS EXAMINED

Royal British Columbia Museum, Victoria, BC