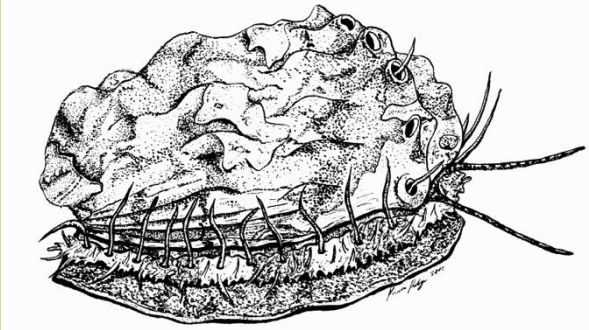
Species at Risk Act

Recovery Strategy Report Series

Report on the Progress of Recovery Strategy Implementation for Northern Abalone (*Haliotis kamtschatkana*) in Canada for the Period 2007- 2012

Northern Abalone



2015

Canada

Report on the Progress of Recovery Strategy Implementation for Northern Abalone (*Haliotis kamtschatkana*) in Pacific Canadian Waters for the Period 2007-2012

2015

Recommended Citation

DFO. 2015. Report on the Progress of Recovery Strategy Implementation for Northern Abalone (*Haliotis kamtschatkana*) in Pacific Canadian Waters for the Period 2007-2012. *Species at Risk Act* Recovery Strategy Report Series. Fisheries and Oceans Canada, Ottawa. v + 28 pp.

For copies of the progress report, or for additional information on species at risk, including COSEWIC Status Reports, residence descriptions, action plans, and other related recovery documents, please visit the SAR Public Registry.

Cover illustration: Pauline Ridings, Fisheries and Oceans Canada

Également disponible en français sous le titre

« Rapport sur les progrès de la mise en œuvre du programme de rétablissement de l'ormeau nordique (*Haliotis kamtschatkana*) dans les eaux canadiennes du Pacifique pour la période 2007 - 2012 »

ISBN 978-0-660-02791-3

Catalogue no. En3-4/35-1-2015E-PDF

AUTHORS

This document was prepared by Christie McMillan (contractor) on behalf of Fisheries and Oceans Canada (DFO).

ACKNOWLEDGEMENTS

Fisheries and Oceans Canada would like to thank Joanne Lessard (DFO) and Lynn Lee (Simon Fraser University) for their contributions to the development of this progress report.

PREFACE

Section 46 of the *Species at Risk Act* (SARA) requires the competent Minister to report on the implementation of the recovery strategy for a species at risk, and on the progress towards meeting its objectives, within five years of the date when the recovery strategy was placed on the Species at Risk Public Registry.

Reporting on the progress of recovery strategy implementation requires reporting on the collective efforts of the competent Minister, provincial organizations and all other parties involved in conducting activities that contribute towards the species' recovery.

EXECUTIVE SUMMARY

Northern Abalone (*Haliotis kamtschatkana*) was initially assessed as threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1999 and listed as threatened under the *Species at Risk Act* (SARA) in 2003. In 2009, Northern Abalone was reassessed and designated endangered by COSEWIC. The species is now legally listed as endangered under SARA.

Present threats to Northern Abalone, as identified in the *Recovery Strategy for Northern Abalone (*Haliotis kamtschatkana*) in Canada* (Fisheries and Oceans Canada 2007) (the Recovery Strategy), include: illegal harvest, low recruitment, habitat loss or degradation, and Sea Otter predation.

This report documents the progress of recovery strategy implementation for the Northern Abalone in Canada for the period 2007-2012. It summarizes progress that Fisheries and Oceans Canada (DFO) and the broader scientific community have made towards achieving the goals and objectives set out in the Recovery Strategy. Progress to date includes:

- Continued monitoring of Northern Abalone abundance, distribution, size, mortality, and density at index sites in five biogeographical zones, including new sites in the Georgia Basin.

- Research into and improved understanding of rebuilding efforts for Northern Abalone through pilot studies conducted by DFO and First Nations abalone stewardship groups, and scientific research into the long-term survival, sources of mortality, and habitat requirements for hatchery-reared abalone.

- Major convictions under both SARA and the Fisheries Act for illegal abalone possession and trafficking due to reactive, preventative and proactive enforcement by DFO.

- First Nations and coastal community involvement in enforcement of fisheries closures through local vessel patrols and Abalone Coast Watch programs.

- Increased public awareness of threats to Northern Abalone and Fisheries and Oceans Canada's Observe-Record-Report toll-free number through communications initiatives undertaken by DFO and Northern Abalone stewardship groups.

- Identification of critical habitat bounding boxes for Northern Abalone in four geographical areas.

While there has been measurable progress towards meeting some of the goals, objectives and performance measures presented in the Recovery Strategy, Northern Abalone abundance, distribution, and density remain below the recovery objectives for index sites in Haida Gwaii and the north and central coasts of British Columbia. Additionally, abalone mortality rates at these index sites remain high. Further work is therefore required to support the recovery of Northern Abalone in Canada.

Table of Contents

LIST OF TABLES

1. BACKGROUND

1.1 COSEWIC Assessment Summary

Common Name:
Northern Abalone

Scientific Name:
Haliotis kamtschatkana

Legal Listing (*SARA*):
Endangered

COSEWIC Status:
Endangered

Assessment Summary:
April 2009[1]

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 in Canada:
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 updated status report.

[1] Assessment updated from that presented in the 2007 Recovery Strategy (COSEWIC 2009)

1.2 Threats

1.2.1. Threats to the Species at Risk

Present threats to Northern Abalone, as identified in the Recovery Strategy (Fisheries and Oceans Canada 2007) include: illegal harvest, low recruitment, habitat loss or degradation, and Sea Otter predation.

1.2.2. Activities Likely to Destroy Critical Habitat

The *Action Plan for Northern Abalone (*Haliotis kamtschatkana*) in Canada* (Fisheries and Oceans Canada 2012) (the Action Plan) identified critical habitat for Northern Abalone to the extent possible within four geographical areas. Critical habitat for Northern Abalone is not limiting; the population currently occupies an area that is larger than that required for population recovery (COSEWIC 2009, Fisheries and Oceans Canada 2012). Therefore, loss of habitat is not thought to be a major threat to the recovery of Northern Abalone (Lessard et al. 2007, COSEWIC 2009).

Finfish aquaculture, log booms and log dumps, and dredging are activities that could affect the features and attributes of critical habitat, and may result in loss of function (Fisheries and Oceans Canada 2012; see Table 1). Similarly, underwater developments such as the construction of pipes or cable placement and installation of pilings may have similar impacts to dredging (Fisheries and Oceans Canada 2012).

Table 1: Examples of activities that are likely to result in destruction of critical habitat.

Activity	Pathway of Effect	Level of Concern	Function Affected	Feature Affected	Attribute Affected
• Dredging • Underwater pipe installation • Cable placement • Piling installation	• Direct loss of habitat resulting from removal or significant alteration of primary substrate • Sedimentation	Low	Attachment	Primary substrate	• Bedrock or boulders with adequate rugosity are necessary for attachment. • Secondary substrate: some cobble may be present but little or no gravel, sediment, sand, mud, or shell present.
• Finfish aquaculture	• Increased sedimentation and physical changes to substrate	Low	Attachment	Primary substrate	• Bedrock or boulders with adequate rugosity are necessary for attachment. • Secondary substrate: some cobble may be present but little or no gravel, sediment, sand, mud, or shell present.
• Log booms • Log dumps	• Shading may alter community structure and algal growth	Low	Feeding Larval settling Cover	Coralline algae Macroalgae	• Presence of encrusting coralline algae (e.g. *Lithothamnium* spp.) • Presence of kelp (e.g. *Nereocystis*, *Macrocystis*, *Pterygophora*, or *Laminaria* spp.

2. RECOVERY

2.1 Recovery Goals and Objectives

Recovery goals and objectives for Northern Abalone, as stated in the Recovery Strategy, are as follows:

2.1.1. Recovery Goals

Immediate goal (over the next five years):

1. Halt the decline of the existing wild Northern Abalone population in B.C. in order to reduce the risk of this species becoming endangered[2].

Long-term Goal (over the next 30 years):

2. Increase number and densities of wild Northern Abalone to self-sustainable levels in each biogeographic zone of B.C. (Haida Gwaii, Queen Charlotte and Johnstone Strait, North and Central Coast, Georgia Basin, West Coast of Vancouver Island), in order to remove Northern Abalone from threatened[2] status.

2.2 Population and Distribution Objectives

Population and distribution objectives for Northern Abalone, as stated in the Recovery Strategy, are as follows:

Objectives for at least the next five years:

1. To observe that mean densities of large adult (> 100 mm shell length) Northern Abalone do not decline below 0.1 per m^2 at surveyed index sites in Haida Gwaii and North and Central Coast, and that the percentage of surveyed index sites with large adult (> 100 mm shell length) Northern Abalone does not decrease below 40%.

2. To observe that the mean total density estimates at newly established index sites in the Queen Charlotte and Johnstone Straits do not decline below the level observed in 2004 (0.06 Northern Abalone per m^2 and 0.02 Northern Abalone per m^2, respectively), and the mean total density estimates for the West Coast of Vancouver Island do not decline below the level observed in 2003 (0.09 Northern Abalone per m^2).

3. To observe at the index sites (in areas without Sea Otters) that the annual estimated mortality rate for mature (≥ 70 mm SL) Northern Abalone is reduced to < 0.20 and

[2] Note: Northern abalone was reassessed by COSEWIC as endangered in 2009, and is now legally listed as endangered under SARA.

the mean densities of mature (≥ 70 mm SL) Northern Abalone are increased to > 0.32 per m^2.

4. To observe at the index sites (in areas without Sea Otters) that the proportion of quadrats (m^2) with Northern Abalone is increased to > 40%.

2.3 Performance Measures

Performance Measures for Northern Abalone, as stated in the Recovery Strategy, are as follows:

Objective-based evaluation criteria:

1. Did the mean density of large adult (> 100 mm shell length) Northern Abalone decline below or increase above 0.1 per m^2 at surveyed index sites in Haida Gwaii and North and Central Coast?

2. Did the percentage of surveyed index sites with large adult (> 100 mm shell length) Northern Abalone decrease (< 40%) or improve (> 40%)?

3. Did the annual estimated mortality rate for mature (≥ 70 mm shell length) abalone drop below 20%, and the mean densities of mature (≥ 70 mm shell length) abalone increase to greater than 0.32 per m^2?

4. Were more than 40% of the quadrats (m^2) occupied by abalone?

Approach-based evaluation criteria:

1. Was the coast-wide closure to Northern Abalone harvesting maintained and enforced?

    a. Was the coast-wide closure an effective measure contributing in halting the population decline?

2. Was a proactive protective enforcement plan implemented?

    a. How many reports relating to abalone harvesting were provided to enforcement officers and the toll free enforcement line (Observe-Record-Report)? To what degree were these reports investigated and did they result in charges and convictions?

    b. How many hours were spent on enforcing abalone closures? What were the trends in enforcement hours and resulting charges and convictions over the period before and during implementation of the recovery strategy?

3. Was a long-term communications strategy implemented?

a. How many and what kind of communication materials and/or actions were produced and/or undertaken?

b. How many people, and where, did the communications activities reach?

c. What indications for increased awareness (e.g., did visits to the abalone web site increase, what level of participation at workshops?) and/or reductions in illegal harvest were a result of communications efforts?

4. What significant new knowledge was gained through research that would directly contribute to the rebuilding of the Northern Abalone population?

    a. How many population rebuilding initiatives were undertaken?

    b. Was there an observed increase in juvenile abundance and/or recruitment as a result of rebuilding experiments?

    c. Does rebuilding appear to be a viable or promising strategy to recover the wild abalone population?

    d. What reports (technical or primary publications) were prepared that provide results of surveys and biological studies?

5. Was baseline abundance data established in each of the biogeographic zones?

3. PROGRESS TOWARDS RECOVERY

Progress towards achieving the goals and objectives set out in the Recovery Strategy is largely detailed in the Action Plan. This section summarizes those achievements, as well as items not captured in the Action Plan.

The Recovery Strategy identified five recovery approaches for Northern Abalone. These included:

1. undertake research and rebuilding experiments for Northern Abalone;

2. monitor the population status of Northern Abalone;

3. maintain fisheries closures;

4. implement a proactive protection plan for the recovery of Northern Abalone; and,

5. implement a communications campaign to stop illegal harvest and raise public awareness for Northern Abalone.

These approaches can be grouped into three broad categories:

1. Research and monitoring activities;

2. Management activities; and,

3. Stewardship activities.

Information regarding the progress toward meeting these objectives was obtained through scientific publications, technical documents, and Habitat Stewardship Program (HSP) and Aboriginal Funds for Species at Risk (AFSAR) reports (2007-2012).

3.1 Research and Monitoring Activities

The Recovery Strategy recommended a schedule of studies to enable the classification of critical habitat. This section addresses the progress toward conducting these studies, as well as progress made toward completing the research and monitoring activities outlined above.

3.1.1. Schedule of Studies to Identify Critical Habitat

Survey juvenile abalone to improve the 'cryptic model' (estimate of the portion of the population that remains cryptic and unavailable to survey).

Efforts to estimate the cryptic (individuals that are not in plain view on the surface of the substrate) proportion of Northern Abalone have been undertaken by DFO in British Columbia, and by the University of Washington in Washington State. DFO surveys of the Haida Gwaii index sites in 1984, 1987, and 1990 included efforts to search for and find cryptic abalone. Zhang et al. (2007) used the results of these survey efforts along with a generalized linear model to describe the relationship between Northern Abalone shell length and the proportion of cryptic abalone. He found that the cryptic proportion was high at shell lengths less than 20 mm, but decreased with increasing shell lengths. Abalone surveys in the San Juan Archipelago estimate a "show factor" of 31% (the number of abalone sighted using standard timed swim surveys, divided by the number of abalone; Stevick 2010).

Compare field observations from known abalone habitat to predicted abalone habitat.

The abalone habitat model developed by Jamieson et al. (2004) for the west coast of Vancouver Island and Haida Gwaii has not been tested using survey data. Though some of the DFO index sites for Northern Abalone surveys (e.g. those off southeastern Haida Gwaii) occur within the areas selected for the habitat suitability model, the survey sites cover only a fraction of the area included in the model, and there have been no dedicated efforts to compare results of these index site surveys with the predicted habitat model.

Determine the habitat characteristics that improve growth rates.

Though there have not been any dedicated studies to identify the habitat characteristics that contribute to higher growth rates of Northern Abalone since the completion of the Recovery Strategy, the data suggest that the dominant understory and canopy algae species, as well as wave exposure, affect Northern Abalone growth rates. As part of a study to identify suitable abalone habitat for focusing rebuilding efforts, Lessard and Campbell (2007) found that the abalone with the largest mean shell lengths were found at the Haida Gwaii index sites with Macrocystis integrifolia as the canopy species. This study, along with previous work by Breen (1986) and Emmett and Jamieson (1988) also found that growth rates of Northern Abalone tend to be higher in sheltered locations. Mean shell length was found to significantly decrease, while mean abalone density significantly increased, with increasing wave exposure (Lessard and Campbell 2007).

Examine growth, survival and distribution of early benthic stages in relation to local habitat, algal, predator and competitor species. Determine the parameters that contribute to higher juvenile densities (recruitment).

Research focused on the growth, survival, and distribution of early benthic stages of Northern Abalone has been conducted by researchers from DFO, the University of Guelph, the California and Washington Departments of Fish and Game, the Puget Sound Restoration Fund, the University of Washington, the University of Victoria, the Bamfield Marine Sciences Centre and Thompson Rivers University. Local habitat has been demonstrated to affect survival and distribution of juvenile abalone in both field and laboratory settings. Based on out-planting experiments of abalone reared by the Bamfield Huu-ay-aht Community Abalone Project (BHCAP) hatchery, Read et al. (2013) found that the addition of complex substrate of any size, from thin layers of cobbles to thick layers of boulders, led to increased survival of juvenile abalone. Laboratory microhabitat trials have found that juvenile Northern Abalone prefer to settle in coralline algae habitat, compared to *Nereocystis* kelp holdfasts or urchin spine canopies, both when the juvenile abalone were faced with the threat of predation, and when they were not exposed to this threat (Rogers-Bennett et al. 2011). In the San Juan Archipelago, coralline algae and kelp holdfasts housed five times more small individual molluscs than the spine canopy of sea urchins, and the kelp holdfasts had more than twice the number of individuals as coralline rocks (Rogers-Bennett et al. 2011). Juvenile abalone were absent from all sites sampled in San Juan Channel during this study, therefore the preferences of other small molluscs were used in lieu of this species.

Salinity has also demonstrated to affect the survival of juvenile abalone. Based on laboratory experiments, Bouma (2007) found that juvenile abalone exposed to salinities of less than 20 ppt experienced complete mortality. For the remaining treatments (23 ppt, 26 ppt, and 30 ppt), survival of juvenile abalone was directly proportional to increasing salinity.

Predator species that posed the greatest threat to juvenile abalone in Barkley Sound were identified by Griffiths and Gosselin (2008). Based on laboratory trials and predator surveys in abalone habitat, decapod crustaceans, including the Black-Clawed Crab *Lophopanopeus bellus* and the Sharp-Nosed Crab *Scyra acutifrons*, were identified as the most important

predators of small juvenile abalone in Barkley Sound. The crab *Cancer productus* and the seastar *Pycnopodia helianthoides* were also observed to consume juvenile abalone, but were more rarely encountered in the study area. Griffiths and Gosselin found that juvenile abalone ≥13 mm shell length faced considerably less predation pressure than smaller abalone.

Monitor the extent to which works and developments on, in and under the water may impact abalone habitat and recovery.

The protocols developed by Lessard et al. (2007) include monitoring approaches that allow for the determination of the impacts of projects, works, or developments on abalone abundance and density. These approaches include surveys conducted at one to three plot sites within the area that will be impacted by development and in a control site outside the impacted area prior to the development, as well as follow-up surveys after five years. These protocols continue to be used for any developments proposed in abalone habitat, and therefore results of the monitoring portion of these protocols will provide information on the extent that these developments may affect abalone recovery.

Refine the predicted abalone habitat suitability model based on field observations.

The predicted abalone habitat suitability model developed by Jamieson et al. (2004) has not been refined. However, knowledge of the requirements for suitable algae habitat has improved. Jamieson et al. (2004) used depth, substrate, extent of kelp coverage, tidal currents, and wave exposure as predictors for their habitat suitability model. Based on DFO index site surveys, it is now known that in addition to these predictors, the presence of coralline algae is an important habitat characteristic, as it provides a settlement cue and food for juveniles, as well as camouflage for adults (Lessard et al. 2007). Additionally, it was found that areas defined as suitable abalone habitat should have salinities >30 ppt (Bouma 2007, Lessard et al. 2007).

Examine abalone distribution in relation to local seawater current patterns and computer simulations to determine potential larval dispersal mechanisms.

No dedicated studies of abalone distribution in relation to local seawater current patterns have been conducted since the completion of the Recovery Strategy. Zhang (2008) conducted a computer-based simulation study of abalone fertilization aimed at predicting fertilization success based on different population parameters, but while these models included predictions of gamete dispersal, they did not examine simulated abalone distribution as a result of the predicted dispersal.

3.1.2. Undertake research and rebuilding experiments for Northern Abalone

Establish experimental pilot research areas and test rebuilding methods by aggregating reproductive adults.

Since 2007, pilot aggregation studies for Northern Abalone have been carried out by the Kitasoo Abalone Stewardship Project (KASP) and the Metlakatla Northern Abalone Coast Watch Program (MNACWP), with advice from DFO and using funds provided by the

Habitat Stewardship Program (HSP) and Aboriginal Fund for Species at Risk (AFSAR). The KASP has conducted two aggregation experiments in their abalone stewardship and research plots on the west sides of Roderick and Price Islands. These plots have been monitored since 2001. In 2004, and again in 2010, abalone from low density areas were relocated to five of these plots (the other five plots served as controls). In 2004, 1,000 abalone were tagged and moved to these plots. Surveys after the 2004 aggregation experiment indicated that this rebuilding effort did not significantly affect the abalone density in the recipient plots (Hankewich et al. 2011). However, because the aggregation experiments had no negative impacts on the local abalone population, it was deemed safe to carry out a larger-scale aggregation in this area (Hankewich et al. 2011). In 2010, 5,000 abalone were moved to the KASP recipient plots. The MNACWP carried out a survey to identify suitable plot sites for an aggregation experiment in 2008, followed by a pilot aggregation study. The results and successes of these pilot aggregation projects are currently being reviewed by DFO Science (J. Lessard, pers. comm.).

Establish experimental pilot research areas and test enhancement through outplanting the hatchery-raised abalone to the wild. Investigate the effects of size, habitat type, season, predators, and site exposure on enhancement success

The BHCAP produced hatchery-spawned abalone from 2001-2011 (OceanLink 2008, Lemay and Boulding 2009). There have been multiple recent studies aimed at evaluating the success of these out-plantings, considering short-term survival (Hansen and Gosselin 2013), long-term survival (Read et al. 2012), and causes of mortality (Hansen and Gosselin, 2013) for these hatchery-raised abalone. The effects of size on out-planting success have also been explored through a pilot out-planting of Northern Abalone in Washington State (Stevick 2010). No dedicated studies focused on the effects of season or site exposure on the survival of hatchery-raised juvenile abalone have been conducted since 2007.

Read et al. (2012) used molecular genetics to assess the long-term survival of out-planted individuals from the BHCAP hatchery. They found that hatchery-stock abalone made up a relatively large proportion of the abalone present in out-planting sites three to seven years after their release. However, the densities of mature abalone in each of the out-planting sites remained below the density identified in the population objectives of the Recovery Strategy of 0.32 abalone/m^2. Additionally, very high mortality and/or emigration rates were inferred in the out-planting areas (Read et al. 2012).

Based on a pilot out-planting of juvenile abalone in the San Juan archipelago, mean initial shell length was a good predictor of survival. Stevick (2010) found that juvenile abalone out-planted at 20 mm had a predicted survival rate of 2.6%, while abalone released at 30 mm, 40 mm, and 50 mm had predicted survival rates of 5.6%, 12%, and 23%, respectively. Predation pressure has been demonstrated to be significantly higher for juvenile abalone less than 13 mm shell length, compared to larger juveniles (Griffiths and Gosselin 2008).

Predation has been identified as the primary cause of mortality of juvenile abalone following out-planting (Hansen and Gosselin 2013, Read et al. 2013). Survivorship of hatchery-spawned abalone was significantly higher when abalone were out-planted into cages that

excluded predators, compared to abalone that were released directly to the substrate (Hansen and Gosselin 2013). When abalone that were initially out-planted in cages were transferred to the substratum after one week, mortality increased quickly; by one week after the abalone were removed from cages, their survivorship was no longer significantly different from that of the abalone that were initially out-planted to the substrate (Hansen and Gosselin 2013). Tagging and handling of abalone were not significant sources of mortality (Hansen and Gosselin 2013). Read et al. (2013) found that adding substrate of any size to out-planting plots (from thin layers of cobbles to thick layers of boulders) led to increased survival of hatchery-raised abalone. It was concluded that in order to successfully become part of the wild abalone population, hatchery-raised individuals should be out-planted in areas with cryptic habitat and low numbers of natural predators (Read et al. 2013).

Test the application of recruitment modules to sample and/or protect early life-stages.

The Haida Gwaii Marine Stewardship Group (HGMSG) completed a report summarizing their efforts to estimate juvenile abalone abundance and provide surrogate habitat for juvenile abalone using human-built concrete block habitats. 144 of these artificial habitats were built at 36 sites in four geographical areas of Haida Gwaii between 2002 and 2006 (Haida Gwaii Northern Abalone Stewardship, 2008). Abalone were found within the structures at all 36 sites. The majority of the abalone measured within the structures were considered juveniles (< 50 mm SL) (Haida Gwaii Northern Abalone Stewardship, 2008). The artificial habitat therefore did provide surrogate habitat for juvenile Northern Abalone. In order to provide an index of recruitment for these early life-stages of Northern Abalone, however, it was suggested that the number of artificial habitat surveys needs to be increased, to allow for knowledge of fluctuations in abundance of these abalone (Haida Gwaii Northern Abalone Stewardship, 2008).

Artificial habitats for juvenile abalone were also built in 2003 and 2004 and have been monitored annually by the KASP. Based on the 2012 HSP report by the KASP, these recruitment modules have been successful, with juvenile abalone documented inhabiting these structures for the past 12 years.

Establish pilot research areas to determine effect of Sea Otter recovery on abalone population parameters; and Determine Northern Abalone population and distribution objectives in the presence of Sea Otters.

Some of the current DFO index sites on the central coast are in areas where Sea Otters are now present. Stryker Island, where Sea Otters have been established since 1996, had the smallest mean abalone size observed during the 2006 index site surveys of the central coast (Hankewich and Lessard 2008). However, the extent to which Sea Otters are affecting the abalone population on the central coast of BC is not yet known.

Since 2008, Sea Otters have been sighted in some of the Kitasoo Abalone Stewardship Program plot sites. Continued monitoring of these sites, which have been surveyed annually since 2001, will lead to improved understanding of the effects of these predators on Northern Abalone (Hankewich et al. 2011).

Chades et al. (2012) used simulation-based optimization procedures to examine the effects of various management actions on the ability to meet recovery targets for both Sea Otters and Northern Abalone. They estimated that under optimal management and in the presence of Sea Otters, abalone density was predicted to be between 0.035 and 0.23 adults/m^2. It was estimated that a management strategy that achieved at least a 50% reduction in poaching of Northern Abalone was a minimum requirement for reaching the current short-term recovery goals for abalone in the presence of Sea Otters.

Research conducted by Simon Fraser University, in partnership with the Haida Gwaii Marine Stewardship Group and the Heiltsuk Integrated Resource Management Group, focusses on determining Northern Abalone population and distribution objectives in the presence of Sea Otters. Results of this research are expected to be available in spring 2014.

Research the effects of disease and/or parasites.

No dedicated research has been conducted related to the effects of disease or parasites on Northern Abalone in Canada over the past five years.

Consult and work co-operatively with First Nations on proposals for projects that are in a First Nations' local area.

DFO has been working collaboratively with First Nations stewardship groups on abalone research and rebuilding experiments. Goals and methodologies for rebuilding experiments, including pilot aggregation studies, out-plantings, and recruitment modules were developed co-operatively by DFO and the participating First Nations groups, including the HGMSG, KASP, MNACWP, and BHCAP. DFO continues to share information about the abalone population, rebuilding techniques, and goals related to recovery of Northern Abalone with First Nations fisheries staff and stewards through annual Abalone Recovery Implementation Group (AbRIG) meetings.

Work co-operatively with coastal communities to share information on the local abalone population and develop rebuilding techniques.

Information about Northern Abalone populations and developing rebuilding techniques is shared with members of coastal communities through annual AbRIG meetings. Additionally, through collaborations with coastal First Nations research and stewardship groups, residents of coastal communities in Bamfield, Haida Gwaii, and the north and central coasts of British Columbia have been included in developing rebuilding techniques.

Incorporate information on abalone from other jurisdictions where appropriate.

Information from California and Washington was shared via Transboundary Abalone Recovery Group during three meetings between 2007 and 2009. Sharing of information between these jurisdictions ensured that efforts to study abalone biology and rebuilding efforts were not duplicated. Due to funding shortages in the U.S., there have been no meetings of this group after 2009 (J. Lessard, pers. comm.).

Consider a broad ecosystem approach in the research of Northern Abalone.

Research conducted by Simon Fraser University, in partnership with the Haida Gwaii Marine Stewardship Group and the Heiltsuk Integrated Resource Management Group, is focused on modeling the effects of Sea Otters and other biotic and abiotic factors on Northern Abalone population and distribution using a social-ecological systems approach and DFO survey data from West Coast Vancouver Island, Haida Gwaii, and the North and Central Coast index sites. Results of this work are expected to be published in 2015.

3.1.3. Monitor the population status of Northern Abalone

Continue index site surveys (every five years).

DFO index site surveys in each region (Haida Gwaii, North and Central Coast, Queen Charlotte Strait, the Georgia Basin, and West Coast Vancouver Island) continue to be carried out every five years (J. Lessard, pers. comm), with the most recent surveys occurring in 2012 in Haida Gwaii, in 2011 on the North and Central Coast, in 2009 in Queen Charlotte Strait, in 2009 in the Georgia Basin, and in 2008 on the West Coast of Vancouver Island.

Establish index sites in Georgia Basin.

An extensive survey for Northern Abalone was conducted by DFO in the northern Strait of Georgia in 2009 (Egli and Lessard, 2011). For this survey, 30 sites were randomly selected from two general areas ("Cortes" and "Texada" areas), and five additional sites were chosen around Mitelnatch and Denman Islands (Egli and Lessard, 2011). These sites were surveyed using the methods described by Breen and Adkins (1979). Only six abalone were found during this survey, three in each of the two survey areas. Egli and Lessard (2011) recommend using Denman Island and Mitlenatch Island sites as index sites for further monitoring of abalone abundance in this region, as abalone populations were known to previously exist in these areas (Lessard et al. 2002, Lucas et al. 2002).Develop an improved measure for 'patch' size.

Zhang (2008) used a theoretical modeling approach to explore the effects of adult abalone density and abundance on fertilization success (defined as the amount of fertilization per spawning female). Based on these computer simulations, fertilization success increased with adult abalone density; however, the rate of increase in fertilization success decreased with increasing densities. This suggests an Allee effect, which appeared to be stronger at lower adult abalone densities. Zhang did not find a specific threshold density below which fertilization would be unsuccessful. Rather, he cautioned that measures need to be taken to maintain fertilization success when density is low. Zhang also found that a single, large population of spawners would result in higher fertilization success than two smaller, isolated populations, even when the abundance in the two smaller populations summed to the abundance of the large population. Additionally, at a given density of adult abalone, fertilization success did not tend to be affected by population abundance, or by size of the spawning ground. Finally, an aggregated distribution (compared to a random distribution) of adult abalone only increased fertilization success at low densities.

Babcock and Keesing (1999) suggested that a mean nearest neighbour distance of approximately 1 m is necessary for successful recruitment of *Haliotis laevigata* in South Australia; however, based on surveys in the San Juan Archipelago between 1992 and 2006, Rothaus et al. (2008) suggest that higher Allee thresholds may exist for Northern Abalone than for other abalone species.

3.2 Management Activities

3.2.1. Maintain fisheries closure

The complete closure of the Northern Abalone fishery (including the commercial, recreational, and First Nations fisheries) in place since 1990 remains in effect.

3.2.2. Implement a proactive protection plan for the recovery of Northern Abalone

Use reactive, preventative and proactive enforcement to curtail illegal harvest and trafficking of Northern Abalone.

DFO has taken reactive, preventative, and proactive actions to reduce incidence of illegal harvest and trafficking of Northern Abalone. These activities include education and stewardship initiatives; monitoring, control, and surveillance activities; and intelligence-based investigations into major cases (Fisheries and Oceans Canada 2012).

Education and stewardship activities include five media releases aimed at raising awareness about the threat of illegal harvest to abalone, promoting the Observe-Record-Report toll-free telephone number, and drawing attention to convictions of those involved with illegal harvest or trafficking of Northern Abalone; the DFO abalone website; and collaborative efforts with Northern Abalone stewardship groups.

Monitoring and surveillance activities include regular vessel patrols and flights, occasionally in collaboration with First Nations abalone stewardship groups. Intelligence-based investigations that have included international collaboration have led to major convictions over the past five years. For example, in 2009, DFO concluded a three-year operation involving the sale and possession of Northern Abalone. The operation involved collaborating with other Canadian agencies, including the Canada Border Services Agency, the Canadian Food Inspection Agency, the Royal Canadian Mounted Police, the Province of British Columbia, and DFO, as well as international agencies, including the National Marine Fisheries Service, the State of California Department of Fish and Game, the U.S. Fish and Wildlife Service, U.S. Customs, and authorities in Mexico (DFO Media Release, October 2009).

Continue to identify illegal abalone in the marketplace using genetic markers.

Molecular genetic research performed by DFO continues to provide DNA evidence that aids in successful convictions of illegal harvest or possession of abalone in both Canada and the US (DFO Media Release, October 2009). Protocols for identifying Northern Abalone using genetic markers, and the application of these methods in detecting Northern Abalone among samples collected by enforcement officers as part of seven different

investigations have been developed (Supernault et al. 2010). Northern Abalone was identified in five of these investigations. Genetic identification of Northern Abalone has also provided incentive for offenders to plead guilty rather than defend in court by increasing the perceived likelihood of detection and conviction among potential illegal harvesters (Supernault et al. 2010)

Promote communication, awareness, stewardship and policing

HSP and AFSAR funding has been provided to First Nations guardians in seven different communities to mitigate threats to Northern Abalone within their traditional territories. The Gitga'at Northern Abalone Assessment and Recovery Program (GNAARP), Nisga'a Abalone Coast Watch Project (NACWP), Heiltsuk Abalone and Sea Otter Stewardship Project (HASP), HGMSG, BHCAP, KASP, and MNACWP have received funding to develop and promote newsletters, websites, and brochures aimed at raising awareness about the threats to Northern Abalone. Additionally, these stewardship organizations have created and delivered school curricula, participated in community events and meetings, and have printed and distributed materials featuring the Observe-Record-Report phone number.

The GNAARP, NACWP, HGMSG, KASP, HASP, and MNACWP have also conducted dedicated and opportunistic patrols within their respective territories to watch for and report any signs of illegal abalone harvest. Based on HSP and AFSAR reports, over 540 dedicated patrols were conducted by these organizations between 2007 and 2012. Opportunistic and in-kind patrols were conducted by fishermen and community members through Abalone Coast Watch programs. Patrols took place within the traditional territories of these First Nations, and included waters around Prince Rupert, Haida Gwaii, Klemtu, Bella Bella, and Hartley Bay.

In addition to independent patrols conducted by First Nations stewardship groups, collaborative patrols have been undertaken as partnerships between First Nations stewardship programs, DFO, and Parks Canada. The HGMSG conducted joint patrols with DFO on the CCGS Vector and the DFO RHIB in 2008 and 2009, and participated in surveillance flights with DFO and Gwaii Haanas/Parks Canada (three per year in 2008 and 2009).

Promote coastal watch programs to involve communities in protecting Northern Abalone.

Between 2007 and 2012, HSP and/or AFSAR funding has been provided to the GNAARP, NACWP, HGMSG, KASP, MNACWP, and HASP stewardship groups to encourage members of their communities to become involved in "Abalone Coast Watch" programs by watching for suspicious activity and reporting signs of illegal harvest to the DFO Observe-Record-Report line from on-water or shore-based platforms. Workshops, outreach events, posters, brochures, community meetings, and community presentations were used to engage and recruit volunteers from these communities.

Additionally, the NACWP and HGMSG received funding to conduct telephone interviews and questionnaires for community members that signed up as Coast Watch volunteers. The purpose of these interviews was to assess participants' knowledge of abalone

conservation concerns, and to determine the extent to which they have participated in Coast Watch activities.

Use 'traceability' protocols to distinguish legally obtained cultured Northern Abalone from illegally obtained wild Northern Abalone.

Traceability protocols used to distinguish hatchery-raised abalone from wild Northern Abalone included "marking" the cultured abalone using diet and/or genetics. The shells of abalone raised in hatcheries can be marked through a change in feed; initially, the abalone were fed a diet of diatoms, which led to red colouration on the shell, followed by a switch to a kelp-based diet, which led to green colouration. The abrupt change from red to green on the shell could therefore distinguish hatchery-raised Northern Abalone from wild abalone (COSEWIC 2009). Additionally, the Northern Abalone that were being legally raised in the BHCAP hatchery from 2001 to 2011 were marked through the crossing of orange variant male abalone with orange variant female abalone, to create primarily orange variant progeny. This hatchery was closed in November of 2011, however, and no other facilities currently exist in British Columbia to culture Northern Abalone.

Foster public support of court imposed sentencing that is appropriate to the threatened status of Northern Abalone.

Since 2007, DFO has prepared and posted to their abalone website five media releases regarding court imposed sentencing following convictions for illegal sale and possession of Northern Abalone. These media releases foster public support of sentencing through drawing attention to the convictions, and through sharing the information that a large proportion of the money from fines is dedicated to research into further tracking of illegal harvesting. Additionally, these releases encourage public participation in decreasing illegal abalone harvest. For example, following the conviction of two seafood companies for illegal sale and possession of Northern Abalone in 2009, DFO created a media release outlining the efforts required to bring these companies to trial, the importance of stopping illegal harvesting, and promoting the Observe-Record-Report line (DFO News Release, October 2009).

Continue to apply precautionary protocols for authorizing works or developments on, in and under the water.

Precautionary protocols developed by Lessard et al. (2007) continue to be applied for authorizing these developments. Proponents for projects located on or near water are directed to contact DFO for developments that may impact species at risk through the DFO "Working Near Water" website.

3.3 Stewardship Activities

3.3.1. Implement a communications campaign to stop illegal harvest and raise public awareness for Northern Abalone

Promote Northern Abalone stewardship projects.

Northern Abalone stewardship projects are promoted through the DFO abalone website, which includes links to the BHCAP, HGMSG, and NACWP websites, along with various links to projects in the US and Australia. Brochures and newsletters outlining the activities of Northern Abalone stewardship projects have also been distributed through local DFO offices. In addition, DFO supported outreach efforts of the MNACWP by providing vessel tours of the Arrow Post for local students in 2009-2011, where students were taught about patrols and the negative implications of illegal abalone harvest.

Continue to update a Northern Abalone web site and newsletter(s) for interested parties and the general public.

The DFO Northern Abalone website is current, with the most recent update taking place in May 2013. Additionally, a website maintained by the NACWP, was created in 2007 and updated in 2008, and the HGMSG website was updated in 2012. Each of these websites contains information about abalone accessible to the general public.

Newsletters have been developed and distributed regularly by various abalone stewardship groups to provide information about abalone biology, threats to their populations, and programs aimed at mitigating these threats to interested members of their communities. These stewardship groups include NACWP (one newsletter each year in 2007 and 2008), HGMSG (two newsletters per year), HASP (one each year), and the MNACWP (two each year).

Work with First Nations, interested local parties, stakeholders and international agencies.

Abalone Recovery Implementation Group (AbRIG) meetings are held annually. The objective of these meetings is to provide opportunities for stakeholders to discuss recovery implementation for abalone. Attendees have included representatives from DFO, HGMSG, Gwaii Haanas National Park Reserve, Namgis First Nation, Gitga'at First Nation, Parks Canada, Kitasoo Fisheries, Heiltsuk Fisheries, Nisga'a Fisheries, LGL Ltd., Metlakatla First Nation, and Huu-ay-aht First Nation.

DFO has also partnered with First Nations Northern Abalone stewardship groups to conduct research, monitoring, and enforcement activities. For example, surveys of the central coast index sites in 2006 were conducted collaboratively by DFO and the Kitasoo and Heiltsuk First Nations (Hankewich and Lessard 2008) and the 2012 surveys of index sites in Haida Gwaii included personnel and efforts from the HGMSG. Study methodologies for aggregation experiments undertaken by the MNACWP, HGMSG, and KASP were developed as a partnership between DFO Science staff and First Nations fisheries technicians. Collaborative monitoring and enforcement activities have included surveillance

flights conducted as a joint effort between DFO, Gwaii Haanas/Parks Canada, and the HGMSG in 2008 and 2009, as well as patrols conducted from the CCGS Vector with the HGMSG.

Collaborations with international agencies, including the National Marine Fisheries Service, the State of California Department of Fish and Game, the U.S. Fish and Wildlife Service, U.S. Customs, and authorities in Mexico have led to successful convictions of illegal abalone harvest and possession (DFO Media Release, October 2009). Additionally, in 2007, the Transboundary Abalone Recovery Group was formed between DFO and researchers from Washington and California to ensure sharing of information regarding abalone research and rebuilding methods (J. Lessard, pers. comm.).

Produce communication materials (e.g., posters, stickers, and brochures) aimed at stopping illegal harvest.

HSP funds have been used to create various materials aimed at raising awareness about the threats to Northern Abalone, and how to report suspected or witnessed incidents of illegal harvest. Since 2007, over 5,700 brochures aimed at stopping illegal harvest have been printed and distributed by the NACWP, HGMSG, KASP, and MNACWP abalone stewardship groups in and around the communities of Prince Rupert, Haida Gwaii, Klemtu, the Nass River Valley, and Bella Bella. Additionally, annual or semi-annual newsletters have been developed and distributed by NACWP, HGMSG, HASP, and MNACWP. In 2008, the HGMSG printed 250 flashlights, 1,000 temporary tattoos, 100 stickers, and 100 buttons that included the DFO Observe-Record-Report number. The BHCAP printed over 2,000 Coast Watch stickers for distribution in 2009. T-shirts and canvas tote bags have also been created by HGMSG with logos and text aimed at stopping illegal harvest of abalone and raising awareness about species at risk, and waterproof notebooks and stickers were created by the HASP in 2008. Posters have been posted in Bella Bella, Shearwater, and Namu by the HASP and in New Aiyansh, Canyon City, Greenville, and Kincolith by the NACWP. Over 700 catch calendars with Coast Watch information were distributed to fishermen in Metlakatla, Hartley Bay, Kitkatla, and Haisla by the MNACWP between 2008 and 2010.

Initiate a proactive media relations campaign, and identify and co-ordinate media opportunities.

Media related to abalone biology, conservation, and stopping illegal harvesting are available on the DFO abalone website. This website includes links to news releases regarding abalone, abalone video clips, abalone publications, and a national abalone conservation poster. These materials raise awareness about threats to Northern Abalone and provide the opportunity to promote the Observe-Record-Report number. Additionally, following charges and convictions for illegal activity involving Northern Abalone, DFO has developed media releases to contribute a positive public relations campaign.

3.4 Summary of Progress towards Recovery

The following is a summary of the progress made towards the recovery of Northern Abalone as outlined in the performance measures from the Recovery Strategy.

1. Did the mean density of large adult (> 100 mm shell length) Northern Abalone decline below or increase above 0.1 per m^2 at surveyed index sites in Haida Gwaii and North and Central Coast?

The 2007 survey of the index sites in southeastern Haida Gwaii (HG, Hankewich et al, 2008) indicated that the mean density of large adult abalone in these sites is only 0.03 abalone/m^2. Although surveys of North and Central Coast (CC) index sites have continued every five years (J. Lessard, pers. comm.), reports on recent index site surveys have not yet been completed, due to a focus on reviewing pilot abalone aggregation projects, combined with limited funding. The most recent survey of the CC index sites in 2006 estimated mean density of large adult abalone in these sites at 0.02 abalone/m^2 (SD = 0.01), a decrease of 50% since 2001 (Hankewich and Lessard 2008).

2. Did the percentage of surveyed index sites with large adult (> 100 mm shell length) Northern Abalone decrease (< 40%) or improve (> 40%)?

The percentage of index sites with large adult abalone has continued to decline, and was estimated at 18.3% in the 2007 survey of HG index sites (Hankewich et al. 2008). Similarly, the percentage of sites with large adult abalone in the CC has been declining since 1985 and was estimated at 17.6% in the 2006 survey of these index sites (Hankewich and Lessard 2008).

3. Did the annual estimated mortality rate for mature (≥ 70 mm SL) abalone drop to < 0.20, and the mean densities of mature (≥ 70 mm SL) abalone increase to greater than 0.32/m^2?

The estimated mortality rate of abalone in the HG index sites as of the 2007 survey is 0.32 (SD = 0.047) (Hankewich et al. 2008). This is higher than the natural mortality rate estimated by Breen (1986), which indicates that abalone harvest is likely still occurring in the Haida Gwaii area (Hankewich et al. 2008). The estimated annual mortality rate for abalone in the CC index sites was similar, estimated at 0.33 (SD = 0.07) during the 2006 survey (Hankewich and Lessard 2008).

The mean density of mature abalone was estimated at 0.15 abalone/m^2 during the 2007 survey of HG index sites (Hankewich et al. 2008), and at 0.23 abalone/m^2 during the 2006 survey of CC index sites (Hankewich and Lessard 2008).

4. Were more than 40% of the quadrats (m^2) occupied by abalone?

During the 2007 survey of HG index sites, the proportion of quadrats containing abalone was below 25% (Hankewich et al. 2008). During the 2006 survey of CC index sites, the proportion of quadrats containing abalone was 21% (Hankewich and Lessard 2008).

In addition to the performance measures addressed above, recovery objectives outlined in the Recovery Strategy also indicated population and distribution objectives for the more recently established index sites in the Queen Charlotte and Johnstone Straits and the West Coast of Vancouver Island. These objectives were to observe that the mean total density estimates at index sites in the Queen Charlotte and Johnstone Straits do not decline below the level observed in 2004 (0.06 Northern Abalone per m^2 and 0.02 Northern Abalone per m^2, respectively), and the mean total density estimates for the West Coast of Vancouver Island do not decline below the level observed in 2003 (0.09 Northern Abalone per m^2). The results of the most recent survey of the Queen Charlotte Strait indicate that mean total density of abalone at index sites in this area was 0.109 abalone/m^2 (SD = 0.033). Johnstone Strait was not resurveyed due to limited abalone habitat in that area (Lessard and Egli 2011). Results of the 2008 survey of West Coast Vancouver Island index sites are not yet available (J. Lessard, pers. comm.).

5. Was the coast-wide closure to Northern Abalone harvesting maintained and enforced? Was the coast-wide closure an effective measure contributing in halting the population decline?

The complete closure of the Northern Abalone fishery (including the commercial, recreational, and First Nations food, social, and ceremonial fisheries) remains in effect; thus limiting the mortality of abalone due to legal harvest. Consequently, the rate of decline of Northern Abalone has slowed since 1990 (Fisheries and Oceans Canada 2012). However, based on surveys of HG and CC index sites, abalone did not achieve the objectives set in the Recovery Strategy regarding abalone density, mortality, and distribution. The high mortality rates and low densities of mature individuals observed in these areas suggest that poaching is likely the main factor preventing recovery of Northern Abalone off southeastern Haida Gwaii and the central coast (Hankewich et al. 2008, Hankewich and Lessard 2008). Additionally, Sea Otter predation may have been exhibiting size-selective pressure on abalone at CC index sites (Hankewich and Lessard 2008).

6. Was a proactive protective enforcement plan implemented?

A proactive enforcement plan for Northern Abalone has been in place since prior to the completion of the Recovery Strategy.

How many reports relating to abalone harvesting were provided to enforcement officers and the toll free enforcement line (Observe-Record-Report)? To what degree were these reports investigated and resulted in charges and convictions?

Enforcement officers received a total of 77 reports related to abalone harvest, sales and possession of abalone over the past five years. All of these reports were responded to, and 61 led to investigations of confirmed violations.

7. How many hours were spent on enforcing abalone closures? What were the trends in enforcement hours and resulting charges and convictions over the period before and during implementation of the recovery strategy?

Pacific Region fishery officers dedicated 23,000 hours to the protection and enforcement of abalone closures over the past five years. While the recovery strategy did not lead to major changes to DFO's abalone monitoring program, Pacific Region fishery officers have been able to increase the amount of time spent monitoring and investigating activities involving Northern Abalone. For example, in 2004, enforcement officers recorded 1,300 hours dedicated to activities involving Northern Abalone, and since 2004, the average effort is 3,500 hours per year. The number of occurrences of illegal activity averaged 13.3 per year, with 10.3 per year resulting in investigations.

8. Was a long-term communications strategy implemented?

Communications activities were undertaken by DFO, as well as by several abalone stewardship groups that were funded through HSP and AFSAR grants.

9. How many and what kind of communication materials and/or actions were produced and/or undertaken?

- Five news releases by DFO regarding abalone charges and convictions since 2007
- School curricula developed and delivered for all grades (GNAARP); grades 4 and 7 (HGMSG); and grade 8 (DFO Stream to Sea program)
- Newsletters (1-2 annually by NACWP, 2 annually by HGMSG, 1 per year by HASP, 2 per year by MNACWP)
- Websites maintained by NACWP, HGMSG, and the BHCAP.
- Community action plans developed by NACWP, HGMSG, and MNACWP
- Printing and distribution of materials aimed at raising awareness of the O-R-R line and stopping illegal harvest. These include: flashlights (250 by HGMSG), temporary tattoos (1,000 by HGMSG), stickers (100 by HGMSG and 2,000 by Huu-ay-aht), buttons (100 by HGMSG), and catch calendars (700 by MNACWP).
- Brochures (over 5,700 created and distributed by the NACWP, HGMSG, KASP, and MNACWP groups in and around the communities of Prince Rupert, Haida Gwaii, Klemtu, and Bella Bella)
- Participation in community events including Crabfest in Kincolith (NACWP), Skidegate Days and Tlell Fall Fair in Haida Gwaii (HGMSG), and Oceans Day in Klemtu (KASP),
- Advertisements on local announcement channel (KASP), television commercials (HASP)

11. How many people, and where, did the communications activities reach? What indications for increased awareness and/or reductions in illegal harvest were a result of communications efforts?

Results from AFSAR and HSP final project reports submitted between 2007 and 2012 indicate that over 19,000 people were reached through communication and outreach efforts. Outreach materials were distributed to community members directly, and to sport fishing lodges, BC ferries, guest houses, tourism offices, eco-tourism vessels, elementary and high school students, and village offices. These outreach materials reached people in the Gitga'at, Heiltsuk, Kitasoo, Metlakatla, Huu-ay-aht, Nisga'a, and Haida territories, as well as members of coastal communities around these territories.

Indications for increased awareness of threats to abalone and efforts to mitigate these threats include participation in Northern Abalone Coast Watch programs; attendance at community meetings, workshops, and AbRIG meetings; and use of the DFO O-R-R line. The number of volunteers participating in Coast Watch activities has continued to increase through efforts of NACWP, HGMSG, KASP, HASP, MNACWP, BHCAP, and DFO. Based on HSP and AFSAR reports, at least 325 people attended community meetings and/or workshops related to abalone conservation in the Haida, Kitasoo, Heiltsuk, Metlakatla, and Huu-ay-aht territories. AbRIG meetings continue to be attended by representatives from First Nations, consulting companies, and Parks Canada, in addition to DFO. Over 77 reports of suspected illegal activity have been provided to DFO in the past five years.

12. What significant new knowledge was gained through research that would directly contribute to the rebuilding of the Northern Abalone population?

Results of pilot abalone aggregation studies are currently being reviewed; however, based on data collected by KASP in partnership with DFO, rebuilding efforts through aggregation of adult abalone from low density areas into KASP stewardship and research plots had no negative impacts on the local abalone population, and therefore larger scale aggregation projects are feasible (Hankewich et al. 2011). Additionally, based on computer simulations, DFO biologist Zhang (2008) found that an aggregated distribution of reproductive adult abalone improved fertilization success when abalone were at low densities.

Knowledge was gained regarding the ideal habitats for out-planting efforts, as well as the sources of mortality for out-planted juvenile Northern Abalone. DFO biologists Lessard and Campbell (2007) used survey data to identify habitats that could sustain high densities of adult Northern Abalone, and therefore the areas where rebuilding efforts should be focused. They found that areas with low to medium wave exposure, some boulders, and the presence of coralline algae and a canopy of *Nereocystis luetkeana* provide the most potential for successful out-planting and aggregation efforts. Studies conducted based on out-planted abalone from the BHCAP hatchery demonstrated that mortality of hatchery-raised juvenile abalone is high immediately after out-planting (Hansen and Gosselin 2013, Read et al. 2013). Predation has been identified as the primary source of this mortality (Read et al. 2013, Hansen and Gosselin 2013). Tagging and handling of abalone were not significant sources of mortality (Hansen and Gosselin 2013). Results of this research indicated that in order to successfully become part of the wild abalone population, hatchery-

raised individuals should be out-planted in areas with cryptic habitat and low numbers of natural predators (Read et al. 2013).

Preliminary results from surveys of artificial concrete block habitats built by HGMSG and KASP indicate that these structures are effective for providing surrogate habitat for juvenile abalone (Haida Gwaii Northern Abalone Stewardship 2008, Hankewich et al. 2011).

13. How many population rebuilding initiatives were undertaken?

There have been at least six new or ongoing population rebuilding initiatives that have been undertaken off the coast of British Columbia since the completion of the Recovery Strategy. These include aggregation projects by MNACWP and KASP; creation of artificial abalone habitat to protect and sample juvenile abalone (undertaken by HGMSG, KASP, and HASP); and out-planting of hatchery-raised abalone spawned from wild broodstock to supplement wild populations by BHCAP.

Preliminary results of aggregation studies are promising (Fisheries and Oceans Canada 2012); however, results of the current review of these projects will provide a better understanding of whether juvenile abundance and recruitment significantly increased as a result of these efforts. Due to predation pressure on juvenile out-planted abalone and associated mortality of out-planted individuals, there remain limitations to the ability of hatchery-raised abalone to increase juvenile abundance and recruitment (Read et al. 2013).

14. Was there an observed increase in juvenile abundance and/or recruitment as a result of rebuilding experiments? Does rebuilding appear to be a viable or promising strategy to recover the wild abalone population?

The completion of the review of pilot aggregation studies will provide further insight into the viability of this strategy to recover wild abalone populations. Molecular genetics research has indicated that hatchery-stock abalone made up a relatively large proportion of abalone present in out-planting sites three to seven years after out-planting (Read et al. 2012). However, the densities of mature abalone in each of the out-planting sites remained below the density identified in the population objectives of the Recovery Strategy of 0.32 abalone/m^2 (Read et al. 2012). Juvenile abalone were observed inhabiting all artificial habitat structures built by the HSMSG (Haida Gwaii Northern Abalone Stewardship Group 2008), and the KASP documented juvenile abalone inhabiting the structures built by this organization for the past 12 years.

15. What reports were prepared which provide results of surveys and biological studies?

The following primary publications and DFO technical reports were prepared since 2007 and provide results of abalone surveys and biological studies. See Reference section for complete citations for these publications:

1. COSEWIC 2009
2. Egli and Lessard 2011

3. Fisheries and Oceans Canada 2012
4. Griffiths and Gosselin 2008
5. Hankewich and Lessard 2008
6. Hankewich et al. 2008
7. Hansen and Gosselin 2013
8. Lemay and Boulding 2009
9. Lessard et al. 2007
10. Lessard and Egli 2011
11. Read et al. 2012
12. Read et al. 2013
13. Supernault et al. 2009
14. Zhang et al. 2007
15. Zhang 2008
16. Zhang et al. 2009

16. Was baseline abundance data established in each of the biogeographic zones?

Baseline abundance data have been collected in each of the five biogeographical zones. These include Haida Gwaii, the North and Central Coasts, West Coast Vancouver Island, Queen Charlotte and Johnstone Straits, and the Georgia Basin. Index sites for all areas except the Georgia Basin had been established prior to the Recovery Strategy, and surveys in each of these areas continue to be undertaken every five years. Index sites for the Georgia Basin were established in 2009 (Egli and Lessard 2011).

REFERENCES

Babcock, R. and Keesing, J. 1999. Fertilization biology of the abalone *Haliotis laevigata*: laboratory and field studies. Can. J. Fish. Aquat. Sci. 56: 1668–1678.

Bouma, J.V. 2007. Early life history dynamics of pinto abalone (*Haliotis kamtschatkana*) and implications for recovery in the San Juan archipelago, Washington State. MSc thesis, University of Washington. 112pp.

Breen, P.A. and Adkins, B.E. 1979. A survey of abalone populations on the east coast of the Queen Charlotte Islands, August 1978. Fish. Mar. Serv. Manuscr. Rep. 1490: 125 pp.

Breen, P.A. 1986. Management of the British Columbia fishery for Northern Abalone

(*Haliotis kamtschatkana*). Can. Spec. Publ. Fish. Aquat. Sci. 92: 300-312.

Chades, I., Curtis, J.M.R. and Martin, T.G. 2012. Setting realistic recovery targets for two interacting endangered species, Sea Otter and Northern Abalone. Conserv. Biol. 26(6): 1016-1025.

COSEWIC. 2009. COSEWIC assessment and update status report on the Northern Abalone *Haliotis kamtschatkana* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 48 pp.

Egli, T. P., and Lessard, J. 2011. Survey of Northern Abalone, *Haliotis kamtschatkana*, population in the Strait of Georgia, British Columbia, October 2009. Can. Manuscr. Rep. Fish. Aquat. Sci. 2955: iii + 12 p.

Emmett, B. and Jamieson, G.S. 1988. An experimental transplant of Northern Abalone, *Haliotis kamtschatkana*, in Barkley Sound, British Columbia. Fish. Bull. (Washington DC.) 87: 95–104.

Fisheries and Oceans Canada. 2007. Recovery Strategy for the Northern Abalone (*Haliotis kamtschatkana*) in Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Vancouver. *vi* + 31 pp.

DFO Media Release, October 2009, http://www.dfo-mpo.gc.ca/media/npress-communique/2009/pr23-eng.htm

Fisheries and Oceans Canada. 2012. Action Plan for the Northern Abalone (*Haliotis kamtschatkana*) in Canada. *Species at Risk Act* Action Plan Series. Fisheries and Oceans Canada, Ottawa. vii + 65 pp.

Griffiths, A.M. and Gosselin, L.A., 2008. Ontogenetic shift in susceptibility to predators in juvenile Northern Abalone, *Haliotis kamtschatkana*. J. Exp. Mar. Biol. Ecol. 360(2): 85-93.

Haida Gwaii Northern Abalone Stewardship. 2008. Monitoring juvenile abalone using artificial habitats.

Hankewich, S., and Lessard, J. 2008. Resurvey of Northern Abalone, *Haliotis kamtschatkana*, populations along the central coast of British Columbia, May 2006. Can. Manuscr. Rep. Fish. Aquat. Sci. 2838: vi + 41 p.

Hankewich, S., Lessard, J. and Grebeldinger, E. 2008. Resurvey of Northern Abalone,

Haliotis kamtschatkana, populations in southeast Queen Charlotte Islands, British Columbia, May 2007. Can. Manuscr. Rep. Fish. Aquat. Sci. 2839: vii + 39 pp.

Hankewich, S., Harding, J., and Lessard, J. 2011. Kitasoo Fisheries Program: Pilot abalone aggregation; is more better?

Hansen, S. C., & Gosselin, L. A. 2013. Do predators, handling stress or field acclimation periods influence the survivorship of hatchery-reared abalone *Haliotis kamtschatkana* outplanted into natural habitats? Aquat. Conserv. 23(2): 246-253.

Jamieson, G.S., Gregr, E.J. and Robinson, C. 2004. Northern abalone case study for the determination of SARA Critical Habitat. Can. Sci. Adv. Sec. Res. Doc. 2004/117. 63pp.

Lemay, M.A., & Boulding, E. G. 2009. Microsatellite pedigree analysis reveals high variance in reproductive success and reduced genetic diversity in hatchery-spawned Northern Abalone. Aquaculture 295(1-2): 22-29.

Lessard, J., Campbell, A. and Hajas, W. 2002. Survey protocol for the removal of allowable numbers of Northern Abalone *Haliotis kamtschatkana*, for use as broodstock in aquaculture in British Columbia. Can. Sci. Adv. Secret. Res. Doc. 2002/126: 41 p.

Lessard, J. and Campbell, A. 2007. Describing Northern Abalone, *Haliotis kamtschatkana*, habitat: focusing rebuilding efforts in British Columbia, Canada. J. Shellfish Res. 26(3): 677-686.

Lessard, J., A. Campbell, Z. Zhang, L. MacDougall, and S. Hankewich. 2007. Recovery Potential Assessment for the Northern Abalone, (*Haliotis kamtschatkana*) in Canada. Can. Sci. Adv. Sec. Res. Doc. 2007/061. 107pp.

Lessard, J., and Egli, T.P. 2011. Survey of Northern Abalone, *Haliotis kamtschatkana*, population in Queen Charlotte Strait, British Columbia, May 2009. Can. Manuscr. Rep. Fish. Aquat. Sci. 2959: iv + 17 p.

Lucas, B.G., Campbell, A., and Brouwer, D. 2002. Survey of Northern Abalone, *Haliotis kamtschatkana*, populations at Chrome and southern Denman Island areas, May - June 2000 and May 2001. Can. Manuscr. Rep. Fish. Aquat. Sci. 2624: 13 p.

Oceanlink (2008) Bamfield Huu-ay-aht Community Abalone Project (BHCAP). Available at http://www.oceanlink.info/Conservation/ abalone/BHCAP/BCHAP_index.html

Read, K. D., Lemay, M.A., Acheson, S. and Boulding, E.G. 2012. Using molecular pedigree reconstruction to evaluate the long-term survival of outplanted hatchery-raised larval and juvenile northern Abalone (*Haliotis kamtschatkana*). Conserv. Genet. 13: 801–810.

Read, K.D., Lessard, J. and Boulding, E.G. 2013. Improving outplanting designs for Northern Abalone (*Haliotis kamtschatkana*): the addition of complex substrate increases survival. J. Shellfish Res. 32(1): 171-180.

Rogers-Bennett, L., Allen, B. L., and Rothaus, D. P. 2011. Status and habitat associations of the threatened Northern Abalone: importance of kelp and coralline algae. Aquat. Conserv. 21(6): 573-581.

Rothaus, D. P., Vadopalas, B., and Friedman, C. S. 2008. Precipitous declines in pinto abalone (*Haliotis kamtschatkana kamtschatkana*) abundance in the San Juan Archipelago, Washington, USA, despite statewide fishery closure. Can. J. Fish. Aquat. Sci. 65(12): 2703-2711.

Stevick, B.C. 2010. Experimental rearing methods of pinto abalone (*Haliotis kamtschatkana*) and their effect on outplant survival in Washington State. MSc Thesis, University of Washington. 61 pp.

Supernault, K. J., Demsky, A., Campbell, A., Ming, T. J., Miller, K. M., and Withler, R. E. 2009. Forensic genetic identification of abalone (*Haliotis* spp.) of the northeastern Pacific Ocean. Conserv. Genet. 11(3): 855-865.

Zhang, Z., Campbell, A., and Lessard, J. 2007. Modeling Northern Abalone, *Haliotis kamtschatkana*, stock and recruitment in British Columbia. J. Shellfish Res. 26(4):1099-1107.

Zhang, Z. 2008. A simulation study of abalone fertilization. J. Shellfish Res. 27(4): 857-864.

Zhang, Z, Lessard, J., and Campbell, A. 2009. Use of Bayesian hierarchal models to estimate Northern Abalone, *Haliotis kamtschatkana*, growth parameters from tag-recapture data. Fish. Res. 95: 289-295.

WEBSITES

The following websites were referenced in this document.

DFO Northern Abalone	http://www.pac.dfo-mpo.gc.ca/fm-gp/commercial/shellfish-mollusques/abalone-ormeau/index-eng.html
DFO “Working Near Water”	http://www.dfo-mpo.gc.ca/pnw-ppe/index-eng.html
Haida Gwaii Marine Stewardship Group	http://www.marinematters.org/programs/abalone.html
Nisga’a Abalone Coast Watch Project	http://oceanlink.info/Conservation/abalone/BHCAP/Nisga/ncw.html