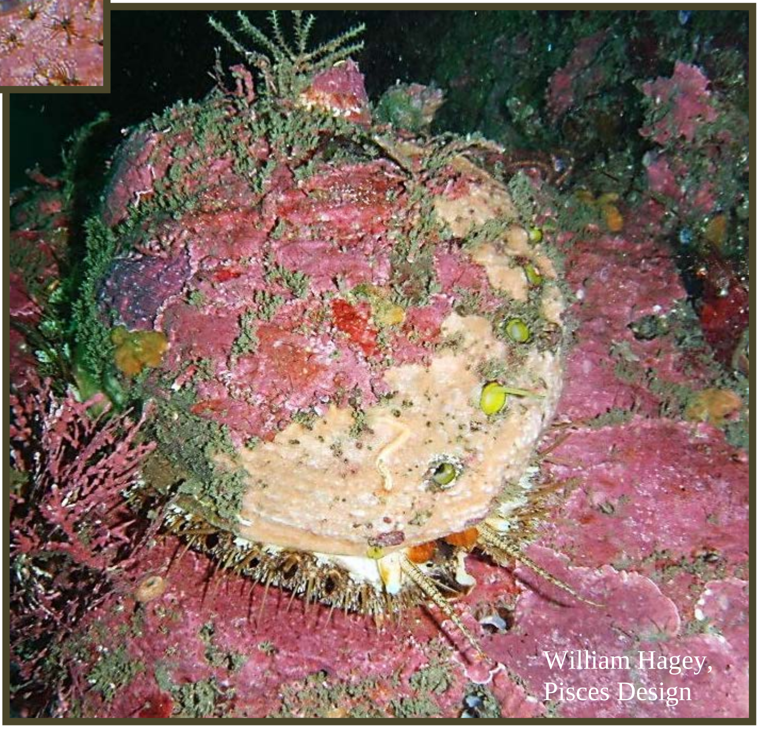
Status Review Report for Pinto Abalone (*Haliotis kamtschatkana*)


Josh Bouma, Puget Sound Restoration Fund


William Hagey, Pisces Design

Status Review Report for Pinto Abalone (*Haliotis kamtschatkana*)

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U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

Executive Summary

The pinto abalone (*Haliotis kamtschatkana* Jonas 1845) is a relatively large prosobranch gastropod mollusk ranging from approximately Salisbury Sound (north of Sitka), Alaska, to Bahia Tortugas, Baja California, Mexico and occurring in intertidal and subtidal habitats from 0-40m depth. The quality and quantity of abundance information derived from both fishery-dependent and independent sources vary by geographic area. The best available data indicate that pinto abalone abundance has declined in many areas throughout the species' range due to fisheries harvest. Subsistence and personal use fisheries in Alaska and a commercial fishery in Mexico persist. Preliminary data from surveys in 2011 and 2012 indicate signs of recovery in pinto abalone populations along the British Columbia coast, most likely due to a reduction in illegal harvest. In contrast, survey data and studies indicate that pinto abalone populations at the San Juan Islands in Washington are experiencing recruitment failure and continuing to decline, despite closure of the fisheries and no evidence of poaching. Throughout the remainder of the species' range, trends are less clear, due to the lack of regular, long-term monitoring surveys for pinto abalone. The limited data from surveys and/or opportunistic sightings indicate that pinto abalone populations are small, patchily distributed, and/or fluctuate episodically in Alaska, California, and Mexico, with evidence of recent recruitment in a number of locations within these three areas. However, we lack baseline abundance and trend data for the species prior to the advent of commercial fisheries and, in some areas, the local extirpation of sea otters. Without a clear baseline with which to compare the current abundance levels and trend information, it is difficult to interpret what these levels mean for the status and viability of the species.

A status review team (SRT) evaluated threats to pinto abalone and characterized the threats using a qualitative rating (i.e., low, moderate, high, very high) based on the threats' scope, severity, and persistence and the sufficiency of the data to support the rating. Overall, the status review team rated most of the threats as low and did not identify any high or very high threats. The SRT identified several threats that posed a moderate level of risk to pinto abalone. Among these, the team was most concerned about low densities as a result of historical overfishing of pinto abalone; the potential threat posed by ocean acidification; and illegal take due to poaching and inadequate law enforcement. Reduced genetic diversity as a consequence of low population densities, potential predation (particularly by sea otters) to further reduce local densities, oil spills and disease outbreaks (through the spread of pathogens) were also considered to pose moderate threats to pinto abalone, but were not ranked as highly as the aforementioned threats because of lower data sufficiency, scope, and/or severity.

Fishing for abalone was banned throughout most of the west coast of North America in the 1990s. In Canada, pinto abalone were first designated as threatened in 2000 and then as endangered in 2009; a recovery strategy and action plan were developed in Canada in 2007 and 2012. A captive propagation and enhancement program was implemented in Washington in the mid-2000s and a recovery plan for the species was finalized in 2014. The California Department of Fish and Wildlife (CDFW) finalized a state recovery and management plan for all of the California abalone species, including pinto abalone, in 2005. These protective measures are showing signs of being effective in some areas within the species' range.

The SRT evaluated the overall risk that pinto abalone faces throughout its range and determined that pinto abalone have a low to moderate level of extinction risk now and in the foreseeable future (over both the 30 year and 100 year time horizons). The SRT recognized that there is a high level of uncertainty regarding demographic factors, in particular regarding whether abundance and productivity levels are sufficient to support the persistence and recovery of the species in the face of continuing and potential future threats. While recruitment failure may be occurring in some areas (e.g., San Juan Islands Archipelago), in other areas throughout the range recurring and/or recent recruitment events have been observed, despite low densities, and have even resulted in increased densities (of mature and all sizes of pinto abalone) at several index sites in British Columbia.

The SRT evaluated the overall risk that three potentially significant areas within the species' range (SPR) face and determined that: 1) the Northern Portion SPR (Alaska, British Columbia, and the San Juan Islands) has a low to moderate level of extinction risk now and in the foreseeable future over both the 30-year and 100-year time frame; and 2) the Southern Portion SPR (Northern California, Southern California, and Mexico) and the portion of the range of pinto abalone including all areas except Northern California has a low risk of extinction now and in a foreseeable future of 30 years and a low to moderate risk of extinction now and in a foreseeable future of 100 years. The SRT expressed greater concern regarding extinction risk to the species within the Northern portion of its range than in the Southern portion or the portion encompassing all areas excluding Northern California. The SRT cited long-term population declines (especially in the San Juan Islands), threats posed by continuing personal use and subsistence harvest in Alaska, the recovery of sea otter populations in several locations, and potential climate change and ocean acidification impacts as cause for greater concern for the Northern portion. Evidence of recent and recurring recruitment in a number of areas throughout the Southern portion was a major factor in the SRT's assessment of lower risk for this portion and for the portion including all areas except Northern California. The SRT expressed greater concern, as well as greater uncertainty, regarding extinction risk to the species when considering a foreseeable future of 100 years compared to 30 years for all three portions. Overall, the SRT concluded that low to moderate risks to the species within any of these portions and over either time frame were the most plausible. The SRT did not believe that the species is likely to be at high or very high risk of extinction in any of the portions over either time frame.

Acknowledgements

NMFS gratefully acknowledges the commitment and efforts of the following SRT members and thanks them for generously contributing their time and expertise to the development of the Pinto Abalone Status Review Report:

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In addition, Susan Wang, part of our internal NMFS pinto abalone team made major contributions to this document. Scott Rumsey and Gary Simms, also members of our internal NMFS pinto abalone team, contributed to document preparation and review. Other individuals who contributed information that aided in the preparation of this report are: Robert Anderson, Charles Boch, Josh Bouma, Cynthia Catton, Ginny Eckert, Kyle Hebert, Joanne Lessard, Fiorenza Micheli, Laura Rogers-Bennett, Daniel Geiger, Buzz Owen, Ed Parnell, Betsy Peabody, Arjay Rafferty, Andrea Saenz-Arroyo, Bob Sizemore, Ian Taniguchi, Leonardo Vazquez, and Scott Walker.

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1.0 Introduction

The pinto abalone (*Haliotis kamtschatkana* Jonas 1845) was added to the National Marine Fisheries Service's (NMFS') "Species of Concern" list on April 15, 2004 (69 FR 19975). On July 1, 2013, the National Marine Fisheries Service (NMFS) received a petition from the Natural Resources Defense Council (NRDC) requesting that the pinto abalone be listed as threatened or endangered under the Endangered Species Act (ESA) and that critical habitat be designated for the species. On August 5, 2013, NMFS received a second petition, filed by the Center for Biological Diversity (CBD) to list the pinto abalone under the ESA and designate critical habitat. The species is currently listed under the "Endangered A2abd" category on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (McDougall *et al.* 2006). On November 18, 2013, NMFS determined that the petitions presented substantial information indicating that the petitioned action may be warranted for pinto abalone (a "positive 90-day finding") and published the finding in the Federal Register (78 FR 69033), pursuant to 50 CFR 424.14.

In the fall of 2013, NMFS assembled a Status Review Team (SRT) to compile and review the best available information regarding the status of the species and to assess the extinction risk and threats facing the species. This status review report provides a thorough account of pinto abalone biology and natural history as it relates to the species' status and the SRT's conclusions regarding the species' status based on an assessment of demographic risks, threats and limiting factors, and overall extinction risk.

1.1 Scope and Intent of Present Document

The purposes of the Pinto Abalone Status Review Report (hereafter Status Report) are to compile and evaluate the best available information and data on the following topics as they relate to the species’ status: (1) historical and current range, distribution, and habitat use of the species; (2) long-term trends in abundance throughout the species range; (3) historical and current estimates of population size and available habitat; (4) knowledge of various life history parameters (size/age at maturity, fecundity, length of larval stage, larval dispersal dynamics, etc.); (5) potential risk factors that the species faces throughout its range (e.g., overharvesting, natural predation, disease, habitat loss, etc.); and (6) projections of population growth or decline and risk of extinction.

The Status Report will aid NMFS in determining if the species warrants listing under the ESA. A listing decision is made by NMFS after considering the Status Report and its conclusions as well as conservation efforts.

1.2 Key Questions in ESA Evaluations

1.2.1 The “Species” Question

In determining whether a listing under the ESA is warranted, two key questions must be addressed: 1) is the entity in question a "species" as defined by the ESA; and 2) if so, is the "species" in danger of extinction (an endangered species) or likely to become an endangered species in the foreseeable future throughout all or a significant portion of its range?

For the purpose of the ESA, a species is defined as "any species or subspecies of wildlife or plants, or any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." Pinto abalone is a marine invertebrate that has been taxonomically subdivided into two subspecies: *Haliotis kamtschatkana kamtschatkana* ranging from Sitka, Alaska to Point Conception, California; and *Haliotis kamtschatkana assimilis* ranging from Monterey, California to Bahia Tortugas, Baja California, Mexico (McLean 1966). Initially, these subspecies were described as separate species by Jonas (*Haliotis kamtschatkana*,) in 1845 and Dall (*Haliotis assimilis*) in 1878. McLean (1966) argued that the two previously described species were unique forms, or subspecies, that represented geographic extremes of a single species. McLean (1966) conjectured that the differences observed in shell morphology between these subspecies might be related to varying environmental conditions, possibly water temperature, along a latitudinal gradient encompassing the species' range from Alaska to Mexico. McLean (1966) described a merging zone between the subspecies that was restricted to an area of Central California between Monterey and Point Conception. Futuyma (1986) defined subspecies as allopatric populations (i.e., populations occurring in different geographic areas or in isolation from one another) with a fixed character that do not yet represent discrete, evolutionary lineages and could interbreed at the periphery of populations. This information supported the idea that subspecies do not have to be defined by a distinct geographic boundary, but instead can merge at the limits of their ranges, in this case Monterey to Point Conception. Geiger (1999) upheld the subspecies classification scheme based on the morphological descriptions of shells provided by McLean (1966) and maintained the subspecies range descriptions as Sitka, Alaska to Point Conception, California for *H. k. kamtschatkana* and Monterey, California to Bahia Tortugas, Baja California, Mexico for *H. k. assimilis* (Figure 1).

More recently, two lines of evidence have raised uncertainty regarding the existing taxonomic structure of pinto abalone. Genetic tools and analyses have been developed to confirm genetic bases for differences observed between abalone species and among populations belonging to the same species (See Section 3.2.1 below). To date, none of these genetic tools, which admittedly are limited because they have only explored a small portion of the entire genome, have been able to confirm a discernable difference between *H. k. kamtschatkana* and *H. k. assimilis.* With new methods that search the entire genome, such as single nucleotide polymorphisms, or SNPs, geneticists may discover genetic support for the subspecies delineation in the future. One highly conserved portion of the genome that has been investigated and that geneticists would have expected to be different between subspecies, is the area that controls the production of the reproductive proteins lysin and VERL (vitelline envelope receptor for lysin). None of the studies that examined these markers provided subspecies-level resolution and thus the subspecies remain indistinguishable at the molecular level to date (see Section 3.2.1 below). Also, several shell collectors have multiple pinto abalone specimens collected from both the northern and southern portions of the species' range that exhibit morphologies representative of both subspecies (Figure 2; B. Owen, pers. comm.; A. Rafferty, pers. comm.). We recognize that shell collectors do not collect a random sample of shells and their collections may misrepresent what is a relatively small population of outliers in the wild. Despite this, the fact that multiple examples of *H. k. assimilis* in British Columbia and Washington as well as multiple examples of *H. k. kamtschatkana* in Baja California, Mexico exist, we believe that the range overlap between the two putative subspecies is much more extensive than was previously thought (Canada to Mexico versus Central California) and that this degree of overlap (approximately 80% of the species' range) does not meet Futuyma's (1986) definition of subspecies as allopatric populations.

The SRT decided to consider pinto abalone as one species throughout its range for the purposes of this report. This is a parsimonious decision given the degree of overlap between the subspecies, no evidence to date for species divergence at the molecular level, and the fact that there are other examples of marine invertebrates with broad geographic ranges (e.g., black turban snail, Pacific littleneck clam, ochre and bat stars) and/or pronounced morphological plasticity (e.g., periwinkle snails) extending on the order of 1,000s of kilometers. While we do not reject the possible existence of pinto abalone subspecies, without some genetic, geographic, or ecological justification for treating these subspecies as separate species, we recommend analyzing extinction risk for this species throughout its range from Alaska to Mexico for the purposes of this Status Report. From this point forward in the Status Report, the species will be referred to as pinto abalone or *H. kamtschatkana*. If we are referring to published information that specifically calls out one of the recognized subspecies, we will refer to those subspecies as *H. k. kamtschatkana* or *H. k. assimilis*.

1.2.2 Extinction Risk

Section 3 of the ESA defines the term "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." The term "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." NMFS considers a variety of information when evaluating the level of risk faced by a species. Important considerations include: 1) absolute numbers and their spatial and temporal distribution; 2) current abundance in relation to historical abundance and carrying capacity of the habitat; 3) any spatial and temporal trends in abundance; 4) natural and human-influenced factors that cause variability in survival and abundance; 5) possible threats to genetic integrity (e.g., artificial rearing); and 6) recent events (e.g., an oil spill or a change in management) that have predictable short-term consequences for abundance of the species. Additional risk factors, such as disease prevalence or changes in life history traits, may also be considered in evaluating risk to populations. The determination of whether a species is “in danger of extinction” or “likely to become an endangered species within the foreseeable future” should be made on the basis of “the best scientific and commercial information” available regarding its current status.

1.3 Summary Evaluation of Information Presented by the Petitioners

NMFS published a 90-day finding on November 13, 2013 (78 FR 69033) that summarized the information presented by the petitioners and other information that was readily available in NMFS’ files regarding the status of pinto abalone. Based on an evaluation of this information, NMFS concluded that: 1) climate change and its associated impacts, especially low salinity, elevated water temperatures, and ocean acidification may already be impacting pinto abalone populations in some areas and may impede the continued existence of the species in to the future; 2) fisheries throughout a large portion of the species’ range had an impact on the viability of pinto abalone populations through density reduction, and subsequent reproductive failure may continue today in some areas; 3) predation may be having an impact on the continued existence of pinto abalone in some areas of the range (i.e., by sea otters in Alaska), but not others; and 4) existing regulatory mechanisms may be inadequate to ensure sustainable fishing, minimize incidental collection, and sufficiently reduce or eliminate poaching of pinto abalone populations. NMFS also concluded that: 1) the available information regarding indirect effects of climate change on the availability of food sources and suitable settlement habitat is insufficient to evaluate whether these factors may be reducing the quality or quantity of pinto abalone habitat; 2) the available information is insufficient to determine if inadequate regulation of greenhouse gas emissions may be threatening pinto abalone populations such that listing may be warranted; and 3) the available information is insufficient to determine whether inadequate regulation of abalone farms or captive propagation and enhancement programs are impacting the continued existence of pinto abalone populations.

2.0 Species Description

Abalone, members of the gastropod genus *Haliotis*, are marine gastropods that occur throughout most of the world (Figure 3; Cox, 1962). There are approximately 60 species (Geiger, 1999) found in temperate to tropical waters from the intertidal zone (i.e., the area of the foreshore and seabed that is exposed to the air at low tide and submerged at high tide) to depths of over 50 m. All are benthic, occurring on hard substrate, relatively sedentary, and generally herbivorous, feeding on attached or drifting algal material. There are seven species of abalone native to the west coast of North America (Geiger, 1999). The taxonomic classification of pinto abalone is as follows: Phylum Mollusca, Class Gastropoda, Subclass Prosobranchia, Order

Archaeogastropoda, Superfamily Pleurotomariacea, Family Haliotidae, Genus *Haliotis*, Species *kamtschatkana*, Subspecies *kamtschatkana* Jonas (1845) and *assimilis* Dall (1878).

As discussed above in section 1.2.1, Geiger (1999) recognizes two subspecies of pinto abalone, *H. k. kamtschatkana* Jonas, 1845 and *H. kamtschatkana assimilis* Dall, 1878, based on morphology according to McLean (1966). To date, the subspecies cannot be genetically distinguished using molecular genetic tools (Gruenthal and Burton 2005; COSEWIC 2009, Supernault *et al.* 2010). According to McLean (1966), the only morphological characteristics that distinguish these subspecies are shell shape and pattern. The multi-colored shell of *H. k. kamtschatkana* attains a maximum length of approximately 160 mm and has 3–6 open respiratory pores that are raised, oval-shaped and medium-sized. The outer surface of the shell is characterized by irregular lumps. Paralleling the respiratory pores is a deep groove (Stevick, 2010). Typically, the shell's interior is pearly white with hints of multi-colored iridescence and no muscle scar (COSEWIC 2009). The shell of *H. k. assimilis* is also multi-colored, but is rounder and more convex than that of *H. k. kamtschatkana*, has 4-7 open respiratory pores that are somewhat elevated, and attains a maximum shell length (SL) of approximately 190 mm. Both shell morphologies are represented in shell collections from Canada to Mexico (B. Owen, pers. comm.; A. Rafferty, pers. comm.; Figure 2), although the shell morphology representative of *H. k. kamtschatkana* may occur more frequently in northern portions of the species range while the shell morphology representative of *H. k. assimilis* may occur more frequently in southern portions of the species range. For both *H. k. kamtschatkana* and *H. k. assimilis*, the epipodium (the circular fringe of skin around the foot) and tentacles are mottled yellow to dark tan with vertical banding patterns and a lacy edge. The muscular foot is tan and is used to adhere to hard substrate and for locomotion.

3.0 Natural History of Pinto Abalone

3.1 Distribution, Depth Range, & Habitat Associations

Of the seven species of abalone found along the west coast of North America (Geiger, 1999), pinto abalone have the broadest latitudinal range extending from Salisbury Sound, Alaska to Bahia Tortugas, Baja California, Mexico (Campbell, 2000), and it is the predominant abalone found in Washington and Alaska, and in British Columbia, Canada. According to Geiger (2000) and updated on Daniel Geiger's ABMAP website (http://www.vetigastropoda.com/ABMAP/NEPacific.html) which visually depicts the geographic distributions for *H. k. kamtschatkana* and *H. k. assimilis* based on specimen and literature records, pinto abalone range from southeast Alaska to approximately Punta Eugenia, and possibly Bahia Tortugas, Baja California, Mexico, with a dearth of records from Puget Sound and Neah Bay, Washington to Cape Mendocino, California (Figure 1).

In the northern portion of its range, pinto abalone occurs in intertidal and subtidal habitats (0–20m depth, most commonly 0–10m depth; Rothaus *et al.*, 2008) that vary with respect to exposure and contain hard substrate (bedrock and boulders/cobble) with ample quantities of benthic diatoms, and micro- and macro-algae, and are often associated with crustose coralline algae that is thought to serve as a settlement cue (Roberts 2003). Typically, the species is found in areas with little freshwater influence (salinity ≥ 30 parts per thousand), and can tolerate wide ranges in temperature, from 2 to 24 degrees Celsius (°C), based on laboratory experiments (COSEWIC, 2009).

In Alaska, pinto abalone are primarily found in rocky substrates and kelp beds in the lower intertidal and subtidal surge zones on the outer coast of Southeast Alaska. They are also found in the Inside Passage of southern Southeast Alaska (e.g., near Ketchikan). The Alaska Department of Fish and Game (ADF&G) has documented pinto abalone occurrence as far north as Salisbury Sound, north of Sitka (ADF&G public comments to NMFS, 17 January 2014).

In Washington, pinto abalone occur from Little Patos Island in the northern San Juan Island Archipelago (SJA) to east of Box Canyon just offshore of Cape Flattery in the west entrance of the Strait of Juan de Fuca (SJF), and north of a line formed by Point Wilson and the Keystone Jetty in North Puget Sound. Pinto abalone were observed at Keystone Jetty in 2006 and 2007 by recreational divers and in 2011 by Reef Environmental Education Foundation (REEF) surveyors, and in two locations in Hood Canal by REEF (by “novice level” surveyors). Pinto abalone likely occur outside this range, but observations were not reported or not from credible sources. Vertical depth distribution in Washington is 3-20 meters depth relative to mean lower low water (MLLW). No comprehensive surveys of pinto abalone habitat have been conducted to determine the entire range of vertical distribution of pinto abalone in Washington. No pinto abalone were observed during a 2010 Washington Department of Fish and Wildlife (WDFW) remotely operated vehicle (ROV) survey in SJA at 165 locations ranging from 5 – 300 meters.

Very little is known about the occurrence of pinto abalone along the Oregon coast. There were no specimens available from this region at the time of Geiger's (2000) review of the distribution and biogeography of this species (Figure 1). In 2009, a solitary pinto abalone, ~100mm shell length (SL), was reported by an urchin diver at a depth of 60ft (18m) on Orford reef (Oregon's biggest offshore rocky reef; Scott Groth, Oregon Department of Fish and Wildlife (ODFW), unpublished data). Since that time the same urchin harvester identified approximately four more pinto abalone, all on Orford reef. Another urchin diver, and former abalone diver, saw one pinto (among a career of harvesting 10 million pounds of red urchins) in Nellies Cove, near Port Orford (Scott Groth, ODFW, unpublished data).

In the southern portion of its range, pinto abalone occurs in subtidal habitats (approximately 12-40 m; Geiger and Owen 2012) commonly on open rock surfaces. The animals appear to be patchily distributed in areas along the Southern California mainland and distribution may be correlated with substrate type (flat rock preferred over uneven), relief (low relief with scattered rock and boulders preferred over high relief), the presence of intermittent sand channels that may accumulate drift kelp, and algal composition in that *Pelagophycus porra*, *Laminaria farlowii*, *Agarum fimbriatum*, *Pterygophora californica*, and coralline algae (articulated and crustose) are often present in areas where pinto abalone occur (Bill Hagey *et al.*, Pisces Designs, unpublished data, Melissa Neuman *et al.*, NMFS, unpublished data). In Mexico, a recent study reported that *H. k. assimilis* and *H. sorenseni* occurred at depths ranging from 11 – 25 m (Boch *et al.* 2014). The majority of the abalone were found between 13-15 m and 19-21 m, but this may reflect a bias towards the depths that were most visited (Boch *et al.* 2014).

3.2 Population Structure and Genetics

3.2.1 Subspecies Delineation

Studies conducted thus far tend to indicate high intraspecific (within species) variability in pinto abalone, depending on the gene sequenced, in pinto abalone but no genetic differentiation between subspecies. Supernault *et al.* (2010) developed high-fidelity size and sequence polymorphic markers in the reproductive proteins lysin and VERL (vitelline envelope receptor for lysin) for forensic analyses of northeastern Pacific abalone species. Results indicated that all species recognized on the basis of morphological differences have been confirmed to be distinct on the basis of genetic sequences, with only the two subspecies, *H. k. kamtschatkana* and *H. k. assimilis*, indistinguishable through molecular analysis. Gruenthal and Burton (2005) had similar results, concluding *H. k. kamtschatkana* and *H. k. assimilis* were statistically indistinguishable at sequenced portions of the mitochondrial genes cytochrome oxidase subunit one (COI) and cytochrome b (CytB), as well as VERL, although the sample sizes were small. Straus (2010) also found no statistically significant differences in either COI or lysin, stating that the two subspecies share identical sequences at both mitochondrial and nuclear loci and cannot be differentiated. Most recently, P. Schwenke and L. Park, NMFS NWFSC, (unpublished data) constructed bootstrapped neighbor-joining trees of new and archived mitochondrial COI and VERL sequences, finding that VERL is currently the best marker available to resolve the most closely related abalone species group found along the Northeastern Pacific coast (white, pinto, flat, and red), whereas COI separates this group from the remaining species (i.e. black, pink, and green; P. Schwenke, pers. comm.). Again, however, neither marker provided subspecies level resolution. To specifically address the subspecies issue, an expanded representation across the *H.*

kamtschatkana species range of genomic variation using SNPs is planned, with a particular focus on the region of overlap between the two putative subspecies.

3.2.2 Population Structure

Withler *et al.* (2001) provide the only published assessment of population structure in *H. kamtschatkana*. Variation at 12 microsatellite loci was estimated for a total of 18 sites located throughout coastal British Columbia (BC) and at one site in Sitka Sound, Alaska. Only 0.2% of variation was attributable to differences between a grouping of Haida Gwaii (formerly Queen Charlotte Islands) with Sitka and the remaining sites, and another 0.2% of variation between Haida Gwaii and Sitka. Overall, 99.6% of variation was within populations, indicating a lack of differentiation among sites. In addition to only weak evidence for isolation by distance, these results suggest historically high gene flow among populations within this region. Unfortunately, research on populations throughout the remainder of the species range or using other genetic marker types has not been performed.

3.3 Movement

Little is known about movement patterns of larval or juvenile pinto abalone anywhere in their range. Based on laboratory observations, post-hatch larvae are phototactic and swim upward, where they are available for transport by water currents (Olsen 1984 and Calderwood 1985, cited in Sloan and Breen 1988). The planktonic larval stage is short (approximately 5-6 days; Olsen 1984, cited in Sloan and Breen 1988), and thus dispersal is likely to be limited and almost certainly determined primarily by patterns of water movement in nearshore habitats near spawning sites. Individual larvae may be able to influence movement to some degree by adjusting vertical position in the water column, but to our knowledge the ability of pinto abalone larvae to move in this way has not been documented.

Larval settlement and metamorphosis in pinto abalone is likely to be associated with chemical cues present in crustose red algae, as has been found for red abalone (*H. rufescens*) (Morse and Morse 1984). Small juvenile (<10 mm) pinto abalone are difficult to find in the field, but are occasionally observed under boulders and on smooth bedrock or boulders that are bare or encrusted with coralline algae, mostly at deeper depths (e.g., 5 to 15 meters) than adults are typically found (Breen 1980a). Other grazers (e.g., sea urchins, chitons, limpets, and adult abalone) may be important in maintaining encrusting coralline algae (Sloan and Breen 1988).

To our knowledge there is no published information on direct observations of movement behavior of small (< 20 mm) juvenile pinto abalone in the field. However, distribution patterns of juveniles and adults indicate an ontogenetic shift in habitat use, with small juveniles (<10 mm shell length) occupying highly cryptic habitats in deeper waters and migrating to shallower depths and more exposed habitats as they increase in size (Sloan and Breen 1988). In surveys in British Columbia, the proportion of exposed abalone increased from 60% for juveniles 10-70 mm in size to 90% for individuals 70-90 mm in size (Boutillier *et al.* 1985, cited in Sloan and Breen 1988). Almost all individuals > 90mm in size were found exposed on rock surfaces (Boutillier *et al.* 1985, cited in Sloan and Breen 1988). This shift may be associated with changes in diet (Sloan and Breen 1988; see section 3.5 below) and predation risk (Griffiths and Gosselin 2008) with size.

Movement generally decreases as individuals grow in size and age. Tagging studies and observational surveys conducted in British Columbia indicate that although adult pinto abalone have the ability to move several meters a day and tens of meters in a year, they typically exhibit minimal movement, likely staying within close proximity to their settlement habitat (Sloan and Breen 1988). Large adults have been observed in home scars (bare rock underneath an individual that matches its shell shape), indicating relatively little movement, particularly if sufficient food (drift algae) is available (Breen 1980a). Pinto abalone can climb up kelp to graze and have been observed to climb back down, rather than just drop off the kelp, when disturbed (Sloan and Breen 1988). A tagging study by Quayle (1971) found lateral movements of less than 50 m in a year and little vertical movement in the 0-10 m depth range. P. Breen, Department of Fisheries and Oceans Canada (unpublished observations, cited in Sloan and Breen 1988) recorded maximum movement of approximately 20 meters in one year in a study of approximately 400 tagged abalone on the west coast of Vancouver Island. In a separate tagging study, Emmett and Jamieson (1988) recorded maximum movement of 125 meters in one year by adults, although they observed little emigration overall from placement sites. It is possible that some tagged individuals moved larger distances but were not detected in subsequent searches. In more recent adult aggregation studies along the coast of British Columbia, translocated adult abalone tended to stay within their new habitat rather than migrating out of the aggregation sites (B. DeFreitas, pers. comm.; J. Harding, pers. comm.; J. Lessard, pers. comm.; cited in COSEWIC 2009). Overall observations indicate that adults exhibit relatively little movement laterally and vertically. Laboratory and field observations indicate that individuals tend to be more active at night (Sloan and Breen 1988) and during the spawning season (spring through summer months). Breen and Adkins (1980) observed a natural spawning event off the Queen Charlotte Islands in July 1979, in which spawners were aggregated and stacked on top of each other and tended to migrate to the highest point available (e.g., boulder tops and up kelp stipes). This behavior was also observed in spawning events in the laboratory (Quayle 1971). The reason for this behavior is unknown, but may serve to increase fertilization rates by aggregating spawners and increasing the distance, and thus the opportunity, for fertilization before eggs land on the bottom (Sloan and Breen 1988).

3.4 Diet

After a short 5-6 day lecithotrophic (non-feeding) larval phase (Olsen 1984, cited in Sloan and Breen 1988), juveniles settle and immediately begin feeding (Morse 1984; Morse and Morse 1984, cited in Sloan and Breen 1988). Laboratory observations and gut content analyses of hatchery-reared juveniles show that post-metamorphic juveniles graze on minute benthic diatoms, microalgae, and bacteria associated with encrusting coralline algae and rock surfaces (Olsen 1984, Norman-Boudreau *et al.* 1986, cited in Sloan and Breen 1988). Juveniles may also feed on the crustose coralline algae itself (Garland *et al.* 1985, cited in Sloan and Breen 1988). These observations are consistent with the microhabitats within which small juveniles are found in the wild (smooth or crustose coralline encrusted bedrock and boulders) (Breen 1980a).

Juveniles shift to feeding on macroalgae as they grow in size and age. Adults have been observed to feed directly on attached macroalgae (Sloan and Breen 1988), but drift macroalgae is believed to be the primary food resource (Breen 1980a). Laboratory studies indicate that adults prefer *Macrocystis* and *Nereocystis*, but will feed on diatoms and brown, red, and green algae, including *Laminaria*, *Pterygophora*, and *Costaria* (Paul *et al.* 1977; unpublished data by Breen and unpublished student reports by P. Gee and J. Lee, Simon Fraser University, cited in Sloan and Breen 1988). Adults avoided *Fucus distichus* and *Agarum cribrosum* (Paul *et al.* 1977; unpublished student reports by P. Gee and J. Lee, Simon Fraser University, cited in Sloan and Breen 1988). Diet composition likely varies by location within the species range, depending on what is available. In British Columbia, drift brown algae makes up an important food resource for pinto abalone (Breen 1980a and b).

3.5 Reproduction

Pinto abalone have separate sexes and are “broadcast” spawners. Gametes are released simultaneously into the water, and fertilization is external. Resulting embryos and larvae are minute and defenseless, receive no parental care or protection, and are subject to a broad array of physical and biological sources of mortality. Species with a broadcast-spawning reproductive system, including many taxa of fish and invertebrates, mitigate some high mortality in early life stages to ensure survival across generations through production of large numbers of gametes. Indeed, broadcast spawners often exhibit high fecundity in both sexes, and it is not uncommon for these species to produce millions of eggs or sperm per individual per year. Broadcast spawners may also be subject to selection for other common reproductive traits, such as spatial and temporal synchrony in spawning and mechanisms to increase the probability of fertilization.

Abalone appear to experience natural fluctuations in abundance and reproductive success, which may be partially driven by environmental variables. Breen (1986) presents several examples of natural declines and recovery in unfished stocks of pinto abalone and other abalone species. Thus, we might expect population abundance and recruitment levels to vary interannually and across longer time frames.

3.5.1 Fecundity

Pinto abalone become emergent and are generally reproductively mature at a size of about 50 mm SL (about 2-5 years in age), with all abalone mature at a size of about 70 mm SL (Leighton 1959, Ault 1985, Campbell *et al.* 1992). Size at maturity can vary by location depending on factors such as water temperature and food availability and quality. Fecundity generally increases with age and shell size, and may also be affected by food availability, water temperature, and local environmental conditions (CDFW 2005). Campbell *et al.* (2003) estimated that the ovaries of individual *H. kamtschatkana* females (101-135 mm SL) may hold an average of 2.6-7.5 million eggs, with a maximum 11.6 million eggs in a 139 mm female. Fewer eggs are likely released per spawning event, however; reports range on the order of 30 thousand to 2.3 million eggs released per event, indicating that pinto abalone may be capable of a number of spawning episodes per spawning season, although this has not been documented.

3.5.2 Spawning period and length

Quayle (1971) found ripe pinto abalone year round at several sites in BC, with spent gonads documented from April through June, and spontaneous spawning of abalone being held in the lab was observed in May. Meanwhile, Breen and Adkins (1979) observed ripe gonads and spawning at Haida Gwaii, BC, in mid-July after collecting and replacing wild abalone for a tagging study. Campbell *et al.* (2003) report a spawning season from April through July, with a few abalone ripe throughout the year, while California Department of Fish and Wildlife (CDFW; formerly known as the California Department of Fish and Game) (2005) reports the spawning season as April through June. More recently, Seamone and Boulding (2011) documented aggregation and spawning in June and July in Barkley Sound, BC. In the laboratory, spawning has been induced from April through December and volitional spawning has been observed from May through July, with ripe individuals found throughout the year (J. Bouma, pers. comm.).

3.5.3 Spawning density

Broadcast-spawning marine invertebrates with separate sexes, such as pinto abalone, must spawn in temporal and spatial synchrony to maximize the probability of successful fertilization. Standard population models predict that a reduction in adult density should be associated with a decrease in intraspecific competition, leading to an increase in growth rate, survival, and gamete production. However, these advantages may be countered by decreases in the rate of successful fertilization if individuals are sparsely distributed (Levitan 1995, Levitan and Sewell 1998, Gascoigne and Lipcius 2004). Fertilization success is a limiting factor for reproduction, and hence recruitment, especially for sessile or semi-sessile broadcast-spawning species (Smith and Rago 2004).

Critical density thresholds have been identified for broadcast-spawning species across a broad taxonomic range (NMFS 2009). Despite apparent risks of local extinction when critical density thresholds for abalone seem to be violated, there are several examples in California where combinations of circumstances have allowed populations to recover to densities above the critical thresholds (e.g., black, green, pink, and red abalone; G. VanBlaricom, pers. comm.; D. Kushner, pers. comm.). These circumstances may include a lengthened larval period (> 10 days) and/or conditions that allow for larval dispersal over long distances (> 10 km). Thus, for most abalone species, key conservation issues are identification of critical density thresholds and an understanding of larval longevity and capacity for dispersal across long distances.

Prince *et al.* (1988), McShane (1992), and Morgan and Shepherd (2006) have demonstrated correlations between densities of adult and newly recruited juvenile abalone at study locations on the southern Australian coast. These patterns are consistent with models in which larval dispersal from natal populations is limited, a relatively common circumstance in broadcast-spawning marine invertebrates with lecithotrophic larvae. It follows that if abalone populations are below critical density thresholds and larval immigration from distant populations is unlikely, then populations will not be sustainable. The available information on the genetic structure of pinto abalone populations suggests that high gene flow exists among populations (Withler *et al.* 2001; see also Section 3.2.2), but the geographic range covered was on the order of 1100 km (700 miles), which is a fraction of the full species range. Thus, although the literature for other abalone species supports the idea that pinto abalone should have limited larval dispersal distances, occasional longer-distance dispersal events may occur, though the magnitude and frequency of such events is not known (see Section 3.7 Larval Dispersal).

Babcock and Keesing (1999) estimated critical density thresholds at 0.15-0.20 m^{-2} for greenlip abalone (*H. laevigata* Donovan, 1808), a Southern Australian species that shares habitat, depth range, and spawning season characteristics with pinto abalone. Shepherd *et al.* (2001) and Shepherd and Rodda (2001) identified threshold densities below which recruitment fails for greenlip abalone and noted that threshold density can vary according to coastal topography. For example, coastal topography can create larval retention areas where threshold density may be lower than in areas where larvae are more easily dispersed. This research has been relied upon by other investigators to set recovery thresholds for a variety of subtidal abalone species along the West Coast of North America (CDFW 2005, DFO 2007, NMFS 2008). The validity of applying this threshold to pinto abalone has not been tested.

VanBlaricom, USGS (unpublished data) measured nearest neighbor distances for black abalone, an intertidal abalone found from Northern California to Mexico, at San Nicolas Island from 2004-2007. Despite dramatic disease-induced reductions in population density beginning in 1992, most animals in surveyed populations remain in close proximity to conspecifics. In the nearest neighbor sample (n=1565 total measurements from 2004-2007), 94% of measurements were within 2 m, 88% within 1 m, and 62% within 10 cm. The data indicate that black abalone have remained strongly aggregated despite: 1) reductions in density averaging nearly 99% at nine separate sites on San Nicolas Island since 1992; and 2) densities below the threshold for successful reproduction (0.34 m^{-2}; Neuman *et al.* 2010) identified for this species at all but one site on the island. The mechanism for maintaining close proximity to other animals may involve behavioral responses to the presence of conspecifics, or alternatively may reflect active selection of particular microhabitat types that facilitates aggregation as a side effect. Regardless of the cause, it appears that persistent gregarious distributions in black abalone have the potential to forestall negative population-level effects of drastic reductions in density. These data emphasize the value of assessing the variance structure in density data as well as the mean values when considering critical density thresholds.

These data are lacking for pinto abalone across much of the species' range. To our knowledge only Seamone and Boulding (2011) studied aggregation characteristics of pinto abalone during one spawning season in Barkley Sound, BC. Nearest neighbor R ratios (i.e. mean distance between individual pinto abalone) were significantly less than 1.0, indicating aggregation, and densities ranged from 0.12 to 0.64 abalone/m^2. Aggregations were independent of sex, and therefore, the probability of encountering an individual of the opposite sex increased with increasing density. Indications overall are that pinto abalone in this region were sufficiently aggregated during spawning to potentially increase fertilization rates and compensate for low densities.

3.5.4 Fertilization

Cox (1962) reports that release of gametes at spawning in abalone begins with discharge from the gonad into the right renal cavity. The gametes then pass through the external renal opening, moving into the respiratory chamber from which they are expelled through the tremata (also known as respiratory pores) into the surrounding waters.

The process of fertilization has been studied intensively in the laboratory with the ormer (*Haliotis tuberculata* Linnaeus, 1758) (Clavier 1992). The ormer occurs along the coast of western Europe and Africa and shares a similar depth distribution with pinto abalone (0-20m). Adult females were found to have instantaneous fecundities of 0.2 to 1.6 x 10^6 eggs per induced spawn, with fecundities increasing with body mass of the spawning individuals, which is similar to the 0.3 to 2.3 x 10^6 eggs per spawn documented for pinto abalone, depending on animal size (Campbell *et al.* 2003). Adult male ormer instantaneous fecundities ranged from 0.5 to 20 x 10^{10} sperm per induced spawn, but the relationship of fecundity to body mass was unclear for males. Clavier (1992) also evaluated the relationship of sperm concentrations per unit volume of sea water to fertilization rate. Fertilization was not observed at sperm concentrations < 10^3 cells ml^{-1}. Fertilization rate was found to increase steadily as sperm concentration increased above 10^3 cells ml^{-1}, approaching 100% fertilization at approximately 10^5 cells ml^{-1}. Fertilization rates fell to zero at sperm concentrations above 10^6 cells ml^{-1}. Apparently, excessively high sperm concentrations cause lysis of the vitelline layer of the ovum, leading to its destruction. In some cases excessively high sperm concentrations were also associated with abnormal embryonic development. Equivalent data have not been collected for pinto abalone, although Bouma (2007) states that sperm densities recommended for fertilization in a hatchery setting have ranged from 200 to 10,000 per egg. However, sperm density is not as important as the time over which sperm is allowed contact with the egg, which should be a maximum of 2-5 minutes to prevent polyspermy.

3.6 Larval Dispersal

Direct measurement of larval travel patterns typically is not tractable for broadcast-spawning marine invertebrates. Planktonic larvae generally are so small and fragile that effective methods for marking and direct tracking of movements do not exist (e.g., McShane *et al.* 1988). Three indirect alternative methods are used to estimate larval dispersal distances empirically, and all have been applied to the problem of determining dispersal distances in abalone. The first is to use objects such as drift cards or drift bottles, labeled with appropriate identifying information, as surrogates for larvae and collecting data on recovery times and locations to make inferences about larval dispersal distances (e.g., Tegner and Butler 1985, Chambers *et al.* 2005). The second approach is to use molecular tools to establish relatedness of adult populations and newly recruited cohorts, allowing inferences about dispersal pattern (e.g., Hamm and Burton 2000, Chambers *et al.* 2006). Most recent research on dispersal distances in marine invertebrate larvae relies on molecular tools. The third approach is to examine the spatial relationship of newly recruited cohorts to known aggregations of breeding adults (e.g., Prince *et al.* 1988). Dispersal distance is estimated based on the range of distances measured between sites occupied by adults and sites occupied by groups of juveniles. This approach probably is most likely to provide accurate results along linear coastlines with relatively simple nearshore current patterns, with increasing errors of interpretation as the complexity of the habitat and dispersal distance capability of the species increases. Each of these methods includes biases and sources of error that must be considered when interpreting the results.

Because specific studies for pinto abalone are limited, we look to the information that is available regarding dispersal distances for other abalone species. Overall, the three indirect methods for assessing larval dispersal distance in abalone point to consistent results, indicating limited larval dispersal distances along the coasts of Southern Australia and California (Prince *et al.* 1987 and 1988, McShane *et al.* 1988, McShane 1992, Hamm and Burton 2000, Chambers *et al.* 2005 and 2006, Gruenthal 2007, Gruenthal *et al.* 2007). Given that most abalone larvae are in the plankton for a period of about 3-10 days before settlement and metamorphosis (e.g., McShane 1992), it seems to follow that abalone in general should have limited capacity for dispersal over distances beyond a few kilometers. However, observations in Southern California suggest that dispersal of abalone larvae (pinto, red, pink, and black) over a few kilometers has occurred in multiple areas and on multiple occasions (D. Kushner, pers. comm.). Available information on the genetic structure of pinto abalone populations suggests that long-distance dispersal events occur frequently enough to maintain high gene flow among populations over distances of at least 1000 km (Withler *et al.* 2001; see also Section 3.2.2).

3.6.1 Settlement

Keough and Downes (1982) define settlement of the larvae of marine benthic invertebrates, including abalone, as contact with the post-larval substratum, resulting in metamorphosis from the larval to the post-larval form. A series of studies over the past two decades have provided insight to the chemical and physiological processes in abalone larvae that are associated with settlement. The work collectively involves a number of abalone species, but there is sufficient empirical evidence to suggest that the mechanisms described below apply in general form to the settlement process in pinto abalone.

Morse (1990) has presented evidence that abalone larvae require exogenous chemical induction for settlement and metamorphosis and Morse and Morse (1984) suggested that settlement cues associated with crustose coralline algae are related specifically to certain chemicals produced by them and present only on their surfaces (Morse, 1992).

The sequence of studies and discoveries summarized above suggests that availability of crustose coralline algae in appropriate habitats may be significant to the success of the larval recruitment process in pinto abalone. Although crustose coralline algae are ubiquitous in rocky benthic habitats along the west coast of North America, a mechanistic understanding of processes that sustain these algal populations has not been established to our knowledge. If the presence of pinto abalone serves an important role in facilitating abundance of crustose coralline algae, it follows that the question of critical density thresholds (see section 3.6.3 of this Status Report) takes on a new dimension. That is, the critical density concept may apply to minimum densities needed to maintain community structure and function, including promotion of crustose coralline algal abundance, as well as to maintain minimum local abalone densities required for fertilization rates adequate to forestall local extinction. However, field observations along the British Columbia coast indicate differential distribution of juveniles and adults, with juveniles observed at deeper depths, suggesting that settlement of larvae occurs in deeper habitats (Sloan and Breen 1988). Thus, settlement may be influenced by other environmental factors independent of the presence and/or density of adults.

3.6.2 Recruitment

In the context of our Status Report we define recruitment as the appearance in one or more locations of measurable numbers of new post-metamorphic individuals. Our definition recognizes the possibility that recruitment may occur regardless of the local presence of breeding adults. Our definition is ecologically based, and should not be confused with the traditional and familiar recruitment definition used in the context of fisheries management. In the latter, recruitment is defined as the appearance in one or more harvested populations of new individuals that have reached a size large enough for legal harvest.

As noted above, Prince *et al.* (1987, 1988), McShane *et al.* (1988), and McShane (1992) have presented evidence that recruitment of abalone is most likely to occur in relatively close spatial proximity to aggregations of breeding adults, at least in part a consequence of the relatively short duration of the planktonic larval phase in abalone. McShane (1992) reviewed literature emphasizing the significance of coastal current regimes, including eddies and other regional-scale flow patterns, in distributing planktonic larvae and influencing locations of settlement and recruitment. Some flow features apparently serve to concentrate larvae and may foster the development of recruited cohorts at high density in appropriate benthic habitat (e.g., McShane *et al.* 1988). In contrast, flow patterns that disperse larvae of benthic species to inappropriate habitats, such as the open sea, may ultimately increase larval mortality rates and diminish recruitment rates (e.g., Strathmann 1985). Predation and starvation may also influence numbers and distribution of planktonic larval abalone (Strathmann 1985), but to our knowledge there are no data available to provide a basis for associating mortality rates to either of these processes.

An overriding problem in quantifying movement and fate of planktonic phase larvae of abalone is the virtual absence of data on abalone larval distribution in the water column, for any abalone species in any location on any scale (e.g., McShane 1992). As a result, effects of larval-phase population dynamics on recruitment processes for abalone can be evaluated only on the basis of various indirect measures. As noted above and in previous sections, abalone recruitment appears to be influenced by distribution of breeding adults, densities of adults on a local scale, availability of benthic recruitment substrata that provide appropriate chemical cues for settlement and metamorphosis of larvae, regional and local flow regimes that control larval dispersal from natal sites, and possibly predation and starvation of larvae.

Some information is available regarding recruitment in pinto abalone populations. As described above in section 3.3.2 of this Status Report (Fishery-Independent Information), data from index site surveys indicate that populations in Washington are experiencing recruitment failure, whereas populations in British Columbia have had successful recruitment despite continued declines in overall densities. A study by Zhang *et al.* (2007) estimating stock recruitment relationships for populations at Haida Gwaii and along the Central Coast found that poaching, rather than lack of recruitment, is an important factor limiting recovery in British Columbia. This is corroborated by preliminary results from 2011 and 2012 surveys in these areas, showing an increase in population densities that is most likely due to reduced poaching within these areas (J. Lessard, pers. comm.). There is also evidence of recent recruitment events in California and Mexico based on observation of animals < 50mm shell length (Boch *et al.* 2014, unpublished data; A. Bird, pers. comm.; E. Parnell, pers. comm.). ADF&G has observed mixed age classes in some areas in Southeast Alaska, including juveniles (S. Walker, pers. comm.). We note that the cryptic nature of juvenile pinto abalone make the detection of recruitment events difficult. Small juveniles (< 10 mm SL) have occasionally been observed under boulders and on smooth bedrock or boulders that are bare or encrusted with coralline algae (Breen 1980a). Juveniles tend to occupy highly cryptic habitats in deeper waters compared to adults (Sloan and Breen 1988). In surveys along the coast of British Columbia, only 60% of juveniles 10-70mm in size were exposed, compared to 90% of individuals 70-90 mm size and almost all individuals greater than 90 mm in size (Boutillier *et al.* 1985, cited in Sloan and Breen 1988). Thus, recruitment events may be occurring but going undetected in regions that are not surveyed on a regular, consistent basis.

In a few areas of Southern California where kelp forest monitoring has occurred somewhat regularly over the course of a decade or more (San Diego, CA and Northern Channel Islands), pinto abalone recruitment rates appear to be variable resulting in episodic pulses of successful recruitment interspersed with periods of no recruitment (E. Parnell, pers. comm.). This pattern has been observed in the absence of fishing pressure, predation by sea otters, and low densities of reproductively mature pinto abalone. As recognized in the preceding paragraph, one explanation for this may be that the frequency and spatial coverage of sampling is not adequate to capture pinto abalone recruitment events that are occurring consistently. Another plausible explanation that is supported based on studies focused on pinto abalone (Breen 1986) and other abalone species (G. VanBlaricom, USGS, unpublished data) is that successful recruitment is variable in space and time and is dependent on naturally occurring, long-term fluctuations in ocean conditions.

3.6.3 Growth rate and maximum size

In a conservation context, growth rate of abalone is important because of linkages of size, age, and reproductive potential. Growth is also important to understand because body size may be an important determinant of vulnerability to predation. Growth may also be a useful indicator of abalone health and may reflect patterns of temperature, food supply, and other environmental features that can be monitored in the interest of abalone conservation. Growth rate data are clearly of value in the context of fishery management as well (e.g., Day and Fleming 1992).

As noted previously, young post-metamorphic abalone are often cryptic in coloration and habitat use, making direct measurements of growth rate in the field difficult. The problem is compounded by the small size of young animals, such that tag attachment is largely intractable and, if attempted, may cause disturbance, injury or death of the subject animal.

Abalone growth models have been developed primarily based on data from populations in British Columbia (Schnute and Fournier 1980, Breen 1986, cited in Zhang *et al.* 2007). Growth in pinto abalone, as measured by shell length, appears to vary by location and season depending on factors such as exposure to wave action, temperature, and the availability and quality of food (Sloan and Breen 1988). Pinto abalone were found to grow faster in moderately exposed areas with giant or bull kelp, compared to highly exposed areas with *Pterygophora californica*; this is likely due to reduced capture efficiency of drift algae in such habitats (Sloan and Breen 1988). Laboratory studies by Paul and Paul (1981) show that growth was highest at 13.5°C, whereas growth was inhibited at 5.5°C. This corroborates with lab and field observations indicating that pinto abalone growth is greatest during May to August, when temperatures range between 13-14°C (Paul *et al.* 1977, Larsen and Blankenbeckler 1980, cited in Sloan and Breen 1988). Growth can also vary with age and maturity. For example, both Paul *et al.* (1977) and Larsen and Blankenbeckler (1980) found that growth slowed with the onset of sexual maturity. In Larsen and Blankenbeckler's (1980) study of tagged pinto abalone in Southeast Alaska, growth decreased from about 19.1mm per year in abalone <50 mm SL and about 12.6 mm per year in abalone from 50-74 mm SL to about 6.2 mm per year in abalone 75-99 mm SL and about 4.3 mm per year in abalone >100 mm SL. Thus, estimates of age at size can vary considerably, for example, from 2-5 years of age for a 50 mm SL individual and 6-9 years (or more) of age for a 100 mm SL individual (Sloan and Breen 1988). Estimated longevity of at least 15-20 years is reasonable for pinto abalone (Shepherd *et al.* 2000, cited in COSEWIC 2009).

In summary, available data on pinto abalone growth in captive settings suggest that young animals reach sizes of about 22 mm SL (range 8-32 mm SL) in their first year (Olsen 1984), then grow at rates of approximately 18 mm per year for the next several years (Sloan and Breen 1988). Growth begins to slow at lengths of about 50 mm, corresponding to the onset of sexual maturity. Growth can vary based on many factors besides age, including water temperature, season, food availability and quality, and exposure to wave action. The maximum recorded shell length for pinto abalone is 165 mm (Breen 1980a).

3.7 Abundance

There are two types of data that can be examined to provide a better understanding of variation in pinto abalone abundance over time: fishery-dependent and fishery-independent data. Due to the general lack of formal data, we include information from peer-reviewed publications and published reports, as well as from observational reports from individuals or groups of people. Also, because both abundance levels and the availability of information vary by region, we summarize the information by the following general regions: Alaska, British Columbia, Washington (San Juan Islands Archipelago), Oregon, California, and Mexico.

3.7.1 Fishery-dependent Information

3.7.1.1 Alaska Fisheries

Harvest of pinto abalone in Alaska occurred in the commercial, sport, personal use, and subsistence fisheries. Data from these fisheries are limited to commercial landings by weight and general information for the other fisheries, but indicate an overall trend of declining catch in the 1980s and 1990s in both the commercial and subsistence fisheries. The commercial fishery was closed in 1995 and the sport fishery in 2012; both remain closed to date. The personal use and subsistence fisheries remain open and harvest is believed to be low. No directed monitoring of pinto abalone occurs in Alaska for management purposes at this time.

Commercial Abalone Fishery

Commercial harvest of pinto abalone, with a minimum size restriction of 76 mm SL, occurred by 1962 in Southeast Alaska (Table 1; Woodby *et al.* 2000). Although pinto abalone in Southeast Alaska can be picked by hand from the intertidal zone during extreme low tides, most of the commercial fishing effort used scuba or hookah diving gear in the subtidal zone (Rumble and Hebert 2011). Commercial harvest of pinto abalone in Southeast Alaska was characterized by a significant increase in effort and harvest in the late 1970s and early 1980s, followed by a steep decline in catch in the late 1980s and 1990s (Figure 4; K. Herbert and S. Walker, ADF&G, unpublished data). The increase in effort can be attributed in large part to an increase in value from less than one dollar per pound in the early 1970s to greater than six dollars per pound by 1993-94 (Woodby *et al.* 2000).

Data on the weight (pounds) of pinto abalone, but not the number, that were harvested and landed in the commercial fishery are available. Overall trends indicate an increase in harvest with a peak at 378,685 pounds in the 1979-80 season (Figure 4), followed by a decline in harvest that was likely due in part to declines in pinto abalone abundance as well as changes in regulations to limit the fishery. The season was open year- round prior to 1979. In 1979-80, the harvest season was reduced to 287 days between September 1-May 31 (Table 2; Rumble and Hebert 2011). Size restrictions varied in the Southeast Alaska fishery between years and fishing district with a general trend of increasing size minimums in order to decrease the harvest rate of mature abalone because of concerns regarding abalone abundance (Table 1; Woodby *et al.* 2000). Additional fluctuating reductions in season length occurred in the remaining years of the fishery (Table 2). A commercial harvest limit (Guideline Harvest Range) was first put in place by ADF&G during the 1980-81 season (250,000 pounds; Rumble and Hebert 2011). Catch per unit effort dropped significantly through the late-1980s and 1990s (Figure 5). The commercial harvest limit was reduced multiple times over the following 15 years, but adjustment of the season length was the primary factor limiting the total annual harvest (Woodby *et al.* 2000). In

1981-82, the annual harvest of 370,894 pounds far exceeded the ADF&G Guideline Harvest Limit of 100,000-125,000 pounds, even though the season was curtailed to 59 days following closure by emergency order (Rumble and Hebert 2011).

Prior to 1996, the commercial dive fisheries in Southeast Alaska were open access. However, as new markets opened and ex-vessel value increased, fishing effort expanded to levels that made it difficult for the ADF&G to manage each fishery (Rumble and Hebert, 2011). Legislation passed in 1996 (HB 547) and the resulting statute (AS 16.43.228) capped the number of participants in the four dive fisheries (i.e., geoduck, sea cucumber, red sea urchin, and pinto abalone) (Rumble and Hebert 2011). The commercial fishery for pinto abalone was closed in 1995 (Woodby *et al.* 2000), and remains closed. HB 547 imposed a 4-year moratorium on entry of new participants into the remaining dive fisheries (Rumble and Hebert 2011). The new, limited-entry fisheries were implemented by the Commercial Fisheries Entry Commission for the red sea urchin in November 2000, and for geoduck and sea cucumber in May 2001 (Rumble and Hebert 2011).

Area closures were implemented in the pinto abalone commercial fishery beginning as early as 1977, with closed area expansions though 1985, to reduce conflicts with sport, personal use, and subsistence fisheries in nearby communities (Figure 6; K. Hebert and S. Walker, ADF&G, unpublished data). Sitka Sound was also closed to commercial harvest of pinto abalone. These area closures remained in place until the entire commercial fishery was closed in1995.

Sport Abalone Fishery

Abalone harvest has occurred in the sport abalone fishery (for non-residents), but data on trends in harvest are not available. In the sport fishery, the daily bag limit was 5 abalone per day (minimum size: 3.5 inches), with no closed season. Scuba and hookah gear were allowed until 1996. The Alaska Board of Fisheries closed the sport abalone fishery in 2012 and it remains closed at present.

Personal Use Abalone Fishery

Abalone harvest still occurs in a personal use abalone fishery (for state residents), but data on trends in harvest are not available. The personal use abalone fishery is only open to residents of the State of Alaska. In 2012, the Alaska Board of Fisheries reduced the daily bag limit to 5 pinto abalone per person. These regulations are currently unchanged. Prior to 2012, the daily bag limit for personal use harvest of pinto abalone was 50 per person, except in one area, around Sitka, where there was a daily bag limit of 20 abalone per person. The minimum size limit of 3.5 inches remains unchanged from past years. There is no closed season. Scuba and hookah diving was legal prior to 1996, but is now prohibited for harvesting abalone for personal use. ADF&G believes that personal use harvest of pinto abalone in Alaska is low (ADF&G comments to NMFS, 17 January 2014).

Subsistence Abalone Fishery

The ADF&G Division of Subsistence has monitored the past subsistence harvest of pinto abalone in Southeast Alaska and found a significant decline (98% decrease) in the subsistence harvest from 1972-1997 (Table 3). In 2012, the Alaska Board of Fisheries reduced the daily bag limit for subsistence harvest to 5 pinto abalone per person, with no closed season and no annual limit (Bowers *et al.* 2011). In the past, the daily bag limit for subsistence harvest was 50 abalone per person. The minimum size limit remains unchanged at 3.5 inches (Bowers *et al.* 2011). Scuba and hookah diving is prohibited for harvesting pinto abalone for subsistence use, but was legal prior to 1996. Current legal harvest methods include use of snorkel equipment, abalone irons, or collection by hand. The ADF&G believes that the subsistence harvest of pinto abalone in Alaska remains low (ADF&G comments to NMFS, 17 January 2014).

<u>Other Dive Fisheries in Southeast Alaska</u>

Commercial dive fisheries for red sea urchin, sea cucumber, and geoduck clams still occur in Southeast Alaska and are managed by the ADF&G. Monitoring by ADF&G for these existing dive fisheries suggest continued declines of pinto abalone. Additional data are presented below in the “Fishery Independent Information” section.

3.7.1.2 British Columbia Fisheries

Historically, pinto abalone in British Columbia were harvested in commercial, recreational, and traditional First Nations food, social and ceremonial fisheries. All pinto abalone fisheries, including recreational, commercial, and First Nations food, social, and ceremonial fisheries were closed in December 1990 due to concerns regarding population declines. Because there is very limited information on the recreational and First Nations fisheries, we briefly describe these and focus primarily on the commercial fishery and harvest data.

Prior to the advent of scuba gear around 1960, harvest occurred primarily at low tide by “shore picking” (Farlinger and Campbell 1992), although some First Nations such as the Haida, used a two-pronged spear to take abalone as deep as 2 m below the lowest tide (Jones 2000). Recreational fishers also originally took abalone by shore picking; however, after the advent of scuba gear this sport or recreational fishery became widespread along the coast, including in remote areas with the operation of dive charters (Farlinger and Campbell 1992). No landing statistics are available for either the First Nations or recreational fisheries (Sloan and Breen 1988, Farlinger and Campbell 1992). However, McElderry and Richards (1984) estimated that during the recreational fishery in 1983, scuba divers in the Strait of Georgia collected 1,172 pinto abalone per thousand sport dives and that between 76,000 and 172,000 recreational scuba dives occurred during 1983 in the Canadian portion of the Strait of Georgia.

Although small, local, and sporadic commercial abalone fisheries began in British Columbia as early as 1889 (Mowat 1890, p. 261), the commercial dive fishery first began to expand significantly in 1972. Several sources (Fedorenko and Sprout 1982, Breen 1986, Sloan and Breen 1988, Farlinger and Campbell 1992, Muse 1998, Harbo and Convey 2006) have provided reviews of the history of the pinto abalone commercial fishery in British Columbia.

Landings in the British Columbia commercial abalone fishery from 1952 to 1990 are presented in Table 4 and Figure 7 (Quayle 1971, Fedorenko and Sprout 1982, Sloan and Breen 1988, Campbell 1997). Prior to the early 1970s, a small domestic market sustained a relatively small commercial fishery. A high landing record of nearly 60 metric tons (mt) occurred in 1972 and landings remained near this level until 1976 when they increased dramatically to 273 mt, topping out at over 480 and 400 mt in 1977 and 1978. A quota was first imposed on this open-access fishery in 1979 and catch that year dropped to about 200 mt. Various explanations for the occurrence of this "gold-rush" fishery (Breen 1986, Sloan and Breen 1988) have included: 1) advent of scuba and dry-diving suits that allowed more diver submergence time; 2) advent of on-board boat freezers; 3) emergence of a market in Japan for pinto abalone; 4) a tripling of the price per pound between 1972 and 1976 to over $3.00 (Canadian dollar) per pound; 5) redirection of fishing effort toward pinto abalone because of restricted access to salmon and herring fisheries; and 6) the unrestricted access to the abalone fishery prior to 1977 (Sloan and Breen 1988, Farlinger and Campbell 1992). Numerous management actions influenced the fishery following 1977 (Sloan and Breen 1988), and landings leveled out to between 44 and 47 mt under quota management. Breen (1986) estimated that at the beginning of 1976 the abalone stock stood at 1,800 mt, in areas that were then open to harvest. By the end of 1980, the stock size had been reduced to just 450 mt (Breen 1986). Various authors (Fedorenko and Sprout 1982, Breen 1986, Sloan and Breen 1988, Farlinger and Campbell 1992, Muse 1998) have reported slightly different landings numbers. The presence of heavy illegal fishing during some of this time period may have affected how various authors reported landings (Muse 1998). During the peak of the commercial fishery in 1977–1979 most abalone landings came from Central Coast areas and Haida Gwaii (Figure 8; Breen 1986, Sloan and Breen 1988).

An attempt has been made in Table 4 to estimate the number of individual pinto abalone landed each year from 1952–1990 in the commercial fishery based on landed biomass and the predicted mean weight of legal-sized northern abalone (≥90 mm SL from 1952–1976, and ≥100 mm SL after 1976). Based on pinto abalone shell lengths and whole animal weights published in Quayle

(1971), abalone over 89 mm SL (n = 1,438) weighed on average 159.7 g, and abalone over 99 mm (n = 976) weighed on average 185.3 g. Using these average measurements, it is estimated that as many as 2.5 million abalone were harvested in 1977, with at least a million abalone being taken each year from 1976 to 1979 and over 240,000 being harvested in each year during the last decade of the fishery (Table 4). After 1990, DFO banned all harvest of pinto abalone in British Columbia as a result of rapidly declining densities in survey sites and overall low population levels (Egli and Lessard 2011).

3.7.1.3 Washington Fisheries

There has never been a commercial fishery for pinto abalone in Washington State. Local indigenous peoples, and later, other early residents of Washington State, reportedly harvested intertidal abalone; however, the magnitude and extent of this subsistence fishery are not well documented (WDFW 2014). Pinto abalone in Washington were first recognized as a recreationally harvestable shellfish with a daily possession limit of three abalone by Washington Administrative Code (WAC) orders first published in 1959. The daily possession limit was set at 5 per person and a 3.5 inch (~ 90 mm) minimum size limit (measured in horizontal line across longest portion of the shell) was implemented in 1980 (shell and body must remain intact in the field). In 1985 the retention of the first 5 legal-sized abalone harvested became required (i.e., upgrading was not allowed) and removal of undersized abalone from the water was banned (Blewett 2007). In 1990 the use of “curved irons, knives, or other sharp instruments” to harvest abalone was banned and harvest was limited to hands or round-edged “abalone irons” of specific dimensions to reduce injury to abalone that were removed from the substrate but not retained

(Blewett 2007, WDFW 2014). In 1992, the daily possession limit was reduced from 5 to 3, the minimum longest shell dimension was increased to 4 inches (101.6 mm SL), and it became a requirement to possess “a 4-inch caliper and use it to determine if the abalone is of legal size before it is removed from its attachment” (Blewett 2007, WDFW 2014). The Washington recreational pinto abalone fishery was closed in 1994 and it became “unlawful to fish for or possess abalone taken for personal use the entire year” (Blewett 2007, WDFW 2014).

Records of pinto abalone harvest in the Washington recreational fishery were not collected (Rothaus *et al.* 2008) and the only estimates of annual harvest in this fishery come from compilations of recreational sport diver interviews, returned questionnaires, diver logbook records, and information from dive clubs all assembled when the fishery was still open (Bargmann 1984, Gesselbracht 1991). Bargmann (1984) assembled data over the period of April 1982 to March 1983 and estimated that sport divers harvested 34,800 and 3,400 abalone annually from the North Sound and the Straits/Admiralty regions, respectively. Farlinger and Campbell (1992) cite a pers. comm. with R. Burge that this “harvest was probably about 12 t annually.” Approximately 91% of the abalone harvest occurred in the North Sound region, which includes the San Juan Islands Archipelago, and the remainder occurred in the Strait of Juan de Fuca and just north of Admiralty Inlet. It was estimated from interviews that at least one abalone was taken during 18% of dive days in the North Sound and 6% of dive days in the Straits/Admiralty region (Bargmann 1984). A daily bag and possession limit of five abalone was in effect during this time period, and Bargmann (1984) believed that this regulation did limit harvest, especially in the North Sound. Gesselbracht (1991, as cited in WDFW 2014) conducted interviews with sport divers from September 1989 to August 1990 and reportedly estimated that 40,934 abalone were harvested annually. WDFW (2014) cautioned, however, that these self-reported harvest data may under-estimate true recreational exploitation rates and also do not reflect cumulative harvest that has occurred over several decades.

Palsson *et al.* (1991) reported on a recreational dive charter observer survey that ran from November 1979 to March 1985 in the San Juan Islands Archipelago. Palsson *et al.* (1991) estimated that over the 7–year study period, an average of 1.57 abalone were taken per dive and that at the fishery's peak in 1981, an average of 2.28 abalone were harvested per "shellfish-targeted" dive (WDFW 2014). On a per diver-day basis, an average of 2.84 abalone were taken per diver per day from 1979–1985 when at least one dive per day was targeted on shellfish, and it was estimated that the daily bag limit of five abalone was achieved by 31% of charter divers during this period (Palsson *et al.* 1991).

3.7.1.4 California Fisheries

Human exploitation of abalone has occurred in the southern California Islands since the late Pleistocene (~10,500 years ago (ya)) and in central California for about 5,000 years. To date it has not been possible to reconstruct species-specific harvest information based on abalone shells observed in middens (Erlandson *et al.* 1996). Commercial abalone fisheries in California began in 1898 and during that same year the first cannery was built in Point Lobos, Monterey County. From 1913-1928, commercial and recreational dive fisheries developed, with red (*H. rufescens*), pink (*H. corrugata*) and green (*H. fulgens*) abalone being the targeted species, but only red abalone were documented in records of commercial landings prior to 1940 (Rogers-Bennett *et al.*

2002). By 1930, after the realization that significant declines in abalone landings were occurring, several laws restricting fishing methods, areas, sizes, numbers, and season were imposed on the abalone fishery (Croker 1931, Lundy 1997). Commercial fishing peaked at an annual harvest of over 2,500 metric tons in 1957 and by 1994 the annual harvest declined to approximately 140 metric tons (CDFW 2005).

Landings data reported by the CDFW Abalone Recovery and Management Plan (ARMP), indicate that pinto abalone were landed at the Farallon Islands, Point Montara, Point Buchon, Point Conception, the Northern and Southern Channel Islands, Santa Barbara, San Diego and the offshore banks from 1950-1997 (Figure 9; CDFW 2005). The highest yields were reported at Point Conception and Point Loma based on CDFW landing receipts from 1950-1997. The peak of the fishery occurred in 1974 when approximately 10,000 pounds (4.5 metric tons) of pinto abalone were landed (CDFW 2005). Pinto abalone made up approximately 13% of the abalone population in northern California in the 1970s according to (Gotshall *et al.* 1974). Cox (1962) reported that the species was often patchily distributed and that dense patches could occasionally be found in deeper waters. Overall, pinto abalone was not considered a major component of the California commercial or recreational catch (CDFW 2005), however, increased fishing pressure and over harvest led to landings < 500 pounds annually (0.2 metric tons) by the 1980s. CDFW closed all commercial and recreational abalone fisheries south of San Francisco in 1997. In 1999, CDFW effectively excluded pinto abalone from the red abalone recreational fishery in northern California by increasing the minimum legal size limit to 178 mm for all species (Rogers-Bennett *et al.* 2002).

Rogers-Bennett *et al.* (2002) estimated baseline abundance (i.e., abundance prior to overfishing) for *H. k. assimilis* using landings data from the peak of the commercial and recreational fisheries (1971-1980). The baseline minimum estimate of abundance for *H. k. assimilis* prior to overexploitation was 21,000 animals. After 1980, only 66 animals were landed suggesting a decline of 99.6% over a ten-year period. This estimate provides a historic perspective on patterns in abundance, defines a relevant baseline abundance against which to compare modern-day trends, and helps to assess the species' current status and risks. However it is important to note that this method assumes that the population was at least as large as the number taken in the fishery, that the fishery "sampled" all size classes, and that no new individuals were added to the population during the ten-year peak of the fishery. In addition, this estimate was based on data from a time period when pinto abalone abundances may have been higher than usual due to the decline of sea otters along the California coast; thus, this estimate may not reflect the true baseline abundances that existed prior to the abalone fishery and the exploitation of sea otters.

3.7.1.5 Mexican Fisheries

The abalone fishery in Mexico dates to approximately 1860 (Bonnot 1930, Lundy 1997), but modern commercial harvests did not develop until the 1940s. The fishery is pursued by 22 fishing cooperatives, distributed across four management zones on the Pacific coast of the Baja California peninsula (Figure 10). Five cooperatives are present in management zone 1, which is the northernmost of the zones and extends from the U.S.-Mexico border and de Islotes Coronado, to Punta Malarrimo, Baja California Sur, and includes Isla Cedros. While green and pink abalone historically have been the primary catch in Baja California, both pinto and white have been relatively abundant and harvested (Boch *et al.*, 2014).

3.7.2 Fishery-independent Information

3.7.2.1 Population Trends in Alaska

There is little information available on abalone populations in Alaska prior to the significant commercial fishery and there has been no rigorous long term monitoring of pinto abalone since the 1995 commercial fishery closure. Observations of pinto abalone made by ADF&G biologists while conducting dive surveys to monitor other benthic invertebrate species for management purposes suggest a continued decline of pinto abalone since the fishery closure (Figure 11). ADF&G noted increases in empty abalone shells and areas devoid of live abalone where they were once common, while on the red sea urchin survey transects between 2001-2012 (K. Hebert, pers. comm.). These observations are coincident with increased sea otter abundance in these areas, and ADF&G thinks it is certain that sea otters are having a severe impact on pinto abalone abundance where the two species overlap. The one exception to this observed pattern is in Sitka Sound, where sea otters and a small population of pinto abalone appear to co-exist (K. Hebert, pers. comm.).

3.7.2.2 Population Trends in British Columbia

Early observations of pinto abalone (aka northern abalone) in British Columbia were reported by Thompson (1914), particularly around Haida Gwaii and in Queen Charlotte Sound, although no estimates of abundance were given (Figure12). A private, exploratory survey for abalone at 26 sites in southeastern Haida Gwaii was conducted in 1955 by a diver with “hard hat” gear and found that pinto abalone were present at 54% of the sites, present but relatively rare at 15% of the sites, and absent from 31% of the sites (Quayle 1962, Sloan and Breen 1988). Breen and Adkins (1979) sampled the same area in 1978 and, in contrast, found pinto abalone present at almost all sites and recorded an overall mean density of 2.5 abalone per m^2.

The Department of Fisheries and Oceans Canada (DFO) began conducting index site surveys in 1978 in British Columbia to monitor populations of pinto abalone. Over the years, most of these abalone surveys have occurred in southeastern Haida Gwaii and along the Central Coast of British Columbia (Figure 12), where pinto abalone were most abundant and most of the commercial harvest was taken (Sloan and Breen 1988, Egli and Lessard 2011). Index survey sites were selected based on the presence of harvestable densities of abalone, with surveys beginning in 1978-1980 and conducted on a 5- year rotation since 2001. Occasional surveys have also been conducted in the Strait of Georgia, Queen Charlotte Strait, Johnstone Strait, Barkley Sound, the northwest coast of Vancouver Island, and the far North Coast (Figure 12; Cripps and Campbell 1998, Lucas *et al.* 2002a-e, Lessard et. al. 2004). DFO abalone surveys began in 2003 and 2004 on the West Coast of Vancouver Island and in Queen Charlotte Strait, respectively. Survey sites were chosen randomly within general areas where abalone were known to be present. Johnstone Strait was also surveyed in 2004; however, abalone habitat was considered limited and this survey has not been repeated. Two areas in the northern Strait of Georgia were first surveyed in 2009. Surveys on the West Coast of Haida Gwaii occurred in 2008 and 2013, but results are still pending for both surveys, although high densities were indicated by preliminary results (J. Lessard, pers. comm.).

Two fishery-independent survey methods have been employed by DFO since index sites were established in 1978: 1) the “ Breen survey” (Breen and Adkins 1979) whereby divers select a site pre-determined to contain pinto abalone habitat, place a 1 m^2 quadrat on top of that habitat, and then proceed to count and measure emergent abalone and score habitat within a 7 m x 16 m area (see Lessard and Egli 2011 for full description); and 2) the “transect survey method” (Cripps and Campbell 1998) whereby transects of varying lengths are randomly selected, 1m x 1m quadrats are searched by divers moving from deep to shallow water on either side of the transect, emergent abalone are measured and counted, and macroalgal cover is noted (see Lessard and Egli 2011 for full description). Below, we summarize the available information regarding pinto abalone abundance from these index site surveys and additional surveys conducted within the sites.

Haida Gwaii

Since the first survey in 1978, 10 abalone density surveys have been conducted at index sites using the Breen survey methodology in the Haida Gwaii area of British Columbia (Hankewich *et al.* 2008; J. Lessard, pers. comm.) (Table 5, Figure 13). Results of these surveys have been presented in numerous reports published by DFO (Breen and Adkins 1979, Boutillier *et al.* 1985, Carolsfeld *et al.* 1988, Thomas *et al.* 1992, Winther *et al.* 1995, Campbell *et al.* 2000, Atkins *et al.* 2004, Hankewich *et al.* 2008). Prior to the main impact of the commercial dive fishery in eastern Haida Gwaii, Breen and Adkins (1979) found abalone densities that averaged 16 abalone/m^2 and that ranged from zero to as high as 28 abalone/m^2 (Sloan and Breen 1988). Adkins and Stefanson (1977) also reported high densities of 4.4–10.0 abalone/m^2 in un-harvested areas of Moresby Island in Haida Gwaii in 1976.

The most recent published Haida Gwaii survey in 2007 (Hankewich *et al.* 2008) counted 559 abalone (SL mean ± SE; 61.5 mm ± 1.0 mm) in over 82 index sites grouped into eight general locations: Cumshewa Inlet, Selwyn Inlet, Tanu Island, Upper Juan Perez Sound, Lower Juan Perez Sound, Skincuttle Inlet, Carpenter Bay, and Kunghit Island (Hankewich *et al.* 2008) (Figure 13). Abalone were found at 80.5% of the 82 total sites surveyed (Hankewich *et al.* 2008). In 2007, no abalone were found at the Cumshewa Inlet area, although additional sites in this area were added to the survey. Large adult abalone were also absent from the Selwyn Inlet survey sites. The mean size of surveyed abalone in Haida Gwaii was 61.5 mm, which was the smallest mean shell length observed in any Haida Gwaii survey. Mean density at index sites in Haida Gwaii declined between 1978 and 2007 from 2.22 to 0.43 abalone/m^2 for total abalone, from 1.28 to 0.15 abalone/ m^2 for mature (≥70 mm SL) abalone, and from 1.39 to 0.27 abalone/ m^2 for immature abalone (COSEWIC 2009) (Figure 14). The mean density for total abalone (all sizes) increased slightly over the previous survey in 2002 (mean density of 0.34 abalone/m^2) due to an increase in immature abalone density; however, this increase was not statistically significant (Figure 14). Concurrently, the percent of sites with large abalone declined from the previous survey from an estimate of 25.0% in 2002 to 18.3% in 2007 (Hankewich *et al.* 2008). Overall, results indicated that the population at Haida Gwaii in 2007 had not yet met the short-term density objectives and recovery strategy goals set in DFO's National Recovery Strategy (2007). The mean density of large adult and mature abalone was only 0.03 and 0.15 abalone/m^2, compared to the short-term targets of maintaining densities of at least 0.1 and 0.32 abalone/m^2; the percentage of sites with large adult abalone was below the goal of at least 40%; and the proportion of quadrats with abalone was 25%, compared to the goal of at least 40% (Hankewich *et al.* 2008).

The most recent abalone survey in this region occurred in 2012 and results have not yet been published; however, abalone density data from the 2012 Haida Gwaii survey are included in Figures 25, 26, and 27, courtesy of J. Lessard (pers. comm.). As in the Central Coast surveys (discussed below), additional survey sites have recently been added in the Haida Gwaii region. For example, two sites were added at Cumshewa Inlet in 2012 where abalone were present; however, densities at previously established sites in Cumshewa Inlet remain at zero (J. Lessard, pers. comm.). The mean densities of abalone of all sizes, mature abalone (≥70 mm SL), and large adult abalone (≥100 mm SL) in all survey index sites from 1978–2012 are shown in Figure 14. Mean density of immature abalone went up significantly between 2007 and 2012, indicating that recruitment is occurring, which may be linked to the recent cold phase of ocean conditions in the Northeast Pacific. The mean density of mature abalone also increased over this time period (Figure 14). As of 2012, the density of mature abalone ≥70 mm SL) at five of the nine index survey sites in Haida Gwaii are at or above the short-term recovery objective of 0.32 abalone/m^2 (Figure 15). The estimated mortality rate of mature abalone in Haida Gwaii decreased from a previous estimate of 0.32 to 0.26 between 2007–2012 (J. Lessard, pers. comm.). In contrast to portions of the Central Coast region of British Columbia, sea otters are currently not present in Haida Gwaii (J. Lessard, pers. comm.).

Abalone Recruitment Modules in Haida Gwaii

DeFreitas (2003) deployed 24 “artificial habitats,” also known as Abalone Recruitment Modules (ARMs), consisting of 24 concrete blocks within a commercial metal crab trap that provided about 3.5m^2 of surface area for abalone settlement, at 6 sites in Juan Perez Sound on Haida Gwaii from 2001–2003. This area then supported about 0.35 emergent abalone/m^2. After 10–12 months, 278 abalone were counted within the ARMS and the mean density of all-sized, mature, and juvenile abalone in the modules was 1.65, 0.06, and 1.27 abalone/m^2. These densities were significantly greater than densities found within adjacent natural habitats following invasive diver surveys (DeFreitas 2003).

Central Coast and North Coast

Since the first survey in 1978, 10 abalone density surveys have been conducted using the Breen survey methodology in the Central Coast area of British Columbia (Hankewich and Lessard 2008; J. Lessard, pers. comm.) (Table 6, Figure 16). Results of these surveys have been presented in numerous reports published by DFO (Breen and Adkins 1980, 1982; Boutillier *et al.* 1984; Farlinger and Bates 1986; Farlinger *et al.* 1991; Cripps and Campbell 1998; Campbell *et al.* 1998; Campbell and Cripps 1998; Lucas *et al.* 1999, 2000, 2002c; Lessard *et al.* 2007; Hankewich and Lessard 2008). The most recent published Central Coast survey conducted in 2006 (Hankewich and Lessard 2008) counted 433 abalone (mean SL = 69.4 mm ± 1.1 mm) in over 63 index sites grouped into nine general locations: North Banks Island, Oswald Bay, Pemberton Bay, Lotbinière Bay, North Aristazabal Island, South Aristazabal Island, Stryker Island, Simonds Group and Spider Island (Figure 16) (Hankewich and Lessard 2008).

The following information is based on descriptions of the 2006 survey on the Central Coast (Hankewich and Lessard 2008) and may not represent current conditions or conditions encountered during the 2011 survey. In 2006, all 9 survey areas on the Central Coast and 52 of the 63 survey sites (76.5%) contained abalone (Hankewich and Lessard 2008). In 2006, the mean size of surveyed abalone on the Central Coast was 69.4 mm, which was the smallest mean size since the 1978 survey. A decrease in maximum size and an increase in the proportion of small abalone resulted in this decrease in mean size (Figure 17). Mean density at index sites on the Central Coast declined between 1978 and 2006 from 2.40 to 0.40 abalone/m^2 for total abalone, from 2.13 to 0.23 abalone/m^2 for mature (≥ 70 mm SL) abalone, and from 0.27 to 0.18 abalone/m^2 for immature abalone (COSEWIC 2009) (Table 6, Figure 17). In 2006, the mean density of total abalone (all sizes) increased slightly over the previous survey in 2001 (mean density of 0.27 abalone/m^2) due to an increase in immature abalone density; however, this increase was not statistically significant (Hankewich and Lessard 2008). Overall, results indicated that the population along the Central Coast in 2006 had not yet met the short-term density objectives and recovery strategy goals set in DFO’s National Recovery Strategy (2007). The mean density of large adult abalone was 0.02 abalone/m^2, compared to the target of 0.1/m^2; the percentage of sites with large abalone was only 17.6%, compared to the target of at least 40%; and the proportion of quadrats with abalone was 21%, compared to the goal of at least 40% (Hankewich and Lessard 2008).

The most recent abalone survey in this region occurred in 2011 and results have not yet been published; however, abalone density data from the 2011 Central Coast survey are included in Figures 20-22, courtesy of J. Lessard, (pers. comm.). Additional survey sites have recently been added in the Central Coast region. The mean densities of abalone of all sizes, mature abalone (≥70 mm SL), and large adult abalone (≥100 mm SL) in all survey index sites from 1978–2011 are shown in Figure 17. Mean density of all sized abalone doubled between 2006 and 2011, indicating that recruitment is occurring, which may be linked to the recent cold phase of ocean conditions in the Northeast Pacific. As of 2011, the density of mature abalone (≥70 mm SL) at 6 of the 8 index survey sites in the North Coast were at or above the short-term recovery target of 0.32 abalone/m^2 (Figure 18). The mean density of all 8 sites in 2011 was also greater than 0.32 abalone/m^2, indicating that the short-term recovery target had been met for the North Coast. In addition, mean density of mature abalone (≥70 mm SL) at the Simonds Group was over one abalone/m^2. Sea otters currently occur in the central part of the Central Coast and sea otter populations on the Central Coast at Stryker Island, the Simonds Group, and Spider Island are expanding. The estimated mortality rate of mature abalone in the Central Coast region has decreased from a previous estimate of 0.33 to 0.25 between 2006–2011 (J. Lessard, pers. comm.).

Lucas *et al.* (2002c) reported on abalone density surveys conducted with the transect survey method in 2000 to determine numbers of abalone available for broodstock collection in Lotbinière Bay on the Central Coast (Figure 16). Density of emergent abalone across all 23 transects averaged 0.29/m^2, and density of abalone in the 90–110 mm SL range was 0.08/m^2 (Lucas *et al.* 2002c). Lucas *et al.* (2002b) also reported on abalone density surveys conducted with the transect survey method in 2000 to determine numbers of abalone available for broodstock collection at McCauley and Goschen islands near Kitkatla on the North Coast of

British Columbia (Figure 19). Density of emergent abalone of all sizes averaged $0.16/m^2$ at McCauley Island and $0.05/m^2$ at Goschen Island (Lucas *et al.* 2002b) (Table 7).

Strait of Georgia

Pinto abalone have been reported in the Strait of Georgia, but they are relatively rare (Quayle 1971). Their distribution may be limited to depths of more than 7m in this area because of higher water temperatures and lower salinities at shallower depths (Sloan and Breen 1988). Adkins (1996, as cited in Egli and Lessard 2011), described abalone surveys on the south coast of Vancouver Island that found densities of 0.73 abalone/m^2 in 1982 and 1.15 abalone/m^2 in 1985. During timed swims in 1996–1997 near William Head Penitentiary, southwest of Victoria, Wallace (1999) found 211 abalone (0.77 abalone/min); however, in 2005 only a single abalone was seen across four sites surveyed at William Head (DFO 2007). Across all 19 sites surveyed in 2005 on the south end of Vancouver Island only 3 abalone were found for a density estimate of 0.0098 abalone/m^2 (DFO 2007).

In contrast to the southern Strait of Georgia, Egli and Lessard (2011) reported that abalone distribution in the northern Strait of Georgia "has been anecdotal and has not been systematically determined." Lucas *et al.* (2002d), using the transect survey method at Chrome Island and southern Denman Island in 2000 and 2001, found a total of 49 abalone across a total of 21 transects for a mean density of abalone (all sizes) of $0.06/m^2$ (Table 8, Figure 20). A conservative mean total population estimate of emergent (90–110 mm SL) abalone for the two sites was 1,577 (Lucas *et al.* 2002d). In October 2009, six pinto abalone were found at 4 of the 30 sites surveyed in the northern Strait of Georgia around Cortes and Texada islands (Table 9,

Figure 21) and overall density was found to be 0.013 ± 0.007 abalone/m^2 (Egli and Lessard 2011).

West Coast Vancouver Island

Atkins and Lessard (2004) surveyed abalone density and size in 2003 at 32 sites in Quatsino Sound, Brooks Bay and on the exposed outer coast of north-west Vancouver Island (Figure 22). No abalone were found on the exposed outer coastline and most abalone in more protected locations were found at depths ≤ 4m, indicating that surf conditions are too severe for abalone to occur in the shallow subtidal, where they are fully exposed to the open Pacific (Atkins and Lessard 2004). However, mean abalone densities within Quatsino Sound and Brooks Bay were 0.212/m^2 and 0.038/m^2, respectively (Table 10).

Two abalone density surveys to determine numbers of abalone available for broodstock collection were conducted by DFO in Southeast Barkley Sound near Bamfield on Vancouver Island; one in 2000 (Lucas *et al.* 2002e) and the other in 2002 (Lessard *et al.* 2004) using the transect survey method (Cripps and Campbell 1998). Thirty-three transects at four sites were surveyed in 2000 and one of these sites (east Edward King Island) was re-surveyed in 2002 across 15 transects (Lucas *et al.* 2002e, Lessard *et al.* 2004) (Table 11, Figure 23).
The mean density of abalone of all sizes was 0.04/m^2 across the 4 sites in 2000 and 0.23/m^2 at east Edward King Island in 2002 (Lucas *et al.* 2002e). Emmett and Jamieson (1988) had recorded a density of 0.56 abalone/m^2 at this latter site in 1984.

Tomascik and Holmes (2003) found a mean density of 0.15 abalone/m^2 at 22 sampling locations across 5 island groups and 2 depth zones (2–5 m and 6–9 m) in the Broken Group Islands in Barkley Sound (Figure 24). Mean density was nearly twice as high in the shallow zone (0.18/m^2) compared to the deep zone (0.10/m^2) and mean size was also greater in the shallow (65 mm SL) versus deep zone (46 mm SL). Although some evidence of abalone recruitment was seen (42% of the sampled population were juveniles), densities were about four times lower than were seen prior to the commercial fishery closure by Emmett and Jamieson (1988) (Tomascik and Holmes 2003).

Queen Charlotte Strait and Johnstone Strait

In 1977, during the commercial fishery, Breen *et al.* (1978) surveyed 34 sites identified by previous fishing activity and found that abalone were abundant enough to sustain commercial fishing pressure at only two of the sites and possibly at a few others. Lucas *et al.* (2002a) reported on abalone density surveys conducted with the transect survey method in 1999 to determine numbers of abalone available for broodstock collection at three sites in Queen Charlotte Strait. Density of emergent abalone across all sites averaged 0.06/m^2 and nearly all abalone were greater than 70 mm SL (Lucas *et al.* 2002a) (Table 12).

Systematic surveys of abalone abundance using the Breen survey methodology were conducted in 2004 in Johnstone Strait (Davies *et al.* 2006) and 2004 and 2009 in Queen Charlotte Strait (Lessard and Egli 2011) (Table 13, Figure 25). Since only marginal abalone habitat exists in Johnstone Strait (Davies *et al.* 2006) it was not re-surveyed in 2009 (Lessard and Egli 2011). By

2008, there were over 200 sea otters in the Queen Charlotte Strait area and sea otter predation, as well as low recruitment, were items of special concern (Lessard and Egli 2011).

In the most recent survey (2009), abalone were found at 41% of the 34 sites surveyed in Queen Charlotte Strait, at an overall density of 0.109/m^2, and with a mature abalone density of 0.072/m^2 (Lessard and Egli 2011) (Table 13). Larger densities were found in 2009 compared to 2004 at index survey sites in Queen Charlotte Strait (nearly four times greater); however, only the differences for abalone greater than 100 mm SL were statistically significant (Lessard and Egli 2011). Nevertheless, Lessard and Egli (2011) reported that even though abalone abundance was low compared to the Central Coast and Haida Gwaii (0.43 and 0.40 abalone/m^2, respectively) abalone and/or their habitat were distributed throughout the area surveyed and densities appeared to be stable as of 2009.

Summary

Overall, pinto abalone populations in British Columbia have experienced large declines since the 1970s due to fisheries harvest and, after the fisheries closure in 1990, continued illegal harvest. The best available data indicate that although recruitment is occurring, the density of large adults (≥ 100 mm SL) has declined and remains low, either due to a high rate of juvenile mortality or due to a high rate of adult mortality that is offsetting juvenile survival (COSEWIC 2009; J. Lessard, pers. comm.). Between 1978-2009, mature (≥ 70 mm SL) abalone densities declined by 88-89% and total abalone densities declined by 81-83% at the Central Coast and Haida Gwaii sites, where pinto abalone were historically most abundant and where most of the commercial harvest occurred (COSEWIC 2009); declines have also been observed at other index survey sites. The most up-to-date information from surveys conducted in 2011 and 2012, however, show increases in mature abalone densities (by approximately 28% since 2001; Figures 14 and 17) and signs of recovery at Haida Gwaii and along the Central Coast, most likely due to reductions in illegal take (J. Lessard, pers. comm.). Densities of immature abalone increased by 29% at the Central Coast sites since 1989 and by 35% at the Haida Gwaii sites since 1990 (COSEWIC 2009).

Pinto abalone populations are believed to have the capacity to recover in British Columbia, especially given that habitat does not appear to be limiting in this region. Evidence of successful juvenile recruitment throughout the years and recent increases in adult abundance and density (Figures 14 and 17) indicate that removing or reducing illegal harvest to minimal levels would likely allow populations to recover. However, with the continued spread of sea otters in the region, populations are not expected to recover to levels observed during the 1970s when sea otters were absent (COSEWIC 2009).

3.7.2.3 Population Trends in Washington

No estimates of pinto abalone biomass, population viability, or extinction risk in Washington have been made and historical levels of abundance are not well understood (WDFW 2014). However, data are available from timed swim and index site surveys, as well as abalone recruitment studies, conducted in the San Juan Islands Archipelago. The best available data indicate that pinto abalone populations in Washington are declining despite the closure of fisheries, and local recruitment failure may be occurring. We summarize the best available information below.

San Juan Islands

Timed Swims

Timed scuba swim surveys designed to quantify abundance and measure shell length of pinto abalone in the San Juan Islands Archipelago were conducted from 1979–1981 by the Washington Department of Fish and Wildlife (WDFW, formerly the Washington Department of Fisheries), and have been variously described by Rogers-Bennett (2007), Rogers-Bennett *et al.* (2011), and WDFW (2014). Rogers-Bennett (2007) described timed swim surveys at eight sites in the northern San Juan Islands conducted in 1979 by WDFW, which averaged 30 min per swim (range of 20–40 min, total search time of 480 min for the eight sites) and resulted in finding 219 abalone that averaged 98.8 mm SL (range of 32–139 mm SL). Rogers-Bennett *et al.* (2011) described what appear to be the same timed swims at eight sites in 1979 by WDFW, which in contrast to Rogers-Bennett (2007), indicated that 224 abalone were located, ranging in size from 57–139 mm SL with an average size of 101 mm. The rate of abalone observation was estimated to be 28 abalone/hour, including the time necessary to obtain length measurements (Rogers-Bennett *et al.* 2011). WDFW (2014) described similar, or additional, 20 minute timed scuba swims conducted in 1979 by WDFW at 30 sites (Figure 26). About 1.1 abalone per min or 25.5 abalone per dive were encountered. Swim times were not adjusted for the time taken to measure abalone shells which, due to the large number of abalone measured, could result in significantly underestimating the abundance of abalone (WDFW 2014). Shell length of abalone measured during the 1979–1981 swim surveys reportedly had an arithmetic mean of 97.6 mm (n = 755) (WDFW 2014). It is likely that Rogers-Bennett (2007) and Rogers-Bennett *et al.* (2011) reported on only a subset of 8 of the total 30 timed scuba swims documented in WDFW (2014).

Rogers-Bennett (2007) and Rogers-Bennett *et al.* (2011) further reported on timed scuba swim surveys conducted in 2005 at 10 sites in the San Juan Islands Archipelago that were selected because they were known to have had abundant pinto abalone populations in the past. Substantially fewer pinto abalone were observed in 2005 than during similar timed swim surveys conducted in 1979 by the WDFW (Rogers-Bennett *et al.* 2011). In 2005, only 17 pinto abalone ranging in size from 75–142 mm (mean SL of 107 mm) were observed during 30–40 min timed swims at the 10 sites (694 total min for two divers). Fourteen of the 17 abalone were found at just two sites; Shark Reef and Long Island (Rogers-Bennett 2007). In contrast to about 25.5. abalone encountered per 20 minute dive during the 1979–1981 surveys, WDFW divers encountered about 1.1 abalone per 20 min dive in 2010-2011 (about a 96% reduction in the encounter rate) (WDFW 2014).

Density Surveys

In 1992, WDFW began conducting non-destructive index site surveys at 10 locations in the San Juan Islands Archipelago (Figure 27) to monitor densities of pinto abalone. These index survey sites were established in areas known to have high pinto abalone abundance and ranged in size from 135–375 m^2 in area (Table 14). The 10 sites have been periodically re-surveyed for abalone abundance, density, and shell length, most recently in 2013 (Tables 14; Figures 28, 29, and 30). From 1992–2006, the mean density at the 10 index sites declined from 0.18 to 0.04 abalone/m^2, with a significantly faster decline observed in the deep stratum sites (4.4–9.0 m depth) than in the shallow stratum sites (0.5–4.3 m depth) (Rothaus *et al.* 2008). WDFW re-surveyed these same 10 index stations in 2009 and 2013 and confirmed that mean density has continued to decline; between 1992 and 2013, abundance at the SJA index sites has declined 92%, to about 0.01 abalone/m^2 in 2013 (Figure 30). (Rothaus *et al.* 2008, WDFW 2014, WDFW unpublished data). In addition, the percentage of emergent juvenile pinto abalone (SL < 90 mm) seen during surveys has declined from 31.8% in 1979, to 17.4% in 1992, and most recently to 7.1% in 2013 (WDFW 2014).

Increase in mean shell length

The mean shell length of pinto abalone measured during timed swim surveys in 1979 was 97.6 mm (n = 755), whereas the mean shell length of pinto abalone measured at the 10 index sites in 2013 was 118.4 mm (n = 56) (WDFW 2014). This general trend from smaller, younger abalone to larger and presumably older individuals in more recent years is illustrated in Figure 31. Overall, the mean size of pinto abalone has been increasing by an average of 0.5 mm per year (WDFW 2014).

Abalone Recruitment Modules in San Juan Islands Archipelago

To estimate recent juvenile pinto abalone recruitment, Bouma *et al.* (2012) deployed 60 ARMs at 3 sites (20 ARMS per site) in the San Juan Islands Archipelago that had supported large abalone populations in the past. These pre-conditioned ARMS were deployed in August–September 2004 and were modeled after those successfully used by DeFreitas (2003) in Haida Gwaii (see above) and contained 24 concrete blocks within a commercial metal crab trap that provided about 3.8m^2 of surface area (Bouma *et al.* 2012). ARMs at the three sites (Big Cactus Island, Long Island,

and Parker Reef) were examined by scuba divers six separate times during 2005 and 2006. Eight abalone (one adult, four emergent, and three juveniles) were observed at the Long Island site, but no abalone were observed in the 40 ARMs deployed at Big Cactus Island and Parker Reef. Juvenile and emergent abalone density in the ARMs across all three sites in 2006 was 0.012/m^2 and 0.008/m^2, respectively. The scarcity of juveniles observed in the ARMs over the 2-year study suggests limited recruitment is occurring in pinto abalone populations (Bouma *et al.* 2012). Taken together with the observations in Rothaus *et al.* (2008), it is likely that local recruitment failure is occurring in the San Juan Islands Archipelago (Bouma *et al.* 2012).

Strait of Juan de Fuca

WDFW (2014) stated that pinto abalone have been observed in the Strait of Juan de Fuca, but they do not have any data regarding trends in abundance in this area. Two quantitative benthic surveys for invertebrates and macroalgae were done along the south shore between Kaidaka Point, near Sekiu, and Port Angeles, with data collections at twenty sites used for both surveys (Washington Cooperative Fish and Wildlife Research Unit, US Geological Survey, unpublished research contract report). Sites were selected with a stratified random protocol. Two pinto abalone (in physical contact with one another) were seen in the 1997 survey, none in 2001.

Outer Coast of Washington

To the best of our knowledge, pinto abalone have not been reported within Washington State waters south of Portage Head (located just south of Cape Flattery) on the outer Olympic Coast. WDFW (1992) provided maps of abalone occurrence in Washington State and stated that pinto abalone are only known to occur north of Portage Head and throughout the Strait of Juan de Fuca and San Juan Islands, with no data for the Washington coast south of Portage Head.

Although purely speculative, reasons for the apparent absence of pinto abalone south of Portage Head on Olympic Peninsula may include the extreme exposure of this habitat to the open Pacific Ocean. Sloan and Breen (1988) stated that the species does not appear to occur in shallow waters at extremely exposed sites. Similarly, Atkins and Lessard (2004) did not find abalone on the open north-west coast of Vancouver Island, but did find abalone in nearby Quatsino Sound and Brooks Bay, indicating that the shallow subtidal on extremely exposed coastlines may be too inhospitable for abalone to survive.

3.7.2.4 Population Trends in California

Northern California

Rogers-Bennett *et al.* (2002) estimated a baseline abundance of 153,000 *H. k. kamtschatkana* in northern California using estimates of fishery-independent densities and suitable rocky abalone habitat derived from data collected in 1971 and 1975. The 95% confidence intervals around this estimate were very large (upper 341,000 and lower 29,000) because of the patchy nature of the abundance data and limited sampling in 1971. Rogers-Bennett (2002) compared this baseline estimate to a modern estimate of 18,000 abalone (upper 95% confidence interval 22,000; lower 95% confidence interval 13,000), derived from data collected in 1999-2000 at five sites in Mendocino County, indicating an estimated ten-fold decline in abundance between the 1970s and 1999-2000.

CDFW conducted dive surveys at multiple sites from 2007-2013 in Mendocino County and 2007-2012 in Sonoma County (L. Rogers-Bennett, CDFW, unpublished data). Mean densities were higher in Mendocino County compared to Sonoma County and were higher at depths greater than approximately 10m (Figure 32). The mean densities recorded for both counties at depths greater than approximately 10m were above the critical density thresholds for successful reproduction reported for other species of abalone (Babcock and Keesing 1999, Neuman *et al.* 2010). In addition, smaller size classes (<50 mm SL) were better represented in Mendocino County compared to Sonoma County, suggesting that recent recruitment has likely occurred in Mendocino County (Figure 33). Abalone recruitment module (ARM) data, however, suggest that very little recruitment has occurred in northern California because only one juvenile has been observed over the entire deployment period from 2001-2014.

Southern California

Generally, there are few reports of pinto abalone from Pt. Conception to the Mexican border from about 1980-1999 (E. Parnell, pers. comm.; D. Kushner, pers. comm.). In 1974, CDFW (Ian Taniguchi, CDFW, unpublished data) conducted timed SCUBA searches in the Northern Channel Islands (focusing on all abalone species that could be observed) and found a total of 53 pinto abalone off the southwest corner of San Miguel Island (range: 1.5 - 36.75 abalone per hour), 10 pinto abalone off the southwest corner of Santa Rosa Island (range: 3.0 - 4.2 abalone per hour), and 18 pinto abalone off the southwest corner of Santa Cruz Island (range: 0.63 - 22.5 abalone per hour). The National Park Service has collected density and “recruitment” data for pinto abalone from 1982-present at annually monitored permanent kelp forest monitoring transects. Most of these transects are not placed in what would be considered good abalone habitat. While no animals were observed from 1982- 2000, in 2001 the species was observed (D. Kushner, pers. comm.) for the first time after two decades of surveys.

From 2006-2012, a number of entities observed pinto abalone during SCUBA surveys that did not necessarily focus on pinto abalone, but did occur in habitats suitable for them (Figure 34). Very low densities, ranging from 0.0002 (southwest San Miguel Island) to 0.0286 (Point Loma) pinto abalone/m^2, were reported (Ian Taniguchi, CDFW, unpublished data). Size frequency distribution data from sites throughout southern California (Figures 35 and 36; 2000-2012) suggest that recent recruitment events occurred in at least two locations: Santa Cruz Island and Point Loma (Ian Taniguchi, CDFW, unpublished data).

Recently, reports of pinto abalone in Southern California have been more common (E. Parnell, pers. comm.; B. Hagey, pers. comm.; D. Kushner, pers. comm.; D. Witting, pers. comm.). In most areas, reports range from a few individuals to up to several dozen. In San Diego, specifically Point Loma, La Jolla, and Mission Beach, there appears to be a relatively large population of pinto abalone of all sizes (depths 15 to 40m) that has been present since about 1997 (E. Parnell, pers. comm.). An average of two to three pinto abalone have been observed on 100x2m band transects and sometimes aggregations of 12 or more have been observed in one area (E. Parnell, pers. comm.). Aggregations of up to three animals are occasionally observed and pairs are frequently observed. In addition, these observations consist of abalone of all sizes up to over 137mm, with small (20-40 mm) freshly dead recruit shells observed regularly.

Surveys are being conducted in summer 2014 to characterize the demographics of pinto abalone populations in nearshore San Diego kelp beds (Point Loma and La Jolla) (A. Bird, CSUF, unpublished data). Preliminary data are summarized in the following paragraph.

Since June 2014, 38 SCUBA band transects (50 x 8m) have been surveyed for pinto abalone in Point Loma and La Jolla, CA. Forty-one pinto abalone (13-151 mm shell length) were observed between 10-26m depth (Figure 37). Pinto abalone densities range from 0-0.015 abalone/m^2 (Figure 38). The average nearest-neighbor distance is 6.7m ± 9.1m (n= 35 animals; Figure 39). Seventy percent of the pinto abalone observed were greater than a 2.5m radius from a conspecific within a transect area based upon methods used to estimate aggregation size and aggregation sizes greater than 2 animals were not observed. (Figure 40; Babcock and Keesing 1999, Button 2008).

Although densities recorded so far are below threshold values identified for other species (Babcock and Keesing 1999, Neuman *et al.* 2010), small animals are present within this population (Figure 37) and greater than 65% of the animals observed occur in pairs that are within 5m of one another (Figure 39). Although these data are preliminary, they highlight the fact that this species is extremely patchy and that densities recorded on a per m^2 basis may not be the best metric for evaluating population viability. Surveys are ongoing and will continue to measure density and size frequency distributions, habitat characteristics associated with higher pinto abalone densities, and aggregation-level characteristics (nearest-neighbor distance and aggregation size) for near shore San Diego kelp beds (A. Bird, pers. comm.).

3.7.2.5 Population Trends in Mexico

There is little information from the southernmost portion of this species range in Baja California, Mexico. Reports of pinto abalone are common, but often not confirmed. The most comprehensive survey conducted on abalone species for Baja California has no information on the distribution and abundance of pinto abalone (Guzman del Proo *et al.*1976). However, a recent collaborative study designed to target green and pink abalone reported density data on pinto and white abalone in five areas surveyed off the El Rosario Coast, Baja California, Mexico in 2012 (Boch *et al.* 2014). Due to similarities in shell morphology and possible misidentification by observers (some surveyors had not been trained to identify abalone in the field), pinto and white abalone were grouped and referred to as a two species complex (*H. k. assimilis/H. sorenseni*) in this study. The authors estimated that 75% of the observations in this group were *H. k. assimilis* (C. Boch, pers. comm.). A total of 178 *H. k. assimilis/sorenseni* were found on 24 transects each covering a 400 m^2 area between 11-25m depth (Figure 41; Boch *et al.* 2014). Taking into account that 75% of these were likely *H. k. assimilis*, the density estimate for *H. k. assimilis* was 0.0139/m^2. *H. k. assimilis/sorenseni* ranged from 40-240 mm SL, with the majority ranging in size from 40 to 180 mm (individuals >165mm SL were likely to be *H. sorenseni*). Recent recruitment was evident in at least one area where the population consisted of primarily 40-80 mm SL animals (Figure 40; Boch *et al.* 2014).

3.7.3 Summary

Overall, data on pinto abalone abundance and trends from both fisheries-dependent and fisheries-independent sources are limited and vary in availability and quality depending on the region and time period. The best available data indicate that pinto abalone abundance has declined in many areas throughout the species' range due to fisheries harvest, and has continued to decline despite the closure of fisheries (except for subsistence and personal use fisheries in Alaska and a commercial fishery in Mexico) throughout most of the species range. Preliminary data from surveys in 2011 and 2012 indicate signs of recovery in pinto abalone populations along the British Columbia coast, most likely due to a reduction in illegal harvest. In contrast, survey data and studies indicate that pinto abalone populations at the San Juan Islands in Washington are experiencing recruitment failure and continuing to decline, despite closure of the fisheries and no evidence of poaching. Throughout the remainder of the species range trends are less clear, due to the lack of regular, long-term monitoring surveys for pinto abalone. The limited data from occasional surveys and/or opportunistic sightings indicate that pinto abalone populations are small, patchily distributed, and/or fluctuate episodically in Alaska, California, and Mexico, with evidence of recent recruitment in a small number of locations in these three areas. However, we lack baseline abundance and trend data for the species prior to the advent of commercial fisheries and, in some areas, the local extirpation of sea otters. Without a clear baseline with which to compare the current abundance levels and trend information, it is difficult to interpret what these levels mean for the status and viability of the species.

3.8 Mortality and Competition

Shepherd and Breen (1992) provide an excellent review of mortality in abalone, and note that an understanding of mortality rates in the three phases of natural abalone populations (larvae, juveniles, and adults) is essential to appropriate population modeling and management. As with most marine species, the various categories of mortality rates often are poorly known in abalone.

3.8.1 Mortalities of abalone larvae

Mortality processes in larval abalone are particularly difficult to evaluate for wild populations. Shepherd and Breen's (1992) review of abalone mortality lists a number of factors that may influence mortality rates and provides a number of supporting references from the published literature. Among physical oceanographic factors, fluctuation beyond species-specific tolerance ranges in temperature and salinity have been identified as possible sources of mortality. As noted previously, larvae that are distributed to inappropriate habitats by ocean currents likely experience high mortality rates as a result of physiological stress, starvation or predation, although documentation of such processes is lacking to our knowledge. Many predators have the capacity for ingestion of abalone larvae in the marine water column, including planktivorous fishes and zooplankton, but rates of mortality associated with planktonic predation are also unknown. Given known fecundities for abalone and in consideration of the largest of estimated post-metamorphic abalone population sizes, it is likely that larval mortality rates in abalone are high even under optimal conditions.

3.8.2 Mortalities of newly metamorphosed abalone

As described above, available information indicates that crustose coralline algae are particularly important recruitment habitats for pinto abalone as well as for other abalone species. Shepherd and Breen (1992) indicate that little is known about predation on newly metamorphosed abalone in this habitat type. It is speculated that a broad range of small benthic invertebrates are capable of consuming new abalone recruits, including polychaetes, nematodes, polyclad flatworms, and anemones. Small, newly-recruited abalone may also be susceptible to mortalities associated with disturbances such as substratum movement or disruption, deposition of sediment, influx of low-salinity waters associated with heavy rainfall and river discharge, and local seawater temperature anomalies associated with local weather events or larger-scale oceanographic perturbations. To our knowledge there are no published data capable of supporting meaningful estimates of mortality rates in newly recruited juvenile abalone in response to any of the listed processes or events, or to any other form of predation or disturbance.

3.8.3 Mortalities of small cryptic abalone (<40-50 mm shell length)

As abalone grow, studying associated mortality processes become somewhat more tractable. Larger animals can be more easily located and monitored in the field as compared to smaller life history phases, allowing an understanding of certain types of mortality processes based on direct observation or tagging methods. In addition, the *post mortem* persistence of robust shells typical of larger animals often provides useful information on mortality sources and rates. Metamorphosed abalone that are still small enough to remain highly cryptic may require cracks or crevices of appropriate dimensions to provide refuge from foraging crabs (e.g, Shepherd 1973). Abalone in this size range (< 40-50 mm) face predatory pressure from a number of other consumer species as well. Ault (1985) and Shepherd and Breen (1992) list gastropods, octopuses, lobsters, sea stars, and fishes as predators capable of ingesting small abalone.

Despite the large number of identified predators on small cryptic abalone, we are not aware of any studies that estimate mortality rates of pinto abalone in association with the predator species that have been identified. Cryptic abalone < 40-50 mm in size may also suffer mortalities from the same range of physical disturbances listed above for minute post-metamorphic abalone, although estimates of rates of mortality from such sources are not available for pinto abalone. In addition, abalone in this size range are large enough to experience illegal harvest by people. Mortalities caused by human removals are reviewed in Section 3.4.5.1 of this Status Report.

3.8.4 Mortalities of emergent abalone (> 40-50mm shell length)

Mortality patterns for large, emergent abalone (> 40-50 mm in size) are reasonably well-known for some species. Identified categories of mortality include predation (e.g., by sea otters, sea stars, crab, lobster, and fishes), variation in food supply, physical disturbance, pollution, disease, and human removal (e.g., Shepherd and Breen 1992). Mortality from human removals, disease, and predation by sea otters are discussed in more detail in Sections 3.8.6, 3.8.7, and 3.8.8 of this Status Report.

3.8.5 Competitive interactions

Abalone and sea urchins often share habitats and food preferences. Tegner *et al.* (1992) noted that sea urchins can have negative effects on other herbivorous marine invertebrates in cases of limited food supply. Tegner and Levin (1982) evaluated possible competitive interactions of red abalone and red sea urchins (*Strongylocentrotus franciscanus* Agassiz, 1879), finding minimal evidence for strong competition for food resources. Tegner (1989) noted that purple sea urchins (*S. purpuratus*) may also be abundant in red abalone habitats in California, and may be capable of destructive overgrazing of kelp populations at a level that could be nutritionally detrimental to abalone, potentially contributing to increased mortality rates.

Pinto abalone co-occur with both of these species of urchins and there are references in the literature to competition for food among them (DFO 2007). However, we did not identify any empirical studies that examine the strength or nature of the competitive interactions that may exist between urchins and abalone.

3.8.6 Mortalities associated with human removals

Mortalities of pinto abalone associated with human removals fall into five major categories: (a) Subsistence harvest by indigenous peoples; (b) Commercial harvest; (c) Recreational harvest; (d) Purposeful illegal harvest; and (e) Accidental lethal injury.

We discuss fisheries harvest of pinto abalone for subsistence, recreational, and commercial purposes in more detail under Section 3.3.1 of this Status Report (Fishery-dependent information). Subsistence harvest occurred historically in California, British Columbia, and Alaska, and still occurs currently in Alaska. Little data is available regarding subsistence harvest levels. In Alaska, subsistence harvest of pinto abalone declined by 98% from 1972 – 1997 (Bowers *et al.* 2011). In 2012, the daily bag limit was reduced from 50 per person to 5 per person, with no annual limit. ADF&G believes that subsistence harvest remains low currently (ADF&G comments to NMFS, 17 January 2014). In British Columbia, First Nations harvest of pinto abalone was primarily conducted by shore-picking in the intertidal. The fishery was closed in 1990. Information is not available to reconstruct indigenous harvest levels in California.

Commercial-scale harvests for pinto abalone were conducted in Alaska, British Columbia, California, and Mexico, but not in Washington. The only commercial harvest of pinto abalone that continues today is in Mexico; all other commercial fisheries have been closed. In Alaska, commercial dive fisheries for pinto abalone peaked in the late 1970s with landings of over 370,000 lbs of abalone during the peak year. High landings were sustained for several years before catch per unit effort declined through the late 1980s and 1990s. After a total of approximately1.86 million pounds of pinto abalone (929 tons) were landed, the fishery was closed in 1995. In British Columbia, the commercial fishery also peaked in the late 1970s with landings of 480 and over 400 metric tons (an estimated 2.5 million pinto abalone per year); management measures were subsequently put in place to limit catch and the fishery was finally closed in 1990 due to concerns regarding population decline in pinto abalone. In California, pinto abalone were not considered a major component of the commercial abalone fishery. Nevertheless, landings data indicate a decline in harvest over time that likely was a result of declines in pinto abalone abundance and in 1997 commercial harvest of all abalone in California was prohibited. In Mexico, no data are available regarding commercial harvest of pinto abalone, but pinto abalone and white abalone were reported to be relatively abundant and harvested.

Recreational harvest of pinto abalone has occurred throughout their range, but harvest data are lacking. In Alaska, the recreational fishery for non-residents was closed in 2012 and remains closed; prior to closure, the daily bag limit was 5 abalone per person. A personal use fishery (for residents) still remains open, with a reduced daily bag limit of 5 abalone per person (compared to 50 per person; this change was implemented beginning in 2012) and no annual limit. No data are available on personal use harvest levels, but ADF&G believes they are low (ADF&G comments to NMFS, 17 January 2014). Recreational harvest data are also lacking throughout the rest of the coast, aside from a few estimates of harvest levels for British Columbia and Washington indicating that recreational harvest was substantial at its peak. Recreational fisheries were closed in British Columbia in 1990, in Washington in 1994, and in 1997 in California (south of San Francisco; size limits established in 1999 for the remaining recreational fishery north of San Francisco effectively excluded pinto abalone from the fishery). No information is available for recreational fisheries in Mexico.

Purposeful illegal harvest (typically termed “poaching”) has been a source of mortality for pinto abalone throughout their range since the establishment of harvesting regulations in Alaska, Canada, Washington, and California. In British Columbia, poaching has been identified as the main cause of declines in mature abalone densities, due to the species’ tendency to aggregate in shallow, accessible waters; their high market value; and the large, mostly uninhabited coastal areas within which pinto abalone occur that are difficult to patrol. Poachers appear to target larger abalone (mean size of poached abalone was 115.1 mm, ± 0.41 SE; J. Lessard, pers. comm. cited in COSEWIC 2009), which tend to be more fecund. Thus, removing individuals may result in the remaining animals being too far apart for successful spawning and also having less reproductive potential. Estimates of annual adult mortality rates for the period prior to 2007 were 0.32 for Haida Gwaii (Hankewich *et al.* 2008) and 0.33 for the Central Coast (Hankewich and Lessard 2008). Both exceeded the estimated natural mortality rate of 0.15-0.2 (Breen 1986) and the estimated annual mortality rate of 0.25 that is believed to be sustainable (Zhang *et al.* 2007). More recent surveys in 2011 and 2012 indicate a decline in annual mortality (estimated at 0.26 for Haida Gwaii and 0.25 for the Central Coast), primarily attributed to a reduction in poaching pressure (J. Lessard, pers. comm.; Section 1.4.2 of this Status Report).

There is no evidence indicating illegal harvest is currently occurring in recreational or commercial fisheries in Washington, although several cases of illegal harvest and laundering of pinto abalone product were investigated in the late 1980s (directly linked to the legal commercial dive fisheries for sea urchins and sea cucumbers). Periodic cases of illegal sport harvest were reported after the 1994 fishery closure. It is generally believed that current populations no longer exist at commercially-viable quantities, and the risk (effort) vs. reward deters poaching. WDFW enforcement covers the entire coast and includes at-sea monitoring of commercial and recreational fisheries and periodic commercial buyer and market emphasis patrols. Outreach and education efforts to diving communities are also conducted. However, Vadopalas and Watson (2013) identify poaching as a major threat to abalone in Washington. Although there is the potential for illegal take of pinto abalone in other areas, we are not aware of any enforcement cases or evidence for poaching.

Accidental injury is also a potential source of mortality for pinto abalone, particularly when fisheries harvest was occurring, For example, animals smaller than the minimum size limit may have been injured when removed from the substrate and died after being put back in place. We know that this was an issue in Washington, where WDFW eventually required abalone harvesters to carry a 4-inch caliper so that animals could be measured and determined to be of legal size before being removed from the substrate. We are not aware of any data to assess the effects of accidental lethal injury to pinto abalone either in the past or presently.

3.8.7 Mortalities associated with disease

No infectious diseases affecting wild pinto abalone have been reported in Alaska, Washington, or California. However, two abalone pathogens have been reported in British Columbia (B.C.) Canada (Bower 2010). Several catastrophic diseases have been reported in wild and cultured abalone worldwide, illustrating the importance of infectious disease to abalone populations (OIE 2012, Crosson *et al.* 2014, Bower 1987a,b,c, 1989, 2000, 2003). Several abalone diseases, some previously unknown, have emerged in recent years highlighting the need for health examinations prior to animal movement to reduce the risk of pathogen introduction with animal movements (OIE 2012).

Diseases affecting pinto abalone in BC include the labyrinthulid protist, *Labyrinthuloides haliotidis,* which caused high losses of young farmed abalone < 5mm in SL during the early 1980s (Bower 1987a,b,c, 2000). In 1991, the renal coccidian *Margolisiella* (= *Pseudoklossia*) *haliotis* (Friedman *et al.* 1995, Desser and Bower 1997) was introduced into barrel culture in Bamfield, B.C. with imports of red abalone from California. In 2005, one broodstock that had been collected in Bamfield and held in captivity for over a year had heavy renal (kidney) coccidian infections. The current distribution of this parasite in B.C. is not known. The coccidian appears non-pathogenic to adult pinto abalone (Friedman *et al.* 1993). However, juvenile red abalone raised in Chile experienced high losses when transferred between sites; mortality occurred predominantly in those with renal coccidian infections suggesting that these infections may play a bigger role in the health of juvenile abalone (M. Godoy, pers. comm.).

Four significant abalone diseases have emerged over the past several decades and include withering syndrome, ganglioneuritis (and the related amyotrophia), vibriosis, and shell deformities (sabellidosis). Withering syndrome (WS) is a rickettsial disease caused by "*Candidatus Xenohaliotis californiensis*" (WS-RLO; Friedman *et al.* 2000) and causes losses in abalone ranging from none to 100% mortality (see review by Friedman *et al.* 2014). Elevated temperature plays an important role in WS-RLO transmission and disease development (Crosson *et al.* 2014). Pinto abalone are highly susceptible to WS as evidenced by recent studies of Crosson and Friedman (unpublished data) during which 100% of the exposed pinto abalone died, while only 50% of exposed pink and 55% of exposed red abalone died. In addition, more rapid transmission of the WS-RLO and a lower thermal threshold for development of clinical WS was observed in pinto abalone relative to red and pink abalone. Abalone viral ganglioneuritis (AVG) appeared in several Victoria, Australia abalone farms in December 2005, killing 90% of the stock. Then, in May 2006, AVG appeared in wild *Haliotis rubra* and *H. laevigata* stocks adjacent to an infected abalone farm. By August 2006, AVG had spread westward (5 km) and eastward (12 km). This disease caused ~80% losses to wild stocks (Hooper *et al.* 2007) and has recently decreased in prevalence. A similar virus has caused high losses in farmed abalone in Taiwan (Chen *et al.* 2012). Vibriosis in the European abalone *H. tuberculata* emerged as a result of thermal and reproductive stress allowing the Gram-negative bacterium *Vibrio harveyi* to increase in virulence and pathogenicity for adult abalone (Nicolas *et al.* 2002, Travers *et al.* 2009). In laboratory experiments, abalone mortality increased from 0% to 80% when abalones were exposed to the bacterium during their spawning season coincident with a temperature change of 1°C (from 17°C to 18°C; Travers *et al.* 2009). In the early 1990s, California abalone farms became infested with a sabellid polychaete, *Terebrasabella heterouncinata* (Kuris & Culver 1999), that an abalone farmer unintentionally introduced along with abalone from South Africa. Although the worms appear benign in natural populations, they slowly disfigure and weaken the shell of farmed California and South African (*H. midae*) abalone. Prior to its introduction into California, this sabellid polychaete was not known (Fitzhugh and Rouse 1999).

3.8.7 Mortalities associated with foraging sea otters

Sea otters (*Enhydra lutris* [Linnaeus, 1758]) ranged historically throughout the North Pacific Rim from northern Japan to the Pacific coast of Baja California, Mexico (Kenyon 1969), encompassing the entire geographic range of pinto abalone. Sea otters were hunted to near-extinction during the maritime fur trade period from 1743 until the late 1960s (Kenyon 1969, Riedman and Estes 1990, VanBlaricom, in press). When otter harvest rates began declining early in the 20th century, sea otters began recovering range wide, a process leading to conflicts with near-shore, marine shellfish fisheries, particularly for abalones, sea urchins, clams, and crabs, that had developed while sea otter numbers were reduced in numbers and distribution (Estes and VanBlaricom 1985). Conflicts have been particularly acute in Prince William Sound and in the Alexander Archipelago of Alaska, off Vancouver Island in British Columbia, near Cape Flattery and Neah Bay on the coast of Washington, and at several locations along the mainland central coast of California. Within the geographic range of pinto abalone, contemporary sea otter populations are present in Southeast Alaska, in two discrete population segments off British Columbia, from Cape Flattery to Destruction Island off Washington, from Half Moon Bay to near Gaviota on the mainland California coast, and at San Nicolas Island (SNI) off southern California. Sea otters remain regionally extinct in the marine waters of Oregon and Baja California, Mexico.

Through the application of innovative behavioral attributes and the use of stones as hammers during foraging, sea otters are capable of imposing significant constraints on abalone abundances, size frequencies, and microhabitat distributions. Significant predation on abalone by sea otters has been documented quantitatively in California and British Columbia. Sea otters in California are known or suspected of consuming most abalone species occurring in the northeastern Pacific region, either presently or prior to the maritime fur trade period. Relationships of sea otters with pinto, white, and black abalone are uncertain because of lesser overlap in habitat characteristics, especially water depth. Sea otters are known to feed on pinto abalone, but the quantitative ecological strength of the interaction has not been directly investigated and remains poorly understood. Quantitative information on impacts at the population level has been obtained only for red (*Haliotis rufescens* Swainson, 1822) and black abalone (*H. cracherodii* Leach, 1814). Available data suggest that predation on red abalone by sea otters typically reduces red abalone density by ~90% (Ebert 1968, Lowry and Pearse 1973, Cooper *et al.* 1977, Hines and Pearse 1982, Ostfeld 1982, Wendell 1994, Fanshawe *et al.* 2003) and eliminates viable commercial and recreational harvests of red abalone (Wild and Ames 1974, Estes and VanBlaricom 1985). Effects of sea otter predation on black abalone remain equivocal at present (e.g., VanBlaricom 1993, Crosson *et al.* 2014). To our knowledge there are no published data documenting effects of predation by sea otters on pinto abalone at the population level in California. The sea otter population in California, currently numbering ~2,700 individuals, was listed as "threatened" in 1977 pursuant to the Endangered Species Act of 1973 as amended (42 FR 2965, 14 January 1977), and as "depleted" pursuant to the Marine Mammal Protection Act of 1972 as amended (16 U.S.C. 1361 *et seq*.). Effective conservation and continued growth of the sea otter population of California will encompass an increasing proportion of pinto abalone habitat on the coasts of California and northwestern Mexico, and will increase the risk of predation by sea otters on pinto abalone populations.

At present, sea otters range from Cape Flattery, Washington southward along the outer coast of Washington to the vicinity of Destruction Island, with an estimated population size of 1,200-1,300 individuals. Beginning in winter 2000, sea otters were observed east of Cape Flattery, in the western Strait of Juan de Fuca, during winter months, retreating westward to outer coastal waters south of Cape Flattery during the succeeding spring and summer seasons. The pattern repeated annually through winter 2005, with otters reportedly moving as far east as Pillar Point. Since spring 2005 only a few sea otters have been observed east of Cape Flattery in any season. Most pinto abalone observed in recent years occurred in the San Juan Archipelago. Pinto abalone are also known to occur along the south shore of the Strait of Juan de Fuca, but there are no data suggesting sustained large populations in the area. Pfister and Bradbury (1996) reported low mean densities (~0.001 m^{-2}) of red sea urchins in nearshore benthic habitats west of the mouth of Joe Creek, near Pillar Point along the south shore of the Strait. Mean urchin densities were much higher (~1.0 m^{-2}) east of Joe Creek. Given known effects of sea otter predation on red sea urchin populations in other regions (e.g., Lowry and Pearse 1973), the pattern suggests a significant impact of benthic foraging by sea otters on urchin populations during winter incursions to the Strait that began in 1995. In such a scenario it is quite likely that sea otters would also consume any pinto abalone encountered while foraging, with possible population-scale impacts. Pinto abalone are not known to occur on the outer coast of Washington south of Cape Flattery, in the areas currently occupied by sea otters, despite availability of apparently good-quality abalone habitat. However, to our knowledge, consumption of pinto abalone by sea otters has not been observed in the coastal marine waters of Washington. Available information suggests that excessive recreational harvests between 1959 and 1994, damaging rates of illegal harvests in the 1980s and 1990s, and depensatory effects of low population densities since 1994 are the primary challenges to sustained, healthy pinto abalone populations in Washington marine waters. Sea otters probably did not begin foraging in pinto abalone habitat until after abalone populations were depleted by other factors. However, predation by sea otters may be a significant impediment to recovery of pinto abalone if the otters return to historically occupied habitats in the Strait of Juan de Fuca and the western San Juan Archipelago. As sea otter populations grow, movement and exchange of animals between the Washington and British Columbia populations, with eventual merging of the populations, are expected (USFWS 2008).

Commercial harvests of pinto abalone in British Columbia began in the early twentieth century, with harvest rates peaking in 1978. Between 1977 and 2002 mean densities of pinto abalone in monitored reference sites declined by 89% along the BC mainland central coast, and by 85% off the Islands of Haida Gwaii (Chadés *et al.* 2012). Following closure of commercial fisheries in 1990 pinto abalone densities continued to decline (Lessard *et al.* 2007). Illegal harvest was the suspected primary factor driving observed reductions in abalone densities (Gardner *et al.* 2000, Jubinville 2000), but sea otter predation may have been a contributing factor to the decline on the mainland central coast (Nichol 2007). Sea otters have been absent from the waters of Haida Gwaii since being hunted to extinction during the maritime fur trade. Based on modeling of sea otter and pinto abalone population dynamics, illegal harvest rates, and a series of conservation objectives for abalone restoration, Chadés *et al.* (2012) concluded that achievement of abalone population recovery in the presence of illegal abalone harvests and sea otter predation is unlikely. Reduction of poaching rate by 50% from current levels was effective in initiating modeled abalone population restoration; more so with a hypothetical removal of sea otters. It was suggested that simultaneous accomplishment of recovery goals for pinto abalone and sea otters in British Columbia waters will be difficult, particularly if illegal harvest rates cannot be reduced.

Sea otters were reintroduced into British Columbia in 1969 and 1972 (Watson *et al.* 1997; Nichol *et al.* 2005) and pose a potential threat to pinto abalone populations, although the effects are not clear. In at least two index sites where sea otters are present, densities of pinto abalone are higher than in areas with no sea otters. In 2003, the mean total density of pinto abalone for the West Coast of Vancouver Island was 0.09 per m^2 for all sites, but 0.21 per m^2 at Quatsino Sound

(Atkins and Lessard 2004), an area that has been inhabited by sea otters since 1991 (Watson *et al.* 1997). In 2011, the density of mature abalone was greatest at one area along the Central Coast where sea otters are present, exceeding the long-term objective of one abalone per m^2 (J. Lessard, pers. comm.; see Section 1.4.2. of this Status Report). As in other areas along the coast, however, data are not available to determine the natural population levels of pinto abalone prior to the local extirpation of sea otters in British Columbia in the early 1920s. Thus, we lack historical levels with which to compare current density estimates. Based on genetic analyses using microsatellites, Withler *et al.* (2001) estimated the long-term historical effective population size of pinto abalone in British Columbia to be 420,000 abalone. This is the only estimate we are aware of for this region and does not reflect the fluctuations in population size that are believed to have occurred, even in the absence of commercial fishing (COSEWIC 2009).

Sea otters were reintroduced to formerly occupied habitats of Southeast Alaska between 1965 and 1969, with 412 animals moved from Prince William Sound and Amchitka Island. Growth of the restored sea otter populations was quite low until the middle 1980s, but has been quite high in recent years. The estimated number of sea otters now present in Southeast Alaska is estimated at ~25,712, with highest concentrations in the vicinity of Glacier Bay, near the northern limit of the geographic range of pinto abalone (USFWS 2014). Over half of the estimated population (12,873) occurs in southern Southeast Alaska (USFWS 2014) in an area that overlaps in large part with known pinto abalone habitat. The sea otter population in northern and southern Southeast Alaska is growing between 12-14% annually (USFWS 2014). The dramatic increase in sea otter numbers and range has caused significant concern about benthic invertebrate fisheries in Southeast Alaska. Observations by divers for the Alaska Department of Fish and Game on the outer coast of Southeast Alaska, suggest that sea otters preferentially select red sea urchins and pinto abalone as prey when foraging in rocky subtidal habitats (Rumble and Hebert 2011). Otter predation on abalone is not considered the major factor in the decline of abalone in the 1980s because sea otter expansion occurred after high harvests by commercial fishing (Woodby *et al.* 2000). The increase in the otter population and predation on abalone will likely affect the recovery of abalone and the potential for a future commercial fishery (Rumble and Hebert 2011). Current research efforts include joint projects by the University of Alaska and the US Fish and Wildlife Service to examine the effects of sea otter recolonization on Southeast Alaska (https://www.sfos.uaf.edu/people/profile.php?uid=2080, http://seagrant.uaf.edu/research/projects/10/otter/, and http://project.nprb.org/view.jsp?id=6af6bc0e-6f46-4795-95aa-aaff483505b9).

The number of reported Northern sea otters harvested legally for subsistence purposes in Southeast Alaska averaged 385 annually from 1989-2012 (USFWS, unpublished data). However, in 2013, the reported harvest increased significantly to 1,479 sea otters (USFWS, unpublished data), but is still below the estimated Potential Biological Removal of 2,179 (USFWS 2014). A large number of sea otters harvested in 2013 were taken from areas within the range of the pinto abalone; primarily in Sitka Sound and around Kuiu and Prince of Wales Islands (USFWS, unpublished data). In a recent study of Northern sea otter diet in Southeast Alaska, in observations of 6,117 foraging dives (699 foraging bouts), primarily along the coasts of Prince of Wales and Kuiu Islands, only 3 pinto abalone were observed, suggesting a low presence of abalone in this region (Hoyt *et al.*, unpublished data).

Concern about interactions of sea otters and shellfisheries often involves significant economic issues, in many cases leading to polarizing controversy among scientists, managers, and stakeholders (VanBlaricom *et al.* 2013, Carswell *et al.*, in press). In some cases the intensity of concern about effects of predation by sea otters on shellfish, and the associated hyperbole, leads to failure of management authorities to consider and manage other natural and anthropogenic sources of shellfish mortality that may be of equal or higher importance to shellfish conservation. Abalone fisheries have been historically characterized by initially high harvests, almost invariably unsustainable and followed, over varying time scales, by collapse. Failures of abalone fisheries have been ascribed to poor fishery management practices, illegal harvests, habitat degradation, changes in regulatory frameworks, diseases, and consumption by natural predators including sea otters (Estes and VanBlaricom, 1985, Neuman *et al.* 2010). However, in no case has local extinction of any abalone population or species in the northeastern Pacific been documented as a result of predation by sea otters. Sea otters have been present in significant numbers in the coastal North Pacific Rim since the Pleistocene, and in northern hemisphere oceans of the earth for approximately seven million years. It seems certain that undisturbed populations of sea otters and abalones can sustainably co-exist as a consequence of co-evolved interactions.

3.8.9 Negative Impacts of Climate Change

Worldwide ocean chemistry is changing due to increasing atmospheric carbon dioxide concentrations (Caldeira and Wickett 2003, Feely *et al.* 2004, Orr *et al.* 2005, Doney *et al.* 2009). About a third of all anthropogenically released carbon dioxide has been absorbed by the oceans since the Industrial Revolution, though ocean carbon dioxide absorption has slowed over time and oceans currently absorb only about a quarter of annual carbon dioxide emissions (Sabine *et al.* 2004, Canadell *et al.* 2007, Le Quéré *et al.* 2010). When carbon dioxide dissolves in seawater, it forms carbonic acid, which lowers seawater pH. Due to the accumulation of carbon dioxide in marine waters over the past ~250 years, the concentration of H^+ ions has increased ~30% and the average pH of global oceans has dropped from ~8.2 to ~8.1, a phenomenon known as ocean acidification (Caldeira and Wickett 2003). The accumulation of carbon dioxide in seawater also decreases the concentration of carbonate ions, which affects how readily calcium carbonate structures accrete or dissolve. Increases in carbon dioxide can reduce the saturation state for calcium carbonate structures to the point at which dissolution is chemically favored (Feely *et al.* 2004), which has implications for the large number of marine species that form calcium carbonate shells, tests, and skeletons (Kroeker *et al.* 2010). Aragonite is a form of calcium carbonate used by many marine organisms that is relatively sensitive to changes in carbon chemistry conditions.

North Pacific waters, which include the California Current Ecosystem, have relatively low seawater pH values and shallow aragonite saturation horizons due to a variety of natural oceanographic processes (Feely *et al.* 2004, Feely *et al.* 2008, Feely *et al.* 2009, Hauri *et al.* 2009). North Pacific waters are at the end of the ocean’s global conveyer belt, meaning that the waters are “old” and have an accumulation of carbon dioxide from respiration processes. Sub-surface waters (150-300 m deep) which are naturally high in carbon dioxide and nutrients and also carry anthropogenic carbon dioxide absorbed from prior contact with the atmosphere commonly upwell along the US West Coast in the summer months (Feely *et al.* 2008). Upwelling events, while ephemeral, amplify the acidification experienced in this region. Near coast and estuarine waters in the California Current Ecosystem also experience acidification events induced by biological processes: high nutrient loads from rivers and run-off from the land can cause phytoplankton blooms that then die and are decomposed by respiring bacteria (but see Borges and Gypens 2010, Cai *et al.* 2011, Sunda and Cai 2012). Respiration of organic carbon is estimated to drive over half of the acidification that occurs in the deep waters of Puget Sound's Hood Canal during summer months (Feely *et al.* 2010). This and a variety of other physical and biological drivers (e.g., day-night cycle of photosynthesis and respiration, tidal cycle, freshwater contributions, pollution) contribute to the wide variation in carbon chemistry conditions observed in nearshore waters (Doney *et al.* 2007, Hofmann *et al.* 2011, Barton *et al.* 2012).

Similar to global estimates, ocean acidification has decreased pH in the California Current Ecosystem by ~ 0.1 unit (to ~8.04) and aragonite saturation state by about 0.4 (to ~2.3) (Hauri *et al.* 2009, Gruber *et al.* 2012). This change is ten times faster than any change in ocean carbon chemistry over the past 50 million years (Pelejero *et al.* 2010). Ocean carbon chemistry in the region is also influenced by changes in ocean circulation due to climate change, such as those induced by the increase in upwelling favorable winds (Bakun 1990, Feely *et al.* 2012). Over recent decades, offshore upwelling in the southern California Current Ecosystem has intensified (Rykaczewski and Checkley 2008). Water upwelled to the surface in some parts of the California Current Ecosystem is now undersaturated with respect to aragonite due to ocean acidification (Feely *et al.* 2008). If carbon dioxide emissions continue as expected, globally, average surface ocean pH will decrease by ~0.3-0.4, to its lowest value in over 40 million years, and carbonate ion concentration will decrease by about 50% (Caldeira and Wickett 2003, Orr *et al.* 2005, Solomon *et al.* 2007, Pelejero *et al.* 2010). This change would occur ~100 times faster than the changes in ocean pH during Earth's recent glacial-interglacial transitions (Pelejero *et al.* 2010). By 2050, models project that over half of the nearshore water mass in the central part of the California Current Ecosystem will be undersaturated with respect to aragonite (Gruber *et al.* 2012). The California Current Ecosystem is one of Earth's three hot spots for the progression of ocean acidification (Gruber *et al.* 2012). If predictions are realized, there could be significant impacts to coastal species within the California Current, including pinto abalone. To our knowledge, no studies have characterized the progression of ocean acidification in British Columbia or Southeast Alaska or made projections about future conditions along these coastlines. However, recent work by Reisdorph and Mathis (2014) highlighted how the effects of climate change on glaciers and precipitation patterns will likely enhance ocean acidification in the regions by decreasing salinity, which decreases aragonite saturation state, during glacial and freshwater discharge events.

Laboratory and field research have found that many organisms, especially calcifiers, respond negatively to ocean acidification (Hall-Spencer *et al.* 2008, Kroeker *et al.* 2010). These changes include decreased growth and survival and altered gene and protein expression and physiology, including acid-base balance and energy metabolism (Kroeker *et al.* 2010, Parker *et al.* 2013). However, there is strong variation in response to acidification between species and even within some species (Kroeker *et al.* 2010, Parker *et al.* 2011, Kelly *et al.* 2013). Some primary producers (e.g., seagrasses, macroalgae, and phytoplankton with low-efficiency CO2 concentrating mechanisms) will likely benefit from ocean acidification (Palacios and Zimmerman 2007, Swanson and Fox 2007, Reinfelder 2011). The fast rate of change in ocean carbon chemistry raises the potential that some marine species harmed by ocean acidification may not be able to adapt, evolve, or adjust quickly enough to persist. Geologically induced ocean acidification events in Earth's history are contemporaneous with extinction events in some taxa, suggesting that ocean acidification may overwhelm evolutionary processes and reorganize ecosystems (Hautmann *et al.* 2008, Kump *et al.* 2009, Pelejero *et al.* 2010). Marine communities near natural CO_2 vents are significantly different than neighboring communities that are not exposed to elevated CO_2 levels (Hall-Spencer *et al.* 2008, Fabricius *et al.* 2011, Kroeker *et al.* 2011). Furthermore, ecosystem modeling suggests that trophic interactions can cause the direct impacts of ocean acidification on sensitive species to ripple through food webs, positively or negatively affecting species to which they are trophically linked (Busch *et al.* 2013). While the literature on the biological and ecological impacts of ocean acidification is growing rapidly, how the vast majority of economically and ecologically important species in the California Current Ecosystem will respond to ocean acidification and how acidification will affect species interactions is largely unknown. However, we do know that production of Pacific oyster (*Crassostrea gigas*) larvae in Pacific Northwest shellfish hatcheries has been negatively affected by changes in ocean carbon chemistry that have already occurred (Barton *et al.* 2012).

Effects of ocean acidification on early life stages of pinto abalone are beginning to be understood. Laboratory studies on pinto abalone indicate that reduced larval survival and shell abnormalities or decreased shell size occur at 800 and 1800 ppm CO_2, compared to 400 ppm CO_2 (Crim *et al.* 2011). At present, atmospheric CO_2 levels exceed 380 parts per million and are expected to climb throughout the century to approximately 800 ppm if emissions are not kept in check (ECOS online http://www.ecosmagazine.com/?paper=EC11142, 2011). C. Friedman, University of Washington, (unpublished data) has also found reduced pinto abalone larval survival at elevated pCO_2 and is currently studying the synergistic effects of increased pCO_2, varying temperature, and exposure to *Vibrio tubiashii* on early life stages of pinto abalone.

Other climate-change related effects that may impact pinto abalone include increased water temperatures and decreased salinity (due to freshwater intrusions). Bouma's (2007) studies with cultured pinto abalone indicated that laboratory rearing temperatures of 11°, 16°, and 21°C did not affect post-larval survival. Larvae tolerated temperatures of 12-21°C, with mortality at 24°C. Captive adult pinto abalone in Alaska showed no behavioral abnormalities at 2-24°C, but high mortality at 0.5°C and 26.5°C. Low salinity intrusions from freshwater inputs to Puget Sound and the San Juan Archipelago may also have negative effects on pinto abalone recruitment. In laboratory experiments, low salinity water reduced larval and post-larval survival of pinto abalone (Bouma 2007).

Overall, some information is available regarding the potential effects of ocean acidification, elevated water temperatures, and low salinity intrusions on pinto abalone. However, our understanding of these effects includes a high degree of uncertainty, due to limited studies involving pinto abalone and the uncertainty and spatial variability in predictions regarding climate change impacts into the future.

4.0 Existing Regulatory and Conservation Mechanisms

4.1 Federal

4.1.1 National Marine Fisheries Service

Pinto abalone was added to the NMFS' Species of Concern List on 15 April 2004 (69 FR 19975). Species of Concern are those species about which NMFS has some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the ESA. Following the receipt of two petitions to list pinto abalone as either an endangered or threatened species under the ESA and to designate critical habitat for the species NMFS formally announced initiation of a pinto abalone status review and on 18 November 2013 the species became a Candidate Species (78 FR 69033). Candidate Species are those species for which NMFS has initiated an ESA status review either due to a petition or as a NMFS-initiated review. Designation as a "Candidate Species" or a "Species of Concern" carries no procedural or substantive protections under the ESA. Thus, no ESA-mandated federal measures that provide protection for pinto abalone are currently in place.

4.1.2 National Marine Sanctuaries

Four coastal national marine sanctuaries contain subtidal habitat suitable for pinto abalone: Channel Islands National Marine Sanctuary (CINMS), Monterey Bay National Marine Sanctuary (MBNMS), Gulf of the Farallones National Marine Sanctuary (GFNMS) and Olympic Coast National Marine Sanctuary (OCNMS) (Figure 45). These sanctuary sites, administered by the

National Oceanic and Atmospheric Administration, are protected by federal regulations pursuant to the National Marine Sanctuaries Act of 1972 as amended (16 U.S.C. 1431 *et seq*.). The regulations, which are similar at all four sites, provide protection against some of the threats to pinto abalone.

Direct disturbance to or development of the subtidal habitat of pinto abalone is regulated at all four national marine sanctuaries by way of a prohibition on the alteration of, construction upon, drilling into, or dredging of the seabed, with exceptions for anchoring, installing navigation aids, special dredge disposal sites (MBNMS only), harbor-related maintenance, and with bottom tending fishing gear in areas not otherwise restricted.

Water quality impacts to pinto abalone habitat are regulated by strict discharge regulations at all four national marine sanctuaries. Essentially, regulations provide that no discharge or deposit of pollutants is allowed within these sanctuaries, except for effluents required for normal boating operations (e.g., vessel cooling waters, effluents from marine sanitation devices, fish wastes and bait).

Although these national marine sanctuaries do not regulate the take of pinto abalone, networks of marine reserves and marine conservation areas have been established by the CDFW within the CINMS and along portions of the MBNMS. Within these areas, especially within CINMS where the protected areas have been in place since 2003 and are within the Channel Islands National Park, multi-agency patrols provide elevated levels of enforcement presence that increase protection against poaching of pinto abalone.

Full texts of the current CINMS, MBNMS, GFNMS, and OCNMS regulations discussed above can be found at 15 Code of Federal Regulations (CFR), Parts 922.71, 922.132, and 922.91, respectively.

4.2 State/Local

4.2.1 Alaska

As described in the "Fishery Dependent Information" section 3.3.1 above, ADF&G manages pinto abalone in Southeast Alaska for ongoing personal use and subsistence harvest. Regulations were recently revised that significantly reduced the possession and annual limits for personal use (residents only) and subsistence harvest, and closed non-resident sport fishing for pinto abalone. ADF&G has the authority to further reduce harvest limits if the agency is concerned with pinto abalone abundance and trends. ADF&G also has the authority to re-open a commercial harvest of pinto abalone but has stated that does not appear feasible given the relatively new pressure exerted on the population by re-introduced sea otters (Rumble and Hebert 2011).

4.2.2 Washington

As described in section 3.3.1 ("Fishery-dependent information"), WDFW manages the sport fishery for pinto abalone, which was closed in 1994 and remains closed. WDFW requires a WDFW Scientific Collection Permit or Shellfish transfer permit for take any take of pinto abalone. A limited number of pinto abalone have been taken under such permits for hatchery broodstock purposes (2010: n=23; 2011: n=23; 2013: n=3) and were later returned to aggregation sites in the wild. In recent years, WDFW has been working with partners to monitor pinto abalone populations as well as support the restoration and recovery of pinto abalone through activities such as development of an experimental hatchery and hatchery/nursery techniques, and experimental outplanting.

4.2.3 Oregon

The ODFW manages a sport fishery for abalone and limits the permittee to one per day, five per year, and a minimum shell length of eight inches (ODFW http://www.dfw.state.or.us/mrp/shellfish/regulations.asp). The fishery target is red abalone and although pinto abalone do occur in Oregon, albeit rarely (see Section 3.1), the minimum shell length of eight inches provides protection for pinto abalone. Although the species name is not explicitly stated in the general rules for the fishery, ODFW requires the following measures which provide additional protection for pinto abalone:

- Special permit required from ODFW.
- Abalone may be taken by abalone iron only.
- Every person while taking abalone shall carry a caliper measuring gauge with fixed opposing arms capable of accurately measuring eight inches by placing the gauge over the shell.
- For permit renewals, previous year's catch record must be submitted to ODFW before next year's permit will be issued.

- Abalone must be brought ashore whole and in such a condition that the size can be determined.
- Abalone must not be removed from their shell in the field, except when being prepared for immediate consumption.

4.2.4 California

California's regulatory jurisdiction for abalone resource management lies with the California Fish and Game Commission. This regulatory power was granted to the Commission by the state legislature. The depleted condition of abalone resources prompted the California Fish and Game Commission to eventually close all abalone fisheries south of San Francisco by 1997, beginning with the black abalone fishery in 1993. The southern abalone fisheries were closed indefinitely with the passage of the Thompson bill (AB 663) in 1997. This bill created a moratorium on taking, possessing, or landing abalone for commercial or recreational purposes in ocean waters south of San Francisco, including all offshore islands.

The Thompson bill also mandated the creation of an Abalone Recovery and Management Plan (ARMP) which was finalized in December 2005. The CDFW Abalone Recovery and Management Plan (ARMP) provides a cohesive framework for the recovery of depleted abalone populations in central and southern California, and for the management of the northern California fishery and future fisheries. All of California's abalone species are included in this plan: red, green, pink, white, pinto (*Haliotis kamtschatkana* Jonas, 1845, including *H.k. assimilis*), black, and flat abalone. The bill further required the Fish and Game Commission to undertake abalone management in a manner consistent with the ARMP. Passage of the

Thompson bill and the resultant change in the California State Fish and Game Code (FGC §5522[a]) specifically calls for the following items in an ARMP:

- Scientific Background: An explanation of the current scientific knowledge of the biology, habitat requirements, and threats to abalone
- Interim and Long-term Goals: A summary of recovery goals, including alternative conservation and management goals and activities. The Department will report why it prefers the recommended activities
- Alternatives for Allocation: Alternatives for allocating harvest between recreational and commercial abalone harvesters
- Costs: An estimate of time and costs required for meeting interim and long-term recovery goals for each species
- Time Frame: An estimate of the time necessary to meet interim recovery goals, and a description of triggers for review and amendment of strategies
- Evaluation Criteria: A description of objective, measurable criteria by which to determine whether the goals and objectives of the recovery strategy are being met.

Recovery of at-risk abalone species and management of abalone fisheries are separate but continuous and complementary processes in the ARMP. The recovery portion of the plan addresses all abalone species that are subject to the fishing moratorium. The management portion of the plan applies to populations considered sustainable and fishable, such as the current northern California red abalone fishery. Abalone in California vary in status from populations bordering on extinction (white abalone) to a sustainable population with a harvestable margin of animals that is still being fished (northern California red abalone). The ultimate goal of recovery is to move species from a perilous condition to a sustainable one with a harvestable margin of abalone available for fishing. The ultimate goal of management is to maintain sustainable fisheries under a long-term management plan that can be adapted quickly to respond to environmental or population changes.

4.3 International

4.3.1 Canada

The pinto abalone (aka northern abalone) is currently listed as endangered (i.e., facing imminent extirpation or extinction) in British Columbia under Canada’s Species at Risk Act (SARA). This listing was based on continued low population numbers and declines despite the closure of abalone fisheries throughout British Columbia since 1990. The species was first assessed in 1999 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and designated as threatened by COSEWIC in 2000 and under SARA in 2003 (COSEWIC 2009). The species was re-examined in 2009 and up-listed to endangered by COSEWIC in 2009 and under SARA in 2011. SARA prohibits killing, harming, harassing, possessing, and buying or selling an individual or its parts (including the shell); these prohibitions apply to both farm-raised and wild pinto abalone (COSEWIC 2009). Because of its endangered status, pinto abalone are also included on British Columbia’s Red-list, with a global status of G3G4 and a provincial status of S2 (BC Conservation Data Centre 2014). A global status of G3G4 indicates uncertainty regarding the species’ status as vulnerable (G3: at moderate risk of extinction due to a restricted range, relatively few populations, recent and widespread declines, or other factors) or apparently secure (G4: uncommon but not rare; some cause for long-term concern due to declines or other factors). A provincial status of S2 means that the species is imperiled in the nation or state/province because of rarity due to very restricted range, very few populations, steep declines, or other factors making it very vulnerable to extirpation from the nation or state/province.

As a result of the species' listing under SARA, DFO (2007) developed and finalized a Recovery Strategy for pinto abalone in Canada in September 2007. This Recovery Strategy sets goals and objectives for halting and reversing the decline of the species and identifies the main areas of activities to be undertaken. DFO (2012) has also finalized the Action Plan, which defines and guides implementation of the recovery strategy. The Action Plan identifies recovery activities to address threats, monitor status, and support rebuilding of pinto abalone populations, and also identifies critical habitat for the species within four areas in British Columbia. Few activities were identified as likely to destroy critical habitat, and the overall estimated impact of works or developments in critical habitat areas was rated as low. An assessment protocol has been established that specifies criteria to avoid harmful alteration, disruption, or destruction of critical habitat (Lessard *et al.* 2007). This protocol applies to works or developments proposed to occur in, on, or under water within pinto abalone critical habitat.

More specifically, the pinto abalone recovery strategy (DFO 2007) set the following population and distribution objectives, as described in the Action Plan (DFO 2012, p. 11):

- To observe that mean densities of large adult (≥100 mm SL) pinto 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 SL) pinto abalone does not decrease below 40%.

- 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 pinto abalone per m^2 and 0.02 pinto 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 pinto abalone per m^2).
- To observe at the index sites (in areas without Sea Otters) that the annual estimated mortality rate for mature (≥70 mm SL) pinto abalone is reduced to < 0.20 and the mean densities of mature (≥70 mm SL) pinto abalone are increased to ≥0.32 per m^2.
- To observe at the index sites (in areas without Sea Otters) that the proportion of quadrats (m^2) with pinto abalone is increased to > 40%.

Both short term (10 year) and long term (30 year) recovery targets were further described by J. Lessard (pers. comm.) as follows:

The measurable short-term objectives over the next 10 years are to: 1) reduce annual estimated mortality rates to < 0.20; 2) ensure that mean densities of mature (≥70 mm SL) abalone increase to ≥ $0.32/m^2$ at surveyed index sites, which is twice the densities observed in 2001 and 2002 on the Central Coast and Haida Gwaii, respectively; and 3) increase the percent of surveyed quadrats in index survey sites that have abalone present to > 40%. The measurable long-term objectives for the next 30 years are to: 1) reduce and maintain annual estimated mortality rate to ≤0.15; 2) ensure that mean densities of mature

(≥70 mm SL) abalone increase to $\geq 0.5/m^2$ at surveyed index sites; and 3) increase the percent of surveyed quadrats in index survey sites with > 1 mature abalone to > 20%.

Prior to development of the final Recovery Strategy and Action Plan, several actions have been undertaken in British Columbia to protect and recover pinto abalone. Index site surveys continue to be conducted every 4-5 years, providing valuable time series and size frequency data to monitor population status. Fisheries harvest has been prohibited since 1990, but poaching remains a major threat and source of mortality for pinto abalone in British Columbia (Lessard *et al.* 2007). To address this threat, protocols have been established to track abalone sold on the market, in order to deter the sale of wild abalone as cultured abalone (COSEWIC 2009). Enforcement patrols, prosecution of poaching cases, and stewardship programs, such as the CoastWatch program, also aim to reduce illegal harvest (DFO 2012). Observations in recent years indicate a decrease in mortality associated with illegal harvest, likely due to these enforcement and stewardship efforts (J. Lessard, pers. comm.; see Section 1.4.2 of this report).

Rebuilding studies and efforts include translocations, as well as outplanting projects. Most of these studies are ongoing, with results pending further monitoring and analysis. Adult translocations have been conducted at Haida Gwaii, the Central Coast, Barkley Sound, and the Broken Group Islands, with the goal to increase local densities and reproductive potential (COSEWIC 2009). Preliminary results at the Broken Group Islands indicate success in increasing juvenile densities at the experimental sites (J. Lessard, pers. comm.; Lessard *et al.* 2007). Outplanting studies have been conducted at various locations between 2000 and 2010, through partnerships between Fisheries and Oceans Canada with First Nations and other coastal communities (DFO 2012). For example, from 2003 to 2006, the Bamfield Huu-ay-aht Community Abalone Project (created in 2001 to restore pinto abalone populations) outplanted approximately 150,000 juveniles and 4.5 million larvae at three sites in Barkley Sound. Based on surveys conducted in 2008 and 2009, outplanted abalone were found to experience high mortality and/or emigration rates; however, genetic analyses of observed abalone indicate that up to 26% were outplanted individuals (Read *et al.* 2012). Continued monitoring of outplanting sites is needed to assess their success at enhancing local populations.

4.3.2 Mexico

Limited information is available regarding existing regulations for pinto abalone in Mexico. Mexico has an active commercial abalone fishery that focuses on pink and green abalone along the central coast of Baja California and red abalone along the northern coast of Baja California (Searcy-Bernal *et al.* 2010). Only fishery cooperatives are allowed to harvest abalone; sport and private harvest is not allowed (Searcy-Bernal *et al.* 2010). It is not known whether and to what extent pinto abalone are harvested. Data are needed regarding harvest levels and regulations.

4.3.3 IUCN

The International Union for Conservation of Nature’s (IUCN) Red List is an assessment of the extinction risk of species worldwide. Listing of a species on the IUCN Red List does not provide any regulatory protections, but serves as another evaluation of the species’ status. When data are sufficient, the IUCN categorizes species as either Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable, Near Threatened, or of Least Concern, based on consideration of the following five quantitative criteria; meeting any one criterion is justification for a threat level listing (IUCN 2001, 2006):

- Declining population (past, present and/or projected);
- Geographic range size and fragmentation, decline, or fluctuations;
- Small population size and fragmentation, decline, or fluctuations;
- Very small population or very restricted distribution;
- Quantitative analysis of extinction risk (e.g., Population Viability Analysis).

In 2006, the IUCN assessed the global status of pinto abalone as “endangered,” based on an observed reduction in population size of more than 50% over the last three generations (i.e., approximately 30 years, based on an estimated generation time of 10 years; McDougall *et al.* 2006). McDougall *et al.* (2006) based their assessment primarily on fisheries harvest data for Alaska and index site survey data for British Columbia from the mid-1970s to early 2000s, assuming that Alaska and British Columbia represent the main portion of the species distribution. Although available data indicate that populations in British Columbia and Alaska have declined by more than 80% over this time period (meeting the criteria for “critically endangered”), the IUCN listed the species as “endangered” based on the reasoning that the local extirpation of sea otters in these areas had led to abnormally large abalone populations prior to abalone fisheries harvest. McDougall *et al.* (2006) identified illegal harvest as a major threat to species recovery, not only because of reduced numbers of individuals, but also the potential for recruitment failure associated with reduced local densities. Other identified threats include sea otter predation, habitat and ecological shifts, and disease.

5.0 Approaches to Evaluating Risk of Extinction

5.1 The "Extinction Risk" Question

The ESA defines the term "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." The term "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." The final determination of whether a species is threatened or endangered is made by NMFS and is based on the best scientific information available regarding its current status, after taking into consideration conservation measures that are proposed or are in place.

During the Status Report process, the SRT was asked to review the best available information on pinto abalone and to evaluate the overall risk of extinction facing the species now and in the foreseeable future. The ability to measure or document risk factors for pinto abalone is limited and the available information is often not quantitative, or less than ideal. Therefore, in assessing risk, we included both qualitative and quantitative information and modeled the assessment on the approaches used in previous NMFS status reviews to organize and summarize the professional judgment of the SRT members. Scientific conclusions about the risk of extinction faced by the species were drawn under the assumption that present conditions will continue into the future (recognizing that existing trends in factors affecting populations and natural demographic and environmental variability are inherent features of "present conditions").

5.2 Factors for Decline

According to Section 4 of the ESA, the Secretary (of Commerce or the Interior) determines whether a species is threatened or endangered as a result of any (or a combination) of the following factors: destruction or modification of habitat, overutilization, disease or predation, inadequacy of existing regulatory mechanisms, or other natural or man-made factors. Collectively, these are often referred to as “factors for decline.”

In Section 5.4.2 of this Status Report, we examine these five factors for their historic, current, and/or potential impact on pinto abalone. Current and potential threats, along with current species distribution and abundance, help determine the species’ present vulnerability to extinction. We include information regarding historic threats to assist in our interpretation of population trends. The relationship between historic threats and population trends also provides insights that may help project future population changes in response to current and potential threats.

5.3 Risk Assessment Methods and Results

5.3.1 Threats Assessment Methods

The SRT examined the potential role that different stressors have played in the status of wild populations of pinto abalone in the United States, Canada and Mexico (Figure 46). For each of the five ESA factors for decline, the SRT identified different stressors and specific sources for those stressors (terms defined below). For example, under the “Overutilization” factor for decline, the SRT identified low density and reduced genetic diversity as two stressors that both result from fisheries harvest (the source). For each stressor/source combination, each SRT member assigned a qualitative rating for the following criteria: the scope and severity of the stressor/source; the level of data available to assess the stressor/source (data sufficiency); and the time frame over which the stressor/source is affecting the species (threat persistence). The time frame of future threat persistence varied for each source/stressor combination, but generally was between 30 to 100 years. Each of these criteria, the qualitative rating levels (e.g., low, medium, high, very high), and the numerical scores associated with each rating level are defined in more detail below. The numerical scores were derived by the SRT members after careful consideration of how to weight each criterion.

To calculate an overall score for each source, we took the product of the scores for scope, severity, data sufficiency, and threat persistence, averaged across all SRT members for each source. We then converted ranges of numerical scores into categorical ratings (low, medium, high, very high) for each source. To calculate an overall score and categorical rating for each stressor, we took the average of the scores across all sources within a stressor category and converted that numerical score into a categorical rating of low, medium, high, or very high. Each category encompassed a range of numerical scores (see below). We calculated the coefficient of variation (CV) as a measure of the variation in scores among SRT members and converted the numerical CV values into categorical ratings of low, medium, high, or very high.

The terms used in Figure 46 are defined as follows (including definitions for the criteria, the qualitative rating levels used for the criteria, and the associated numerical scores for each qualitative rating level):

- **Factors for Decline =** according to Section 4 of the ESA, NMFS determines whether a species is threatened or endangered as a result of any (or a combination) of the following five factors for decline: destruction, modification or curtailment of habitat; overutilization; disease or predation; inadequacy of existing regulatory mechanisms; or other natural or man-made factors.
- **Stressors** = the specific condition that causes stress to the organisms (e.g., elevated temperature, predation).
- **Sources** = natural or anthropogenic processes that create stressful conditions for organisms (e.g., climate change, reintroduction and recovery of sea otter populations).
- **Life Stage Affected** = the life stage (i.e., adult, juvenile, larval) of pinto abalone directly or indirectly affected by a threat. The life stages affected are: Adult (A) = settled and > 45 mm shell length; Juvenile (J) = settled and between 10-45 mm shell length; and Larval (L) = < 10 mm shell length.
- **Scope –** The proportion of the species’ population that has been or can reasonably be expected to be affected by the threat. This refers to the spatial extent of the impact of the threat, not of the threat itself. Specific ratings for this criterion are defined as follows:
    - **Very high**: The effects of the threat are or are likely to be very widespread or pervasive in scope, affecting most of the species’ population (the area over which >90% of the species’ population occurs). Numerical score = 1
    - **High**: The effects of the threat are or are likely to be widespread in scope, affecting much of the species’ population (the area over which 51-90% of the species’ population occurs). Numerical score = 0.7
    - **Medium**: The effects of the threat are or are likely to be restricted in scope, affecting the species across some of the species’ population (the area over which 11-50% of the species’ population occurs). Numerical score = 0.3

  - **Low**: The effects of the threat are or are likely to be very narrow in scope, affecting the species across a small proportion of the species' population (the area over which 0-10% of the species' population occurs). Numerical score = 0.05
- **Severity –** Within the scope, the level of damage to the habitat or population from the threat that has been or can reasonably be expected given the continuation of current circumstances and trends. Specific ratings for this criterion are defined as follows:
  - **Very High:** Within the scope, the threat has or is likely to destroy or eliminate the habitat or affected population, or reduce its habitat or affected population by > 90%. Numerical score = 1
  - **High:** Within the scope, the threat has or is likely to seriously degrade habitat or reduce the affected population by 51-90%. Numerical score = 0.7
  - **Medium:** Within the scope, the threat has or is likely to moderately degrade habitat or reduce the affected population by 11-50%. Numerical score = 0.3
  - **Low:** Within the scope, the threat has or is likely to only slightly degrade habitat or reduce the affected population by 0-10%. Numerical score = 0.05
- **Data Sufficiency –** The quality of data available upon which to assign a rating. In other words, are the available data sufficient to support a credible threats assessment? Specific ratings for this criterion are defined as follows:
  - **High:** An abundance of data is available for the threat and its effects on the species, and the reviewer has no reservations in reaching a rating decision. Numerical score = 1
  - **Medium:** Data are available for the threat and its effects on the species, and a rating can be assigned but additional data are desired. Numerical score = 0.75
  - **Low:** Ratings are based on expert opinion, based on biological concepts or inferences from data or information on other species or areas. Numerical score = 0.5
- **Threat Persistence: Historical, Current, and/or Future –** The relative time frame(s) over which the threats and/or their impacts were/are/will occur. Historical (H) threats and/or impacts are those that occurred in the past and may or may not be occurring presently. Current (C) threats and/or impacts are those occurring presently. Future (F)

threats and/or impacts are those likely to affect the species. Numerical scores were assigned as follows:

  - **Historical threat (H) =** 0
  - **Future threat (F) =** 0.5
  - **Current threat (HCF, CF, or HC) = 1**
- **Overall Rating for Sources –** The overall score/rating for each source, based on the mean (across all SRT members) of the product of scope, severity, data sufficiency, and threat persistence. The products (numerical scores) were converted into categorical ratings as follows:
  - **Very High (VH):** Mean score = 0.9 to 1.0
  - **High (H):** Mean score = 0.49 to <0.9
  - **Medium (M):** Mean score = 0.07 to <0.49
  - **Low (L):** Mean score = <0.07
- **Overall Rating for Stressors –** The overall score/rating for each stressor, based on the mean of the overall scores across all sources within that stressor category. The average scores were converted into categorical ratings as follows:
  - **Very High (VH):** Mean score = 0.9 to 1.0
  - **High (H):** Mean score = 0.49 to <0.9
  - **Medium (M):** Mean score = 0.07 to <0.49
  - **Low (L):** Mean score <0.07
- **Coefficient of Variation (CV) values –** CV values were calculated as a measure of the variation in scores among SRT members. The CV values were converted into categorical ratings as follows:
  - **Very High (VH):** CV value > 2
  - **High (H):** CV value >1 to 2
  - **Medium (M):** CV value >0.5 to 1
  - **Low (L):** CV value = 0 to 0.5

5.3.2 Threats Assessment Results

The SRT identified multiple stressors associated with each of the factors for decline that either have or may contribute to declines in pinto abalone (Figure 46). Overall, the SRT rated most of the stressors and sources as low threats and did not identify any high or very high threats. The SRT identified several stressors and sources posing a moderate level of threat to pinto abalone. Among these, the SRT was most concerned about low densities as a result of past fisheries harvest of pinto abalone; the potential threat posed by ocean acidification; and illegal take due to poaching and inadequate law enforcement. The potential for reduced genetic diversity as a consequence of low population densities and the potential for predation (particularly by sea otters) to further reduce local densities were also identified as threats of greater concern. Finally, oil spills and disease outbreaks (through the spread of pathogens) were highlighted as highly uncertain risks to pinto abalone that need to be addressed through careful planning, monitoring, and management. We discuss the threats associated with each factor for decline below.

5.3.2.1 Habitat destruction, modification, or curtailment

Most of the threats that result in substrate destruction or modification, such as coastal development, recreational access, cable repairs, nearshore military operations, and benthic community shifts, occur infrequently, have a narrow geographic scope, or have uncertain or indirect effects on pinto abalone. Some exceptions may exist in the cases of water temperature increases and reduced food quantity and quality associated with the El Niño/Southern Oscillation (ENSOs), Pacific Decadal Oscillations (PDOs), Interdecadal Pacific Oscillation (IPOs), and long-term climate change, as well as sea level rise due to long-term climate change, in that these threats have the potential to produce more widespread impacts, but the certainty in how these factors will affect pinto abalone is low. For example, increased water temperatures associated with climate change may be widespread throughout the U.S. West Coast, though the latest climate report suggests that water temperature impacts will be least felt in the Pacific Northwest (Mote *et al.* 2014). Increased water temperatures could affect the health and range of pinto abalone, particularly at the northern and southern extremes of the species' range. However, pinto abalone have a wide temperature tolerance and may be able to adapt to changing temperatures over time, such as by seeking depth refuges. It is also not clear how ENSO, PDO, IPO, and climate change may affect food quantity and quality for pinto abalone. Sea level rise may result in loss of suitable habitat in a preferred depth range because of increased erosion, turbidity and siltation; however, the effects on pinto abalone are uncertain because they typically occupy subtidal habitats throughout much of their range and this would not change under rising sea level conditions. We are not aware of any studies that have examined the potential effects of sea level rise on abalone, and therefore, we currently lack information to determine whether these habitat changes will be important factors for species decline.

Climate change impacts, such as ocean acidification, could affect settlement habitat by affecting the growth of crustose coralline algae, but the effects to pinto abalone are unclear. For example, McCoy (2013) and McCoy and Ragazzola (2014) found morphological changes (e.g., reduced thickness or density) in crustose coralline algal species in response to ocean acidification, with responses varying by species. However, Johnson *et al.* (2014) found that crustose coralline algal species exposed to varying carbon dioxide levels may be acclimatized to ocean acidification, with species-specific variation in the responses. North Pacific waters, including the California Current Ecosystem, have relatively low seawater pH values due to a variety of natural oceanographic processes (Feely *et al.* 2004, Feely *et al*. 2008, Feely *et al.* 2009, Hauri *et al.* 2009), and this may make crustose coralline algal species within the pinto abalone's range better able to adapt to the effects of ocean acidification. In addition, it is unclear how ocean acidification may affect the chemical cues that are believed to attract pinto abalone to settle on crustose coralline algae. Overall, climate change impacts such as ocean acidification could affect settlement habitat, but the effects are highly uncertain at this time.

Oil spill and response activities were also identified as a concern for pinto abalone, for both the potential effects on habitat (substrate destruction or modification) and on the abalone themselves (environmental pollutant/toxins, under "Other Natural or Man-made Factors"). These effects would be of particular concern where the species occurs in intertidal and shallower waters (e.g., Alaska and British Columbia). The threat of an oil spill is greater in areas with higher ship traffic and human development. If a spill were to occur, acute effects could be very damaging in the localized area of the spill. However, there is little information available on the effects of oil spills on subtidal habitats where pinto abalone tend to occur throughout most of their range, as well as little information available on the effects of oil on abalone.

5.3.2.2 Overutilization

The SRT identified the current low densities of pinto abalone populations as the threat of greatest concern for the species. In a variety of locations throughout the pinto abalone range, local densities are estimated to be below the critical threshold densities identified for successful spawning and recruitment in other abalone species (0.15-0.34 per m^2; Babcock and Keesing 1999, Neuman *et al.* 2010). Fisheries harvest of pinto abalone for commercial and recreational purposes (i.e., prior to the fishery closures) has contributed to this predicament (see Sections 3.7.1 and 3.8.6 of this report). Harvest of pinto abalone is currently prohibited throughout the coast except in Alaska (i.e., for personal use and subsistence harvest) and Mexico. Data on harvest levels and the impacts on pinto abalone are not available for Alaska and Mexico, but the best available information indicates that these fisheries are not contributing substantially to overutilization of the species (ADF&G comments to NMFS on 17 January 2014). In Mexico, green and pink abalone are the focus of the abalone fishery, with other abalone species (including pinto abalone) making up only one percent of the abalone fishery (Boch *et al.* 2014). In Alaska, the daily limits for personal use and subsistence harvest were reduced in 2012 from 50 to 5 abalone per day. We do not have data to assess how this harvest level would affect pinto abalone populations in Alaska; however, ADF&G believes that personal use and subsistence harvest of pinto abalone is currently low (ADF&G comments to NMFS on 17 January 2014). The average subsistence harvest of pinto abalone ranged from 350-382 abalone per household in 1972 but decreased to 3-9 abalone per household in 1997 (Bowers *et al.* 2011). In recent interviews, local residents have indicated to ADF&G that they are not participating in the personal use fishery due to the lack of abalone (Bowers *et al.* 2011). Based on this information, it is likely that personal use and subsistence harvest of pinto abalone in Alaska is low. Monitoring of harvest levels and pinto abalone populations is needed to obtain a better understanding of the impacts of these fisheries in Alaska and Mexico.

The effects of past fisheries harvest on local densities still persist today throughout the species range. Past harvest levels, particularly in commercial fisheries in Alaska and British Columbia, were not sustainable and reduced densities to very low or non-existent levels. Some populations (e.g., at the San Juan Islands Archipelago in Washington) appear to be experiencing recruitment failure. In these cases, pinto abalone densities may be too low for successful spawning and recruitment. However, evidence of recent recruitment exists in several areas throughout the species' range (British Columbia, California, Mexico), indicating that densities at those locations remain high enough to support reproduction and recruitment. In addition, Seamone and Boulding (2011) have demonstrated that successful reproduction and recruitment can occur despite very low densities because of the aggregative behavior of pinto abalone during the spawning season. These observations show that we have much more to learn about the species' population dynamics and the factors influencing successful reproduction and recruitment. For example, mean adult densities may not be an appropriate metric for predicting reproductive and recruitment success because they may not adequately represent the patchy distribution of abalone within an area. Fine-scale spatial distribution patterns (e.g., aggregations) may be more important for reproductive and recruitment success than the overall density of adults in an area.

Reduced genetic diversity is a potential risk associated with low densities. Withler *et al.* (2001) provide the only published assessment of population structure in pinto abalone and found high levels of genetic variation in pinto abalone populations sampled at 18 sites throughout coastal British Columbia and at one site in Sitka Sound, Alaska. Unfortunately, research on populations throughout the remainder of the species' range has not been conducted, and thus the Wither *et al.* (2001) study represents the best available information. Based on this, the SRT expressed a moderate degree of concern, but most members felt that the species' genetic diversity likely remains high.

5.3.2.3 Disease and Predation

As discussed in Section 3.8.7 of this Status Report (Mortalities associated with disease), disease has been identified as a major threat to abalone species worldwide, with four significant abalone diseases emerging over the past several decades (withering syndrome, ganglioneuritis, vibriosis, and shell deformities). Pinto abalone are likely susceptible to all of these diseases, and have been confirmed to be highly susceptible to withering syndrome, a disease that has resulted in significant declines in black abalone populations throughout southern California. No infectious diseases affecting wild pinto abalone have been reported in Alaska, Washington, or California, but two pinto abalone pathogens (see Section 3.8.7) have been reported in British Columbia. To date, no outbreaks have been observed in wild populations and there is no evidence indicating that disease has been a major source of mortality in the recent past or currently. However, multiple sources and pathways exist for pathogens or invasive species to be introduced into wild pinto abalone populations, including aquaculture facilities and the movement of abalone (e.g., import, transfer) for aquaculture, research, and food/hobby markets (identified under the "Inadequacy of existing regulatory mechanisms" factor below). Great care is needed to closely monitor and manage these sources and pathways, to protect wild populations from potentially devastating pathogens and invasive species.

Abalone face non-anthropogenic predatory pressure from a number of consumer species such as gastropods, octopuses, lobsters, sea stars, fishes and sea otters (Ault 1985; Estes and VanBlaricom, 1985; Shepherd and Breen 1992). Pinto abalone have been exposed to varying predation pressure through time and this pressure is likely to continue. However, in the past, pinto abalone populations may have been better able to absorb losses due to predation without compromising viability. Specifically, predation by sea otters has been raised as a potentially significant factor in the continued decline and/or lack of recovery of pinto abalone populations in areas where the two species overlap. Sea otters were hunted to near extinction in the mid-1700s to 1800s, but have begun to recover in recent decades with protection from the North Pacific Fur Seal Convention of 1911, the Marine Mammal Protection Act, and reintroductions in Southeast Alaska, British Columbia, and Washington in the late 1960s. Sea otter populations in these areas have been expanding in both abundance and distribution in recent years and are likely to continue to expand as the populations grow. Without a good understanding of how expansion and/or contraction rates of sea otter and pinto abalone populations will proceed and a better understanding of the predation pressure that sea otters exert on pinto abalone, it is very difficult to predict the long-term, population-level impacts that sea otters may have on fragile or recovering pinto abalone populations. As discussed in Section 3.8.8 of this Status Report, the best available information at this time supports the view that sea otters and abalone can sustainably co-exist, though abalone populations are not likely to reach the high abundances achieved in the recent past when sea otters were locally extirpated.

5.3.2.4 Inadequacy of existing regulatory mechanisms

Poaching has been a source of mortality for pinto abalone throughout their range since the establishment of harvesting regulations by the States and Canada (see Section 3.5.1 [Competitive interactions and anthropogenic mortality] above for further discussion). The problem of poaching clearly persists in some regions along the coast, particularly in British Columbia. Existing regulatory mechanisms, as well as outreach and education programs, have effectively reduced the risks posed by illegal take in British Columbia in the past five years, as indicated by increases in local densities at survey sites. In other regions along the coast, poaching is recognized as a historical and future risk, but specific information on current levels of poaching is lacking. Although regulatory measures have been established, continued efforts to enforce the regulations and monitor their effectiveness are needed to protect the species from this threat.

As discussed above (see Section 5.3.2.3), the introduction of pathogens or invasive species was also a concern identified by the SRT, given the potentially high risks posed by disease to pinto abalone and the recent issues with devastating disease introductions and transmission in other parts of the world. Regulatory mechanisms are needed to ensure adequate monitoring whenever animals are moved (e.g., imports, transporting between facilities) for aquaculture, research, and/or food/hobby markets, to protect the wild populations from pathogens and invasive species. In California, state regulations require abalone health monitoring at aquaculture facilities and control the importation/exportation of abalone between facilities. The State also monitors aquaculture facilities for introduced organisms and disease on a regular basis and restricts out-planting abalone from facilities that have not met certification standards. These measures will likely reduce the transmission of pathogens or invasives from aquaculture facilities. In Washington and British Columbia, where abalone hatcheries are operated in support of restoration efforts, disease monitoring is also conducted and precautions are taken to avoid and minimize the transmission of pathogens and invasives. Some improvements to existing regulations are needed to further protect the species. Although a permit is required to import non-native abalone species into California, a permit is not needed to import native abalone species, even if the source of those abalone is outside of the U.S. This presents a potential risk because live abalone imported into the State could carry pathogens. Information was not available regarding the amount of native abalone species that are imported into the U.S. from other countries each year.

5.3.2.5 Other natural or man-made factors

Among the other natural or human factors affecting pinto abalone, the SRT identified ocean acidification as a threat of particular concern. Ocean acidification is a concern particularly for early life stages because of the potential for reduced larval survival and shell growth, as well as increased shell abnormalities. The impacts of ocean acidification can be patchy in space and time and may develop slowly. Some studies have shown deleterious effects of ocean acidification on abalone and other shell-forming species. However, data availability is low, especially regarding how ocean acidification may affect the species throughout its range, given variability in local conditions throughout the coast, natural variation in ocean pH, species adaptability, and projections of future carbon dioxide emissions.

Environmental pollutants and toxins are likely present in areas where pinto abalone have occurred and still do occur, but evidence suggesting causal and/or indirect negative effects on pinto abalone due to exposure to pollutants or toxins is lacking. In addition, very little is known regarding entrainment and/or impingement risks posed by coastal facilities. Direct effects would be localized and focused on larval stages. Despite uncertainties due to lack of data, the overall risk that environmental pollutants and toxins and entrainment/impingement pose on the species throughout its range is probably low given their limited geographic scope.

5.3.2 Demographic Risk Assessment Methods

To evaluate demographic risks to the species, the SRT analyzed the collective condition of individual populations at the “species” level according to four criteria: abundance, growth rate/productivity, spatial structure/connectivity, and diversity. These four general viability criteria, reviewed in McElhany *et al.* (2000), reflect concepts that are well founded in conservation biology, are generally applicable to a wide variety of species, and describe demographic risks that individually and collectively provide strong indicators of extinction risk. In the following paragraphs, we briefly summarize these demographic risk criteria as they relate to a species’ extinction risk and provide an overview of the demographic risk scoring method employed by the pinto abalone SRT.

Evaluating the extinction risk of a species includes considering the available information concerning the abundance, growth rate/productivity, spatial structure/connectivity, and diversity of a species and assessing whether demographic risks are such that it is nearing extinction or likely to become so in the foreseeable future. A species at very low levels of abundance and with few populations will be less tolerant to environmental variation, catastrophic events, genetic processes, demographic stochasticity, ecological interactions, and other processes (e.g., Gilpin and Soule 1986, Meffe and Carroll 1994, Caughley and Gunn 1996). A rate of productivity that is unstable or declining over a long period of time may reflect a variety of causes but indicates poor resiliency to future environmental variability or change (e.g., Lande 1993, Foley 1997, Middleton and Nisbet 1997). For species at low levels of abundance, in particular, declining or highly variable productivity confers a high level of extinction risk. A species that is not widely distributed across a variety of well-connected habitats will have a diminished capacity for recolonizing locally extirpated populations and is at increased risk of extinction due to environmental perturbations and catastrophic events (Schlosser and Angermeier 1995, Hanski and Gilpin 1997, Tilman and Lehman 1997, Cooper and Mangel 1999). A species that has lost locally adapted genetic and life-history diversity may lack the raw resources necessary to endure short- and long-term environmental changes (e.g., Groot and Margolis 1991, Wood 1995).

The demographic risk criteria described above are evaluated based on the present species status in the context of historical information, if available. We evaluated demographic extinction risk by assessing the likelihood of a number of questions related to the four risk criteria (abundance, growth rate/productivity, spatial structure/connectivity, and diversity). These questions, listed below, were taken from the document “Guidance on Responding to Petitions and Conducting Status Reviews under the Endangered Species Act” released by NMFS Protected Resources on May 24, 2013 (Table 15).

Abundance Questions

1. Is the species’ abundance so low that it is at risk of extinction due to environmental variation or anthropogenic perturbations (of the patterns and magnitudes observed in the past and expected in the future)?
2. Is the species’ abundance so low, or variability in abundance so high, that it is at risk of extinction due to depensatory processes?
3. Is the species’ abundance so low that its genetic diversity is at risk due to inbreeding depression, loss of genetic variants, or fixation of deleterious mutations?
4. Is a species’ abundance so low that it is at risk due to demographic stochasticity?

Population Growth Rate Questions

1. Is a species’ average population growth rate below replacement such that it is at risk of satisfying the abundance conditions described above?
2. Is the species’ average population growth rate below replacement such that it is unable to exploit requisite habitats/niches/etc. or at risk due to depensatory processes during any life-history stage?
3. Does the species exhibit trends or shifts in demographic or reproductive traits that portend declines in per capita growth rate which pose risk of satisfying any of the preceding conditions?

Spatial Structure Questions

1. Are habitat patches being destroyed faster than they are naturally created such that the species is at risk of extinction due to environmental and anthropogenic perturbations or catastrophic events?

2. Are natural rates of dispersal among populations, metapopulations, or habitat patches so low that the species is at risk of extinction due to insufficient genetic exchange among populations, or an inability to find or exploit available resource patches?
3. Is the species at risk of extinction due to the loss of critical source populations, subpopulations, or habitat patches?

Diversity Questions

1. Is the species at risk of extinction due to a substantial change or loss of variation in life-history traits, population demography, morphology, behavior, or genetic characteristics?
2. Is the species at risk of extinction because natural processes of dispersal, migration, and/or gene flow among populations have been significantly altered?
3. Is the species at risk of extinction because natural processes that cause ecological variation have been significantly altered?

After reviewing all relevant biological information for the species, each SRT member assessed the questions (above) using a voting process that was first used in an ESA status review by Brainerd *et al.* (2011) to assess extinction risk for 82 coral species. For each question, each SRT member scored the likelihood that the answer to each question was true by anonymously assigning 10 points to 8 likelihood bins developed by the IPCC (Intergovernmental Panel on Climate Change) 2007: exceptionally unlikely (<1%), very unlikely (1-10%), unlikely (10-33%), less likely than not (33-50%), more likely than not (50-66%), likely (66-90%), very likely (90-99%), virtually certain (>99%). For each question, the scores were tallied (mean score and range of scores for each SRT member and among all SRT members) and reviewed, and the range of perspectives was discussed by the SRT. Each SRT member then had the opportunity to change their scores before submitting a final version for demographic risk determination (see section 5.3.4 of this Status Report). In order to adequately capture the variability within and among team members for each demographic question, the total number of points that each team member placed into the likelihood bins is presented in this report. In order to evaluate the relative importance of each demographic risk category (i.e., abundance, population growth rate, spatial structure, and diversity), the total number of points that were placed into each likelihood bin by all team members for all questions within a risk category combined is presented in this report.

5.3.4 Demographic Rick Assessment Results

Team members exhibited some variability in their assessment of the level of risk posed by the different demographic risks to range-wide pinto abalone persistence, as illustrated by Figures 47-50. This variability can be ascribed to differences in the interpretation of often limited data (e.g., as evidenced by different point distribution means, minima, or maxima) and/or a high degree of uncertainty in the perceived risk to the species across its range (e.g., as evidenced by broader point distributions and/or more points allocated between the “less likely than not” and “more likely than not” likelihood bins, representing 33-50% and 50-66% likelihood).

Team members unanimously agreed that depensatory processes due to low and/or highly variable abundance or low population growth rate (Figures 47 and 48) were a concern for pinto abalone in a number of locations (e.g., San Juan Islands, Alaska), and this led the team to conclude that low/variable abundance and population growth posed higher relative risk to the species throughout its range compared to spatial structure and diversity (Figures 49 and 50). Pinto abalone abundance and population growth have declined throughout the species' range, and, while there is some indication that recent recruitment has occurred in localized areas (e.g., Mexico, Point Loma, Palos Verdes, Mendocino County, British Columbia, Alaska), the rate of population growth is unknown. The SRT expressed some concern that population growth may not be occurring at a pace or extent sufficient to buffer against possible further declines due to processes happening over longer (e.g., PDO, IPO, climate change, and ocean acidification over decades; ENSO events over years) and/or uncertain time scales (e.g., cumulative oil spill impacts, poaching events, or harvest impacts).

The majority of team members agreed that habitat destruction and loss of variation in life-history traits, population demography, morphology, behavior, or genetic characteristics were of lower concern for pinto abalone (Figures 49 and 50), and this led the majority of the team to support the conclusion that spatial structure and diversity posed lower relative risk to the species throughout its range compared to abundance and population growth (Figures 47 and 48). The prevailing justification here was that other related species of abalone that experienced sharp declines in abundance (e.g., red, pink, black and green abalone) and that may exhibit lower spatial connectivity and/or genetic diversity than suspected for pinto abalone, have made remarkable recoveries in multiple locations over a period of roughly two decades (Richards and Whitaker 2012, Van Blaricom unpublished data, Vantuna Research Group unpublished data). Still, within the spatial structure category, team members were concerned, but highly uncertain, about whether pinto abalone are at risk due to the loss of critical source populations or subpopulations in many areas as a result of intense past fishing pressure (Figure 49).

Overall, most team members expressed low (i.e., for spatial structure and diversity) to moderate levels (i.e., for abundance and population growth) of concern and a high degree of uncertainty for the majority of questions and demographic categories (Figures 47-50). The SRT expressed a higher degree of uncertainty regarding productivity and abundance, as shown by the more even allocation of points across multiple likelihood bins and the shift in distribution toward the “less likely than not” and “more likely than not” bins. None of the team members placed any of their likelihood points in the highest risk category (>99%) and they placed very few points (<5%) in the next highest risk category (90-99%) across all questions and demographic categories, indicating that no team member thought the risk of extinction of pinto abalone was virtually certain, or even very likely, due to any of the demographic risks identified.

Although this process helps to integrate and summarize a large amount of diverse information, there is no simple way to translate the results of this demographic risk assessment directly into a determination of overall extinction risk. This demographic risk assessment did not take into consideration the effects of past, present, and future threats on the persistence of the species into the foreseeable future. Thus, the SRT undertook an additional assessment of overall extinction risk, described in the following section, to incorporate the results of both the threats assessment and demographic risk assessment.

5.4 Overall Risk Determination

The overall risk assessment considers demographic risks together with threats to evaluate the level of extinction risk faced by the species now and in the foreseeable future. Because data are not available to quantitatively assess the species' extinction risk (e.g., through development of a population viability model), the SRT adopted an approach similar to what has been done in previous NMFS status reviews, using a voting process to organize and summarize the professional judgment of the SRT members regarding the overall level of extinction risk to the species.

For the purpose of this extinction risk analysis, the term "foreseeable future" was defined by NMFS as the timeframe over which threats can be predicted reliably and over which their impacts to the biological status of the species may be observed. The SRT considered the life history of pinto abalone and the availability of data regarding threats to the species, and recommended that the foreseeable future can be defined in two ways:

- **30 years:** A time frame of 30 years represents approximately three generations for pinto abalone (McDougall *et al.*2006, COSEWIC 2009). This time frame is consistent with what was used to define the foreseeable future in the black abalone status review report (NMFS 2009) and represents a reasonable time frame over which threats can be predicted reliably and impacts to the species' status would be observable.

- **100 years:** Although a longer time frame introduces more uncertainty, the SRT felt that a time frame greater than 30 years may be needed to adequately consider the effects of longer-term threats, such as climate change, ocean acidification, ENSOs, and PDOs/IPOs. A foreseeable future of 100 years was selected as a reasonable time frame over which we have some information on and predictions regarding these longer-term threats, and has been used by the status review for multiple coral species that are threatened by climate change and ocean acidification (Brainard *et al.* 2011).

NMFS determined that the 30 year and 100 year timeframes for foreseeable future were appropriate and asked the SRT to assess overall extinction risk for the species over both timeframes. The assessment over a foreseeable future of 30 years represents the SRT's view of the overall level of extinction risk faced by pinto abalone given the species' current status and threats that can be predicted over the next 30 years. This assessment recognizes that predictions regarding longer-term threats are highly uncertain and can change within this time frame, as can our understanding of the species and the environment. The assessment over a foreseeable future of 100 years represents the SRT's view of the overall level of extinction risk faced by the species in light of current predictions regarding long-term threats (e.g., climate change, ocean acidification) and expectations regarding oceanographic regime shifts (e.g., ENSOs, PDOs/IPOs).

5.4.1 Overall Risk Assessment Methods

The SRT considered the following five levels of extinction risk, defined below, in their assessment of the overall extinction risk to the species now and in the foreseeable future (defined as 30 years and 100 years):

No or very low risk: It is unlikely that this species is at risk of extinction due to projected threats or trends in abundance, productivity, spatial structure, or diversity.

Low risk: It is unlikely that this species is at risk of extinction due to trends in abundance, productivity, spatial structure, or diversity; however, current threats (or projected threats) may (or will) alter those trends, but not yet by enough to cause the species to be influenced by stochastic or depensatory processes.

Moderate risk: The species exhibits a trajectory indicating that it is approaching a level of abundance, productivity, spatial structure, and/or diversity that places its current or future persistence in question. A species may be at moderate risk of extinction due to declining trends in abundance, productivity, spatial structure, or diversity and current or projected threats that inhibit the reversal of these trends.

High risk: The species is at or near a level of abundance, productivity, spatial structure, and/or diversity that places its current or future persistence in question. Similarly, it faces clear and present threats that are likely to create such demographic risks.

Very high risk: The species is strongly influenced by stochastic or depensatory processes, facing current threats exacerbating the demographic risks and indicating imminent extinction.

To allow individuals to express their level of uncertainty in assessing the overall level of extinction risk facing the species, the SRT adopted the “likelihood point” method, often referred to as the FEMAT method because it is a variation of a method used by scientific teams evaluating options under the Forest Plan (Forest Ecosystem Management: An Ecological, Economic, and Social Assessment Report of the Forest Ecosystem Management Assessment Team, or FEMAT) (FEMAT 1993). This approach has been used in previous status reviews (e.g., Pacific salmon, rockfish in Puget Sound, Pacific herring, black abalone, and scalloped hammerhead sharks) to structure the SRT’s thinking and express levels of uncertainty in assigning risk categories. For this approach, each SRT member distributed 10 ‘likelihood points’ among the five levels of risk. The scores were then tallied and summarized.

The SRT did not make recommendations as to whether the species should be listed as threatened or endangered. Rather, the SRT drew scientific conclusions about the overall risk of extinction faced by the species under present conditions and in the foreseeable future based on an evaluation of the species' demographic risks and assessment of threats.

5.4.2 Overall Risk Assessment Results

Over both time frames, SRT members distributed likelihood points across all five extinction risk categories, with the majority of likelihood points placed in the Low risk and Moderate risk categories and very few (1-2) points placed in the Very High risk category (Figure 51). When considering a foreseeable future of 100 years, most of the SRT members moved some of their likelihood points from the No/Very Low and Low risk categories to the Moderate and High risk categories, indicating greater concern regarding demographic risks and threats over the 100 year time frame (Figure 51b) compared to the 30 year time frame (Figure 51a). The results for each time frame are summarized below.

5.4.2.1 Overall risk now and in a foreseeable future of 30 years

The SRT distributed their likelihood points across five extinction rick categories as follows: No or Very Low Risk (11/80, or 14%), Low Risk (33/80, or 40%), Moderate Risk (32/80, or 41%), High Risk (3/80, or 4%), Very High Risk (1/80, or 1%). Only one SRT member placed a likelihood point in the "Very high risk" category for the overall level of extinction risk now and in the foreseeable future (Figure 49). Based on the likelihood point distributions, the SRT was fairly certain that the species has a low to moderate risk of extinction currently and in a foreseeable future of 30 years. Of the 80 points distributed across categories, the SRT placed 76 points across the Very Low, Low, and Moderate risk categories. The categories with the greatest number of points were the Low risk (33 points) and Moderate risk (32 points) categories.

The main concerns highlighted by the SRT include declines in abundance and uncertainty regarding whether current abundance and productivity levels are sufficient to support the persistence and recovery of the species in the face of continuing and potential future threats. The best available data on species abundance indicate long-term declines in certain areas that may put those populations at risk, though this situation is localized. Observed recruitment events indicate that demographic characteristics are sufficient to support reproduction, but productivity is variable and occurring at undetermined rates. The lack of information regarding how naturally occurring events may affect the species into the future (e.g., IPOs, predation) and the unpredictability of some threats (e.g., oil spills, climate change impacts) introduces additional uncertainty into the SRT's evaluation of the species' status through the foreseeable future. Protective measures have been put in place throughout the species range; in particular, harvest prohibitions in all areas except for Alaska (where subsistence and personal use fisheries still exist) have removed a primary threat to the species. In addition, conservation actions have been implemented and their effectiveness is currently being evaluated. Evidence from other abalone species shows that populations are able to recover from low abundances; the same may be true for pinto abalone.

5.4.2.2 Overall risk in a foreseeable future of 100 years

The SRT distributed their likelihood points across the five extinction risk categories as follows: No or Very Low Risk (6/80, or 8 %), Low Risk (24/80, or 30 %), Moderate Risk (36/80, or 45 percent), High Risk (12/80, or 15 %), Very High Risk (2/80, or 3 %). Only two SRT members placed likelihood points in the Very High risk category. All but one SRT member (who made no changes to their point distribution when considering 100 years vs. 30 years) shifted some of their likelihood points from the No/Very Low and Low risk categories to the Moderate and High risk categories when considering a foreseeable future of 100 years rather than 30 years (Figure 51). This shift indicated that the SRT was more certain that the species has a Moderate risk of extinction currently and in the foreseeable future when considering a foreseeable future of 100 years vs. 30 years. Again, the SRT distributed most of their points (66 out of 80 points) across the Very Low, Low, and Moderate risk categories.

The main reason for the increase in likelihood points for the Moderate risk category vs. the Low risk category was the general perception by most SRT members that the species is likely to face more challenging conditions in a foreseeable future of 100 years, given current predictions regarding climate change impacts, ocean acidification, and increasing sea otter populations. The effects of climate change and ocean acidification may become more significant over the next 100 years. For example, ocean acidification and increasing ocean temperatures and freshening (due to runoff and glacial melting) may reduce habitat suitability for abalone larvae and increase the risk of disease among abalone populations. In addition, increasing predation pressure from recovering sea otter populations may cause further reductions in local population abundances.

However, the SRT also recognized that there is more uncertainty associated with our understanding of and predictions regarding these threats and their effects on the species over the longer time frame.

5.4.3 Overall Risk Conclusion

Overall, the SRT concluded that pinto abalone have a Low to Moderate level of extinction risk now and in the foreseeable future (over both the 30 year and 100 year time horizons). The SRT recognized that there is a high level of uncertainty regarding demographic factors, in particular regarding abundance and productivity levels. The main concerns highlighted by the SRT include declines in abundance and uncertainty regarding whether current abundance and productivity levels are sufficient to support the persistence and recovery of the species in the face of continuing and potential future threats. Long-term declines have been observed in surveyed areas throughout the species range. There is concern that these declines may be putting the populations at the San Juan Islands Archipelago at risk, because the populations appear to be experiencing recruitment failure. Throughout the rest of the species' range, densities remain low but recurring and/or recent recruitment events have been observed and have even resulted in increased densities (of mature and all sizes of pinto abalone) at several index sites in British Columbia. Observed recruitment events indicate that demographic characteristics are sufficient to support reproduction in locations throughout the species range, but productivity is variable and occurring at undetermined rates. Observations suggest that abalone recruitment and populations, in general, are both temporally and spatially episodic. One of the main data gaps is the lack of historical data on the status of the species prior to fisheries harvest and prior to the removal of sea otters throughout most of the coast. Lacking this baseline for comparison further increases the uncertainty regarding how to interpret the limited demographic data available for the species, and points to the need for improved monitoring of pinto abalone populations throughout its range in order to adequately assess the species' status.

The main reason for the increase in likelihood points for the Moderate risk category versus the Low risk category when considering a foreseeable future of 100 years was the general perception by most SRT members that the species is likely to face more challenging conditions over the longer time frame, given the currently available predictions regarding climate change impacts, ocean acidification, and increasing sea otter populations. However, the SRT also recognized that there is more uncertainty associated with our understanding of and predictions regarding these threats and their effects on the species over the longer time frame. Additional sources of uncertainty include: the lack of information regarding how naturally occurring events may affect the species into the future (e.g., IPOs, predation); the unpredictability of some threats (e.g., oil spills, climate change impacts); and the potential for pinto abalone to adapt to changing climate and conditions, as well as to recover from low abundances, which has been observed for other abalone species.

6.0 Significant Portion of the Range of the Species

The ESA defines an "endangered" species as "any species which is in danger of extinction throughout all or a significant portion of its range," and a "threatened" species as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range” (emphasis added). On July 1, 2014, the USFWS and NMFS issued a final policy on the interpretation and application of the phrase “significant portion of its range” under the ESA (79 FR 37578). Under this policy, the phrase “significant portion of its range” provides an independent basis for listing a species under the ESA. In other words, a species would qualify for listing if it is determined to be endangered or threatened throughout all of its range or if it is determined to be endangered or threatened throughout a significant portion of its range. This policy defines the term “significant” as follows: “a portion of the range of a species is ‘significant’ if the species is not currently endangered or threatened throughout its range, but the portion’s contribution to the viability of the species is so important that, without the members in that portion, the species would be in danger of extinction, or likely to become so in the foreseeable future, throughout all of its range.” The range of the species is defined as “the general geographical area within which that species can be found at the time FWS or NMFS makes any particular status determination.”

To inform NMFS’ assessment of whether pinto abalone are endangered or threatened throughout all or a significant portion of its range, the SRT was asked to conduct a 3-step process. First, to help identify any potentially significant portions of the species’ range, the SRT was asked to evaluate whether any portions of the range may be significant and whether the members of the species in those portions may be endangered or threatened. If any potentially significant portions of the range were identified, the SRT was then asked to conduct a more detailed analysis to evaluate the level of extinction risk faced by the species within those portions. Finally, if the SRT’s assessment of extinction risk indicated that the species is at risk of extinction now or likely to become so in the foreseeable future within any of the portions, the SRT was asked to conduct a more detailed analysis to evaluate whether under a hypothetical scenario, the portion's contribution to the viability of the species is so important that, without the members in that portion, the remainder of the species would be at risk of extinction now or in the foreseeable future. If the SRT's assessment did not indicate that the species is at risk of extinction now or likely to become so in the foreseeable future within any of the portions, then the SRT was not asked to conduct this more detailed analysis. The SRT did not determine whether any portions of the range are significant or whether the members of the species within any portion of the range are endangered or threatened. These determinations are to be made by NMFS upon consideration of the SRT's evaluation.

6.1 Approaches to the "Significant Portion of its Range" Question

According to the final policy on the interpretation of "significant portion of its range" (SPR), the first step in identifying an SPR is to assess whether there is substantial information indicating that a portion of the species' range may be significant and whether the members of the species within that portion may be either threatened or endangered. If any portions are identified, then the next step is to conduct a more detailed analysis to determine whether these standards are indeed met. The SRT undertook a 2-step analysis to help identify potential SPRs and then evaluate the level of extinction risk within those potential SPRs. The SRT's analysis will be used by NMFS to determine whether the species is threatened or endangered within a significant portion of its range.

6.1.1 Identifying potential SPRs

To help in identifying any potential SPRs, the following portions of the species range were presented to the SRT and each member was asked to indicate whether they thought the portion may be significant (based on the final SPR policy's definition of "significant") and whether the members of the species within that portion may be considered threatened or endangered. Each SRT member answered these two questions with a simple yes or no. The portions considered by the SRT were: Alaska (AK), British Columbia (BC), San Juan Islands Archipelago (SJA), Northern California (NorCal), Southern California (SoCal), and Mexico (MX). Only two of the eight voting members indicated that British Columbia may be significant and only one member indicated that Alaska may be significant. The SRT unanimously agreed that the remaining portions (SJA, NorCal, SoCal, and MX) are not significant. Overall, the SRT agreed that none of these portions contribute substantially to the viability of the species such that the loss of that portion would put the species in danger of extinction presently or in the foreseeable future. As a result, none of these six portions were considered further as potential SPRs.

The SRT was also asked to consider two larger portions representing: (a) the Northern portion of the species range and consisting of Alaska, British Columbia, and the San Juan Islands Archipelago; and (b) the Southern portion of the species range and consisting of Northern California, Southern California, and Mexico. The Northern and Southern portions were delineated based on the geographic proximity of the areas and what appears to be a natural gap in the species' range between Washington and California (based on the absence of pinto abalone observations along the outer coasts of Washington and Oregon, except for a handful of pinto abalone found off Oregon). More than half of the SRT members that voted indicated that the Northern portion (AK/BC/SJA) may be significant, because this portion encompasses a large part of the species' range, including areas that historically supported the greatest numbers of pinto abalone (British Columbia). More than half of the SRT members also indicated that the members of the species within the Northern portion may be threatened or endangered, based on the declines in pinto abalone abundance from historical levels, increasing sea otter populations in several areas, and what appears to be recruitment failure in the San Juan Islands Archipelago. More than half of the SRT members that voted indicated that the Southern portion (NorCal/SoCal/MX) may be significant, based on the large area encompassed by this portion and evidence of recent recruitment throughout California and Mexico, which could benefit the species throughout its range. Half of the SRT members indicated that the members of the species within the Southern portion may be threatened or endangered based on the declines in pinto abalone abundance from historical levels, but expressed a high degree of uncertainty regarding this question. As a result, the Northern and Southern portions were considered as potential SPRs. We also identified one additional SPR based on an alternative approach presented in Waples *et al.* (2007). In this approach, we focused on the six smaller portions considered above (AK, BC, SJA, NorCal, SoCal, and MX) and identified those for which at least half of the voting SRT members indicated may be threatened or endangered. These portions were AK, BC, SJA, SoCal, and MX (i.e., all portions except for Northern California). These five portions were considered together as one potential SPR.

In summary, three potential SPRs were identified based on the SRT's analysis: (a) the Northern portion (AK/BC/SJA); (b) the Southern portion (NorCal/SoCal/MX); and (c) all portions excluding Northern California (AK/BC/SJA/SoCal/MX). The SRT was then asked to evaluate the level of extinction risk to the species within these three potential SPRs.

6.1.2 Level of Extinction Risk Within SPRs

To evaluate the level of extinction risk to pinto abalone within the three potential SPRs, the SRT used the same methods used to evaluate the overall level of extinction risk to the species throughout its range (see Section 5.4 of this Status Report). For each of the three potential SPRs, each SRT member distributed 10 likelihood points among the following five levels of extinction risk: No/Very Low, Low, Moderate, High, and Very High risk. The SRT assessed extinction risk to the species now and in the foreseeable future, considering both a 30-year and a 100-year time frame for foreseeable future. The SRT's assessment for each potential SPR is summarized below and displayed in Figure 52.

6.1.2.1 Extinction risk within the Northern portion

Likelihood points attributed to the categories for the level of extinction risk now and in a foreseeable future of 30 years are as follows: No or Very Low Risk (14/80, or 18%), Low Risk (29/80, or 36%), Moderate Risk (30/80, or 38%), High Risk (7/80, or 9%), Very High Risk (0/80, or 0%). None of the SRT members placed likelihood points in the Very High risk category and few points were placed in the High risk category. The majority (54%) of likelihood points were placed in the No/Very Low and Low risk categories. The categories with the greatest number of points were the Low (29 points) and Moderate (30 points) risk categories.

Likelihood points attributed to the categories for the level of extinction risk now and in a foreseeable future of 100 years are as follows: No or Very Low Risk (11/80, or 14%), Low Risk (19/80, or 24%), Moderate Risk (31/80, or 39%), High Risk (17/80, or 21%), Very High Risk (2/80, or 3%). When considering a foreseeable future of 100 years rather than 30 years, most of the SRT members shifted some of their points from the No/Very Low and Low risk categories to the Moderate and High risk categories. One member placed two likelihood points in the Very High risk category. Two SRT members made no changes to their point distribution. One member stated that the level of uncertainty was too great to reliably assess the level of extinction risk beyond a foreseeable future of 30 years. The other member stated that extinction risk is Very Low or Low over either the 30-year or 100-year time frame, citing field observations indicating that abalone species have the capacity to recover from low population levels given proper management actions (e.g., harvest prohibitions). In general, more points were placed in the No/Very Low and Low risk categories (total: 30 points) than in the High and Very High risk categories (total: 19 points). The category with the greatest number of points was the Moderate risk category (31 points).

Overall, the SRT concluded that the Northern Portion SPR has a Low to Moderate level of extinction risk now and in the foreseeable future over both the 30-year and 100-year time frame. The SRT expressed concern regarding long-term declining trends in abundance throughout British Columbia and the San Juan Islands Archipelago and the limited data from Alaska that also suggests declines in abundance. The SRT focused on the threats posed by continued personal use and subsistence harvest in Alaska, the recovery of sea otter populations in several locations, and potential climate change and ocean acidification impacts. Concern regarding climate change and ocean acidification impacts increased when considering the 100-year time frame versus the 30-year time frame for foreseeable future; however, the level of uncertainty also increased when considering the longer time frame. There is evidence of continued/recent recruitment in several areas throughout British Columbia and in Alaska, as well as evidence of increasing abundance in British Columbia. At some of the index survey sites in British Columbia, densities have increased to levels that meet or exceed recovery targets for the species (DFO 2012). It is unclear how much of this recovery can be attributed to the protections implemented in British Columbia versus the favorable oceanographic conditions we are currently experiencing (e.g., negative PDO/IPO). The SRT recognized that abalone recruitment, generally speaking, is highly episodic and that many species have exhibited localized recovery from low abundance levels (e.g., red, pink, black and green abalone; Richards and Whitaker 2012, Van Blaricom unpublished data, Vantuna Research Group unpublished data). Thus, the SRT placed the majority of their points in the Very Low, Low, and Moderate risk categories.

6.1.2.2 Extinction risk within the Southern portion

Likelihood points attributed to the categories for the level of extinction risk now and in a foreseeable future of 30 years are as follows: No or Very Low Risk (25/80, or 31%), Low Risk (37/80, or 46%), Moderate Risk (18/80, or 23%), High Risk (0/80, or 0%), Very High Risk (0/80, or 0%). None of the SRT members placed likelihood points in the High or Very High risk categories. The majority (77%) of likelihood points were placed in the No/Very Low and Low risk categories. The category with the greatest number of points was the Low risk category (37 points).

Likelihood points attributed to the categories for the level of extinction risk now and in a foreseeable future of 100 years are as follows: No or Very Low Risk (17/80, or 21%), Low Risk (28/80, or 35%), Moderate Risk (30/80, or 38%), High Risk (5/80, or 6%), Very High Risk (0/80, or 0%). When considering a foreseeable future of 100 years rather than 30 years, most of the SRT members shifted some of their points from the No/Very Low and Low risk categories to the Moderate and/or High risk categories. None of the SRT members placed any likelihood points in the Very High risk category and few points were placed in the High risk category. Two SRT members made no changes to their point distributions, for the same reasons as stated above. In general, the majority (56%) of points was placed in the No/Very Low and Low risk categories. The categories with the greatest number of points were the Low (28 points) and Moderate (30 points) risk categories.

Overall, the SRT concluded that the Southern Portion SPR has a Low risk of extinction now and in a foreseeable future of 30 years and a Low to Moderate risk of extinction now and in a foreseeable future of 100 years. The SRT expressed less concern regarding extinction risk for pinto abalone in California and Mexico compared to the Northern portion. Although there are generally fewer data for the Southern portion, the data that are available indicate recent and recurring recruitment in a number of areas throughout this portion. Just as in the Northern portion, the SRT’s concern regarding the impacts of climate change and ocean acidification increased when considering the 100-year time frame versus the 30-year time frame. This increased concern led the majority of SRT members to shift some of their points from the No/Very Low and Low risk categories to the Moderate and/or High risk categories. However, only three members placed any points in the High risk category and the majority of points remained in the No/Very Low and Low risk categories.

6.1.2.3 Extinction risk within the AK/BC/SJA/SoCal/MX portion (all areas excluding Northern California)

Likelihood points attributed to the categories for the level of extinction risk now and in a foreseeable future of 30 years are as follows: No or Very Low Risk (22/80, or 28%), Low Risk (34/80, or 43%), Moderate Risk (23/80, or 29%), High Risk (1/80, or 1%), Very High Risk (0/80, or 0%). None of the SRT members placed likelihood points in the Very High risk category and only one member placed a likelihood point in the High risk category. The majority (71%) of likelihood points were placed in the No/Very Low and Low risk categories. The category with the greatest number of points was the Low risk category (34 points).

Likelihood points attributed to the categories for the level of extinction risk now and in a foreseeable future of 100 years are as follows: No or Very Low Risk (15/80, or 19%), Low Risk (29/80, or 36%), Moderate Risk (30/80, or 38%), High Risk (6/80, or 8%), Very High Risk (0/80, or 0%). When considering a foreseeable future of 100 years rather than 30 years, most of the SRT members shifted some of their points from the No/Very Low and Low risk categories to the Moderate and/or High risk categories. None of the SRT members placed any likelihood points in the Very High risk category and few points were placed in the High risk category. Two

SRT members made no changes to their point distributions, for the same reasons as stated above. In general, the majority (55%) of points were placed in the No/Very Low and Low risk categories. The categories with the greatest number of points were the Low (29 points) and Moderate (30 points) risk categories.

Overall, the SRT concluded that the portion of the range of pinto abalone including all areas except Northern California has a Low risk of extinction now and in a foreseeable future of 30 years and a Low to Moderate risk of extinction now and in a foreseeable future of 100 years. The SRT's conclusions regarding extinction risk within this portion was similar to the conclusions for the Southern portion. Although this portion encompasses the Northern portion, the SRT expressed less concern regarding extinction risk for pinto abalone in this portion compared to the Northern portion alone. The majority of the SRT members attributed less risk to this portion due to the inclusion of the Southern California and Mexico populations, stating that the larger geographic area being considered provides a buffer from threats that may be more pronounced in the Northern portion compared to the Southern portion. In addition, this portion includes more areas where recent recruitment and increasing population abundances have been identified. The likelihood that the species will persist increases when considering the larger geographic area. As for the Northern and Southern portions, the SRT's concern regarding the impacts of longer-term threats such as climate change and ocean acidification increased when considering the 100-year time frame versus the 30-year time frame. This increased concern again led the majority of SRT members to shift some of their points from the No/Very Low and Low risk categories to the Moderate and/or High risk categories. However, only three members placed any points in the High risk category and the majority of points remained in the Very Low and Low risk categories.

6.1.2.4 Overall extinction risk analysis for potential SPRs

The SRT expressed greater concern regarding extinction risk to the species within the Northern portion of its range (AK/BC/SJA) than in the Southern portion (NorCal/SoCal/MX) or the AK/BC/SJA/SoCal/MX portion encompassing all areas excluding Northern California. The SRT also expressed greater concern, as well as greater uncertainty, regarding extinction risk to the species when considering a foreseeable future of 100 years compared to 30 years. Even so, the SRT concluded that Low to Moderate risks to the species within any of these portions and over either time frame were the most plausible. Within the Southern portion and AK/BC/SJA/SoCal/MX portion, the level of extinction risk to the species now and in the foreseeable future (30 years and 100 years) is most likely to be Very Low to Low. The SRT did not believe that the species is likely to be at High or Very High risk of extinction in any of the portions over either time frame.

We note that the distribution of likelihood points across extinction risk categories for the Northern portion was similar to the distribution of likelihood points for the species throughout its range, across both time frames for foreseeable future (Figure 52). This indicates that the SRT’s assessment of overall extinction risk to the species throughout its range was greatly influenced by the SRT’s view of the species’ status within the Northern portion. We also note that the distribution of likelihood points across extinction risk categories for the AK/BC/SJA/SoCal/MX portion differed from the distribution of likelihood points for the species throughout its range, though the two areas differed only in the inclusion or exclusion of Northern California (Figure 52). Almost all SRT members attributed lower risk to the species within the

AK/BC/SJA/SoCal/MX portion than throughout the species range. This is likely because evaluating the Northern portion and the Southern portion separately gave the SRT a new perspective on the overall extinction risk to the species. When considering the AK/BC/SJA/SoCal/MX portion compared to the Northern portion alone, most SRT members stated that the inclusion of populations in Southern California and Mexico reduced their concern regarding extinction risk to the species. The SRT's assessment may also have been influenced by recent reports of pinto abalone off Southern and Northern California in greater numbers than previously observed (L. Rogers-Bennett, pers. comm.; A. Rafferty, pers. comm.). This information became available after the SRT conducted the overall extinction risk analysis for the species throughout its range, but before the analysis of potential SPRs.

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8.0 Tables

Table 1. History of pinto abalone size limits in the commercial fishery in Southeast Alaska (modified from Woodby *et al.* 2000).

Year*	Minimum Shell Length (mm/in)	Fishing Districts
1962	76/3	All
1967	102/4	1-4
1968	102/4	1-6
1976	89/3.5	9-14
1977	89/3.5	All
1979	95/3.75	All
1994	102/4	All

*__Note:__ The first year that the stated size limit was imposed is given for the listed districts

Table 2. Registration Area A (Southeast Alaska) commercial abalone harvest, effort, value, and season length, 1970/71 through 1996/97 (Rumble and Hebert 2011).

Season	Guideline Harvest Range (lb x 1,000)	Southern Southeast Harvest (lb)	District 13 Harvest (lb)	Total Southeast Harvest (lb)	Number of Divers	Exvessel Value	Season Length (days)
1970/71							365
1971/72		Confidential Data—Less than 3 divers reporting landings					365
1972/73		65	2,610	2,675	6	$2,675	365
1973/74			3,000	3,000	3	$4,500	365
1974/75			13,826	13,826	3	$20,739	365
1975/76		55	8,497	8,552	8	$17,104	365
1976/77		Confidential Data—Less than 3 divers reporting landings					365
1977/78		805	10,861	11,666	10	$14,816	365
1978/79		130,607	49,320	179,927	35	$253,697	365
1979/80		316,952	61,733	378,685	43	$408,980	287
1980/81	250	233,589	18,382	251,971	40	$420,792	273
1981/82	100–125	338,305	32,589	370,894	54	$445,073	59
1982/83	100–125	100,458	12,826	113,284	41	$240,162	36
1983/84	100–125	99,294	8,735	108,029	31	$302,481	126
1984/85	100–125	59,237	8,379	67,616	25	$165,659	151
1985/86	25–58	32,817	7,720	40,537	18	$117,963	71
1986/87	25–58	47,404	13,820	61,224	24	$168,366	146
1987/88	25–58	57,209	10,406	67,615	42	$208,930	36
1988/89	25–58	65,928	10,172	76,100	45	$307,444	33
1989/90	25–58	57,784	4,020	61,804	67	$330,651	40
1990/91	25–58	62,779	5,607	68,386	97	$374,071	9
1991/92	25–58	35,987	8,095	44,082	96	$267,578	35
1992/93	25–58	26,905	9,083	35,988	100	$386,151	19
1993/94	25–58	27,680	7,172	34,852	86	$487,928	7
1994/95	25–58	15,055	7,824	22,879	102	$330,373	8
1995/96	0–16	8,524	5,828	14,352	100	$126,526	6
1996/97				closed			

Table 3. Average number of pinto abalone harvested for subsistence uses per household, by community, 1972-1997 (Bowers *et al.* 2011).

	Town		
Year	**Hydaburg**	**Klawock**	**Craig**
1972	382	397	350
1977	373	307	283
1980	230	128	125
1981	236	111	68
1987	75	60	41
1997	9	3	6

Table 4. Landings, CPUE, catch quota, and number of individual pinto (aka northern) abalone in the British Columbia commercial fishery from 1952–1990. The fishery did not operate after December 1990. Estimated number of individual abalone landed are based on the predicted mean weight of a legal-sized northern abalone of 159.7 g (n = 1,438) from 1952–1976 (≥ 90 mm SL) and 185.3 g (n = 976) from 1977–1990 (≥ 100 mm SL). Mean weight of legal-sized abalone derived from pinto abalone length and weights reported in Quayle (1971) at Sivart Island in Haida Gwaii, Ramsbotham Reef on the Central Coast, Bauke Island on the West Coast of Vancouver Island, and Hornby Island in the Strait of Georgia. Other data from Fedorenko and Sprout (1982), Sloan and Breen (1988), and Campbell (1997).

Year	Landings (mt)	CPUE (kg per hr)	Quota (mt)	Commercial licenses	Legal size SL (mm)	Number of abalone landed
1952	5.4		N/A	open	90.0	33,809
1953	10.3		N/A	open	90.0	64,487
1954	6.9		N/A	open	90.0	43,200
1955	3.5		N/A	open	90.0	21,913
1956	0.5		N/A	open	90.0	3,130
1957	0.9		N/A	open	90.0	5,635
1958	5.3		N/A	open	90.0	33,183
1959	0.2		N/A	open	90.0	1,252
1960	1.5		N/A	open	90.0	9,391
1961	9.4		N/A	open	90.0	58,852
1962	17.5		N/A	open	90.0	109,565
1963	5.7		N/A	open	90.0	35,687
1964	57.1		N/A	open	90.0	357,496
1965	3.1		N/A	open	90.0	19,409
1966	0.7		N/A	open	90.0	4,383
1967	0.9		N/A	open	90.0	5,635
1968	0.1		N/A	open	90.0	626
1969	0.6		N/A	open	90.0	3,757
1970	16.2		N/A	open	90.0	101,426
1971	6.4		N/A	open	90.0	40,070
1972	59.6		N/A	open	90.0	373,148
1973	67.1		N/A	open	90.0	420,105
1974	26.3		N/A	open	90.0	164,661
1975	56.7		N/A	open	90.0	354,992
1976	273.1		N/A	open	90.0	1,709,846
1977	481.4	43.5	N/A	29	101.6	2,597,755
1978	403.9	34.2	N/A	27	101.6	2,179,546
1979	208.6	32.7	227	26	101.6	1,125,658
1980	104.6	31.4	113	26	101.6	564,448
1981	93.6	34.2	94	26	100.0	505,089
1982	82.1	31.2	94	26	100.0	443,032
1983	53.1	34.5	71	26	100.0	286,541
1984	57.7	31.0	59	26	100.0	311,364
1985	45.2	31.6	47	26	100.0	243,911
1986	45.7	24.3	47	26	100.0	246,609
1987	46.4	26.9	47	26	100.0	250,386
1988	47.3	23.2	47	26	100.0	255,243
1989	46.9	23.9	47	26	100.0	253,084
1990	47.3	23.6	47	26	100.0	255,243

Table 5. Mean (± SE) total, immature, mature, and large pinto abalone (aka northern abalone) density estimates (exposed abalone/m^2) by year from all sites surveyed in Southeast Haida Gwaii, British Columbia (Hankewich *et al.* 2008, COSEWIC 2009).

Haida Gwaii	Year								
	1978	1979	1984	1987	1990	1994	1998	2002	2007
Number of sites	51	10	70	70	69	70	115	68	82
All abalone / m^2	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	0.4 ± 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

Table 6. Mean (± SE) total, immature, mature, and large pinto abalone (aka northern abalone) density estimates (exposed abalone/m^2) by year from all sites surveyed in the Central Coast region of British Columbia (Hankewich and Lessard 2008, COSEWIC 2009).

Central Coast	Year									
	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006
Number of sites	12	14	19	42	28	26	33	47	55	68
All abalone / m^2	2.40 ± 0.43	2.94 ± 0.66	3.09 ± 0.49	1.58 ± 0.26	1.50 ± 0.18	0.55 ± 0.11	0.46 ± 0.07	0.42 ± 0.07	0.27 ±0.04	0.40 ±0.06
Immature (<70 mm SL)	0.27 ± 0.08	0.59 ± 0.13	1.40 ± 0.31	0.37 ± 0.08	0.32 ± 0.07	0.14 ± 0.05	0.15 ± 0.02	0.12 ± 0.03	0.10 ± 0.02	0.18 ± 0.03
Mature (>70 mm SL)	2.13 ± 0.38	2.35 ± 0.61	1.68 ± 0.30	1.22 ± 0.21	1.18 ± 0.03	0.41 ± 0.08	0.32 ± 0.06	0.30 ± 0.06	0.17 ± 0.03	0.23 ± 0.04
Large (>100 mm SL)	1.10 ± 0.22	0.62 ± 0.17	0.26 ± 0.09	0.24 ± 0.04	0.33 ± 0.07	0.10 ± 0.02	0.08 ± 0.02	0.10 ± 0.02	0.04 ± 0.01	0.02 ± 0.01

Table 7. Mean densities, total count, and populations size estimates of pinto abalone (aka northern abalone) surveyed for broodstock purposes using the "transect survey method" at McCauley and Goschen islands near Kitkatla, British Columbia in 2000 (Lucas *et al.* 2002b).

	McCauley Island	Goschen Island
Year	2000	2000
Number of transects	33	16
All size abalone (#/m^2)	0.16	0.05
Total abalone count	322	82
Mean size (mm SL)	86	80
Total population all sizes	34,405	20,750

Table 8. Mean densities, total count, and populations size estimates of pinto abalone (aka northern abalone) surveyed for broodstock purposes using the "transect survey method" at southern Denman and Chrome islands in the Strait of Georgia in 2000 and 2001 (Lucas *et al.* 2002e).

	S. Denman and Chrome Islands	S. Denman Island
Year	2000	2001
Number of transects	15	6
All size abalone (#/m^2)	0.06	0.05
Mean density (90–110 mm SL)	0.02	0.02
Total abalone count	40	9
Total population all sizes	7,351	5,216

Table 9. Mean (± SE) densities, total count, and mean (± SE) shell length of pinto abalone (aka northern abalone) surveyed using the “Breen survey method” at Cortes and Texada islands in the Strait of Georgia in 2009 (Egli and Lessard 2011).

	Cortes Island	Texada Island
Year	2009	2009
Number of transects	14	16
All size abalone (#/m^2)	0.013 ± 0.007	0.012 ± 0.012
Total abalone count	3	3
Mean size (mm SL)	81.7 ± 31.5	89.3 ± 7.8
Percent of sites with abalone	21%	6%

Table 10. Mean (± SE) densities, total count, and percent of sites with pinto abalone (aka northern abalone) surveyed using the “Breen survey method” on the north-west coast of Vancouver Island in 2003 (Atkins and Lessard 2004).

	Quatsino Sound	Brooks Bay	Exposed Coast	All areas
Year	2003	2003	2003	
Number of sites	13	5	14	32
All size abalone (#/m^2)	0.212 ± 0.080	0.038 ± 0.020	0	0.092 ± 0.038
Immature (<70 mm SL)	--	--	0	0.055 ± 0.032
Mature (>70 mm SL)	--	--	0	0.037 ± 0.014
Large (>100 mm SL)	--	--	0	0.004 ± 0.004
Total abalone count	44	3	0	47
Mean size (mm SL)	--	--	--	59.1 ± 3.7
Percent of sites with abalone	54%	20%	0%	25%

Table 11. Mean densities, total count, and populations size estimates of pinto abalone (aka northern abalone) surveyed for broodstock purposes using the “transect survey method” at South-east Barkley Sound on Vancouver Island in 2000 and 2002 (Lucas *et al.* 2002e, Lessard *et al.* 2004).

	Aguilar Point	Dixon Island	West Edward King Island	East Edward King Island	
Year	2000	2000	2000	2000	2002
Number of transects	5	6	11	11	15
All size abalone (#/m^2)	0.07	0.01	0.02	0.235 ± 0.049	0.295 ± 0.051
Total abalone count	11	1	29	77	108
Mean density (81–120 mm SL)	--	--	--	0.179 ± 0.044	0.123 ± 0.027
Mean population all sizes	1,082	239	7,085	21,161	21,075
Mean population (81–120 mm SL)	--	--	--	16,086	8,791

Table 12. Mean densities, total count, and populations size estimates of pinto abalone (aka northern abalone) surveyed for broodstock purposes using the "transect survey method" at three sites in Queen Charlotte Strait in 1999 (Lucas *et al.* 2002a).

	Cormorant Island	Bere Bay	Trinity Bay
Year	1999	1999	1999
Number of transects	7	8	4
All size abalone (#/m^2)	0.05	0.04	0.03
Total abalone count	23	25	19
Total population all sizes	3,614	5,081	4,038

Table 13. Mean densities, total count, and percent of sites with pinto abalone (aka northern abalone) surveyed using the "Breen survey method" in Johnstone Strait (Davies *et al.* 2006) and Queen Charlotte Strait (Davies *et al.* 2006, Lessard and Egli 2011) in 2004 and 2009.

	Johnstone Strait	North Queen Charlotte Strait	Queen Charlotte Strait - Gordon Channel	
Year	2004	2009	2004	2009
Number of sites	24 (random sites)	17	19	17
All size abalone (#/m^2)	0.003 ± 0.003	0.055 ± 0.020	0.042 ± 0.020	0.164 ± 0.061
Immature (<70 mm SL)	0.000 ± 0.000	0.018 ± 0.015	0.019 ± 0.016	0.057 ± 0.023
Mature (>70 mm SL)	0.020 ± 0.020	0.037 ± 0.016	0.023 ± 0.010	0.106 ± 0.047
Large (>100 mm SL)	0.000 ± 0.000	0.007 ± 0.005	0.003 ± 0.003	0.035 ± 0.016
Total abalone count	1	15	13	39
Mean size (mm SL)	135.0	76.1 ± 5.6	77.7 ± 4.9	79.8 ± 2.9
Percent of sites with abalone	4.2%	41%	26%	41%

Table 14. Survey sites, survey area, and number of pinto abalone observed at each of 10 survey sites from 1992–2013 in the San Juan Islands Archipelago. Data from WDFW public comment submission Excel file: 13July29_1992_2013_Index_Station_Summary_Data (revised 12/31/2013). Site numbers correspond with those in Figure 27.

		Pinto abalone index station abundance by survey year							
Index Stations	Area (m^2)	1992	1994	1996	2003	2005	2006	2009	2013
(1) Long Island West	152	48	36	7	8	2	4	4	1
(2) Williamson Rocks	190	20	34	32	7	9	10	9	7
(3) North Cypress Island	316	46	21	8	0	1	0	1	0
(4) Parker Reef	375	45	19	19	2	0	0	0	0
(5) Ripple Island	135	41	23	3	1	1	0	0	0
(6) Big Cactus Island	158	49	41	74	39	14	13	6	12
(7) Spieden Island	176	49	30	18	17	10	5	5	1
(8) Deadman’s Bay	155	22	24	31	19	15	11	9	0
(9) Old Eagle Point	229	22	29	14	18	11	12	17	0
(10) Long Island East	356	17	30	24	27	13	9	9	6
Total	2242	359	287	230	138	76	64	60	27

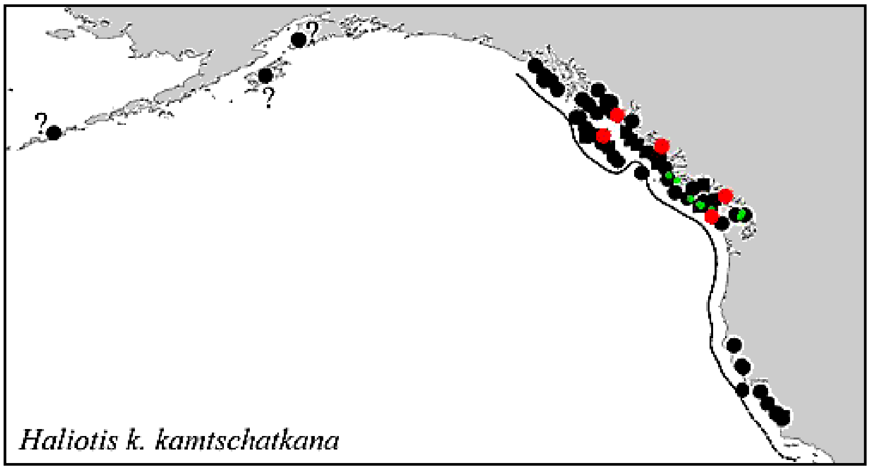
Table 15. Demographic “risk matrix” evaluation worksheet for pinto abalone. Each SRT member scored the likelihood of the following questions related to the four demographic risk criteria of abundance, growth rate/productivity, spatial structure/connectivity, and diversity, by distributing10 points among eight likelihood bins: exceptionally unlikely (<1%), very unlikely (1-10%), unlikely (10-33%), less likely than not (33-50%), more likely than no (50-66%), likely (66-90%), very likely (90-99%), and virtually certain (>99%).

Risk category	**<1%**	**1-10%**	**10-33%**	**33-50%**	**50-66%**	**66-90%**	**90-99%**	**>99%**
ABUNDANCE								
1. Is the species’ abundance so low that it is at risk of extinction due to environmental variation or anthropogenic perturbations (of the patterns and magnitudes observed in the past and expected in the future)?								
2. Is the species’ abundance so low, or variability in abundance so high, that it is at risk of extinction due to depensatory processes?								
3. Is the species’ abundance so low that its genetic diversity is at risk due to inbreeding depression, loss of genetic variants, or fixation of deleterious mutations?								
4. Is a species’ abundance so low that it is at risk due to demographic stochasticity?								
GROWTH RATE/ PRODUCTIVITY								
1. Is a species’ average population growth rate below replacement and such that it is at risk of satisfying the abundance conditions described above?								
2. Is the species’ average population growth rate below replacement and such that it is unable to exploit requisite habitats/niches/etc. or at risk due to depensatory processes during any life-history stage?								
3. Does the species exhibit trends or shifts in demographic or reproductive traits that portend declines in per capita growth rate which pose risk of satisfying any of the preceding conditions?								
SPATIAL STRUCTURE/ CONNECTIVITY								
1. Are habitat patches being destroyed faster than they are naturally created such that the species is at risk of extinction due to environmental and anthropogenic perturbations or catastrophic events?								
2. Are natural rates of dispersal among populations, metapopulations, or habitat patches so low that the species is at risk of extinction due to insufficient genetic exchange among populations, or an inability to find or exploit available resource patches?								
3. Is the species at risk of extinction due to the loss of critical source populations, subpopulations, or habitat patches?								
DIVERSITY								
1. Is the species at risk due to a substantial change or loss of variation in life-history traits, population demography, morphology, behavior, or genetic characteristics?								
2. Is the species at risk because natural processes of dispersal, migration, and/or gene flow among populations have been significantly altered?								
3. Is the species at risk because natural processes that cause ecological variation have been significantly altered?								

9.0 Figures

Figure 1. Geographic distribution of a) *H. k. kamtschatkana* and b) *H. k. assimilis* based on specimen records (after Geiger, 2004). A continuous line shows the range on which most experts agree, broken lines show the range that some authors mention, others do not. Circles indicate specimen records, squares indicate literature record, question marks show a dubious record. Dots in red are new records not published in Geiger (2000), dots in green are from the Australian Museum, Sydney. Maps adapted from: http://www.vetigastropoda.com/ABMAP/kamt-map.html and http://www.vetigastropoda.com/ABMAP/assi-map.html

a)



b)

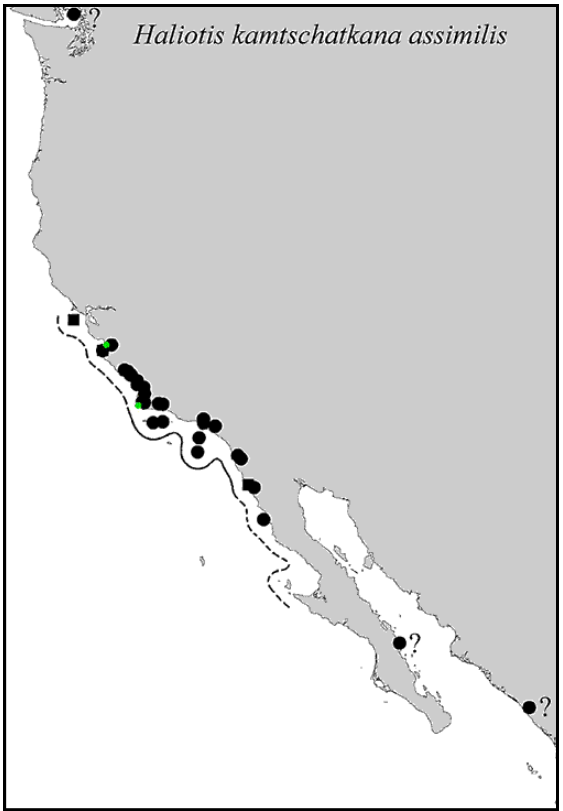
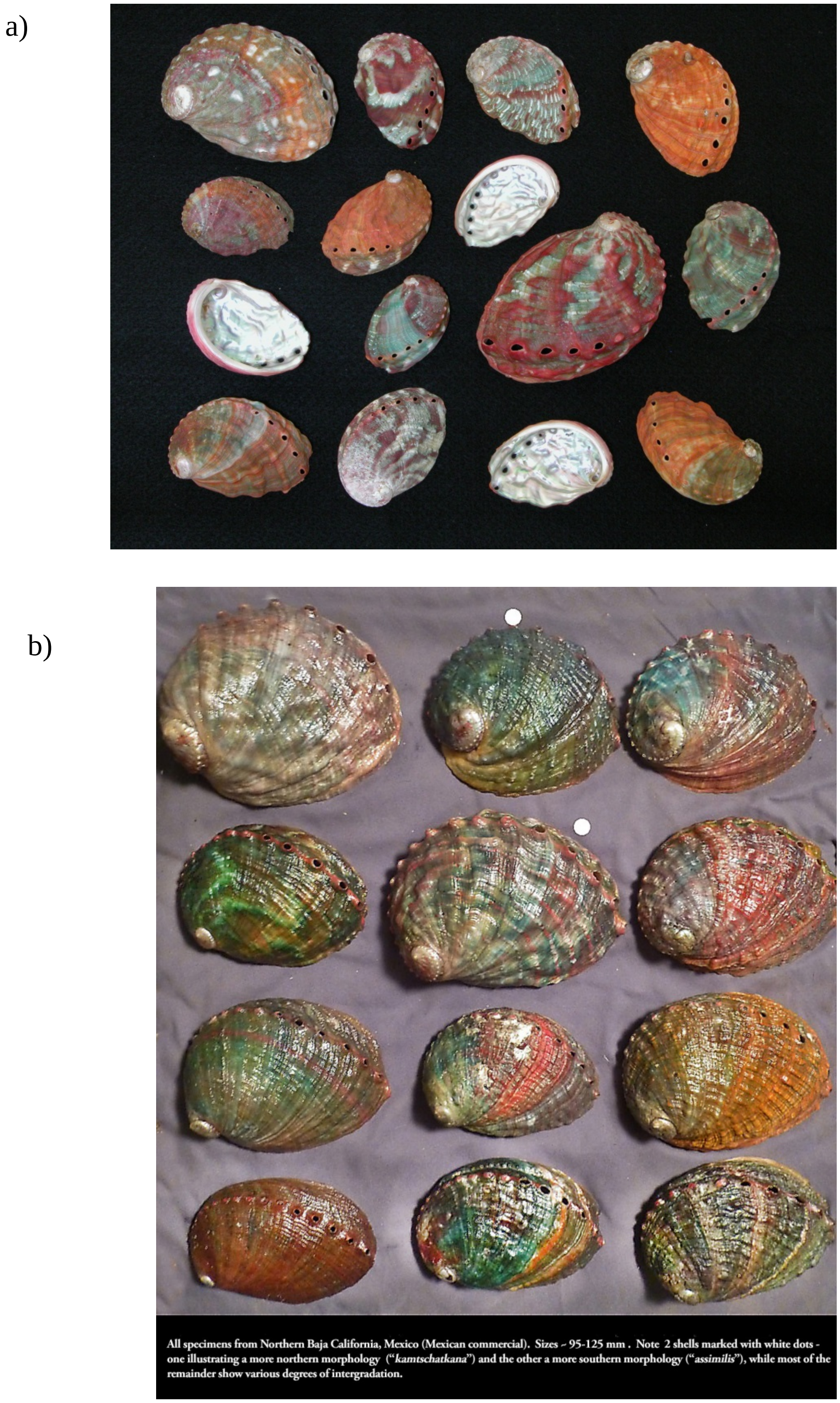


Figure 2. Examples of morphological variation in shells collected by Buzz Owen and Arjay Rafferty at a) northern (Washington) and b) southern (Baja California) limits of the species range. a) and b) provide examples of shells that represent both taxonomically recognized subspecies in Washington and Baja California, respectively.



All specimens from Northern Baja California, Mexico (Mexican commercial). Sizes ~ 95-125 mm . Note 2 shells marked with white dots - one illustrating a more northern morphology ("*kamtschatkana*") and the other a more southern morphology ("*assimilis*"), while most of the remainder show various degrees of intergradation.

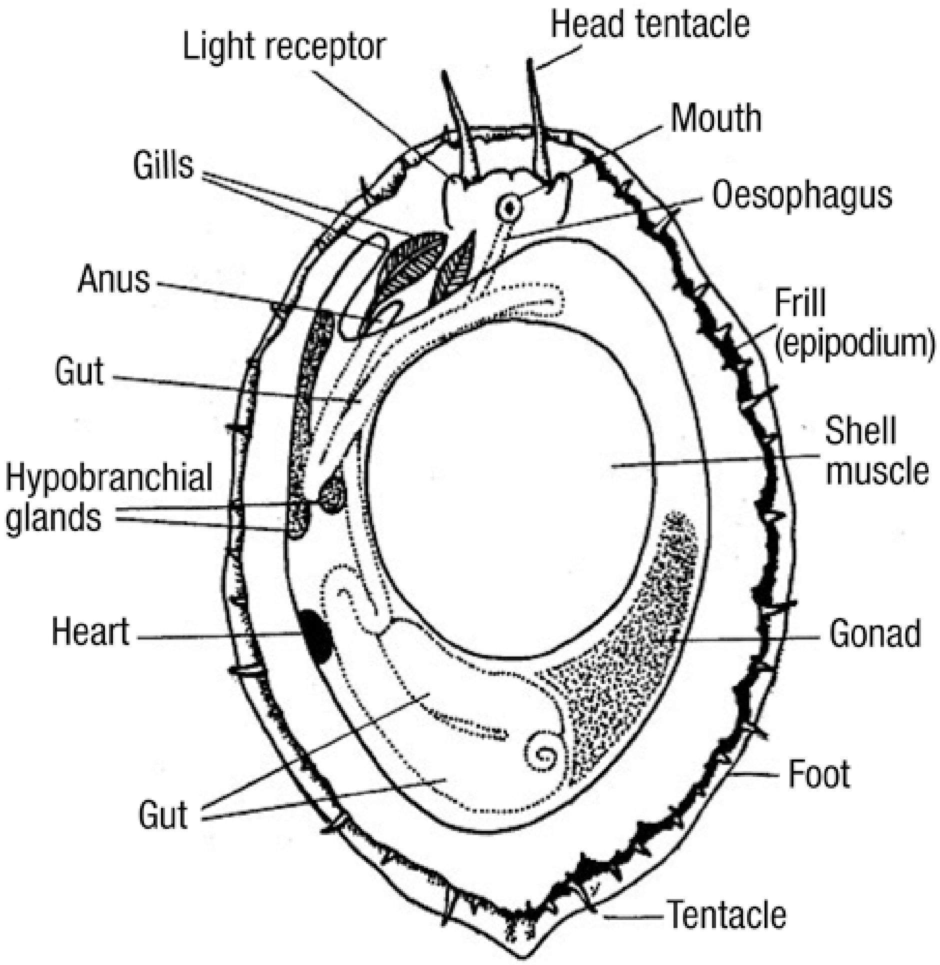


Figure 3. Anatomy of an abalone with shell removed. From Cox, 1962.

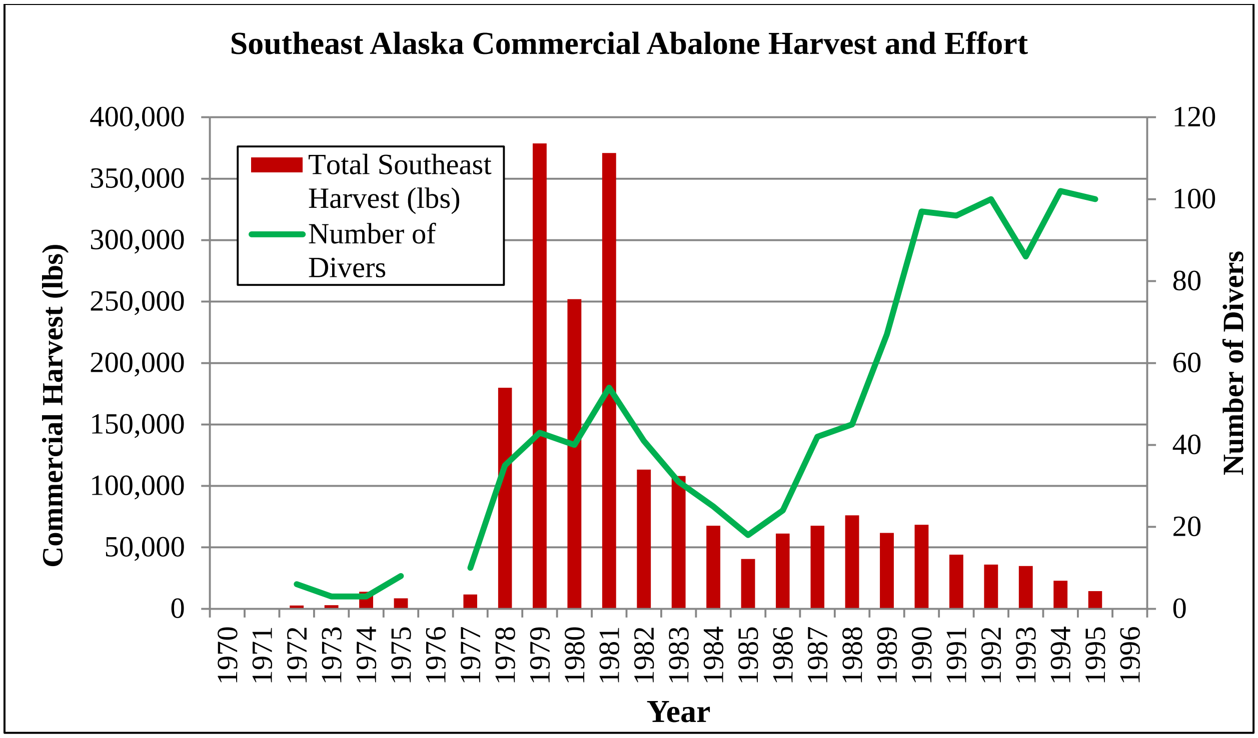


Figure 4. Commercial harvest amount and number of divers in the pinto abalone dive fishery in Southeast Alaska from 1970-1996 (adapted from K. Hebert and S. Walker presentation, March 2014).

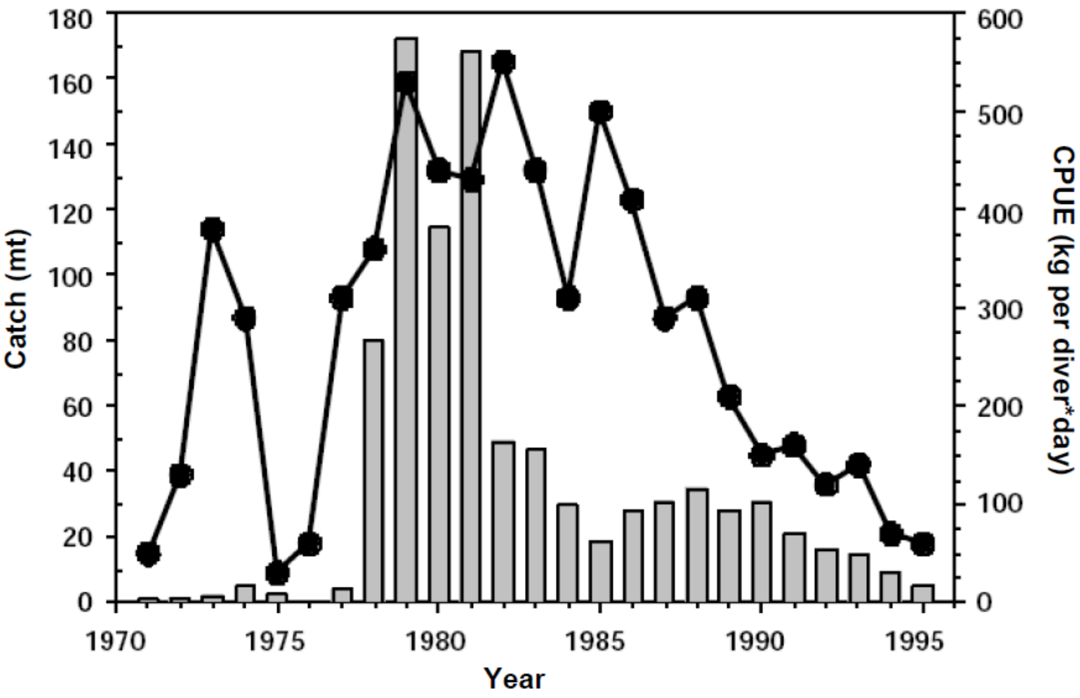
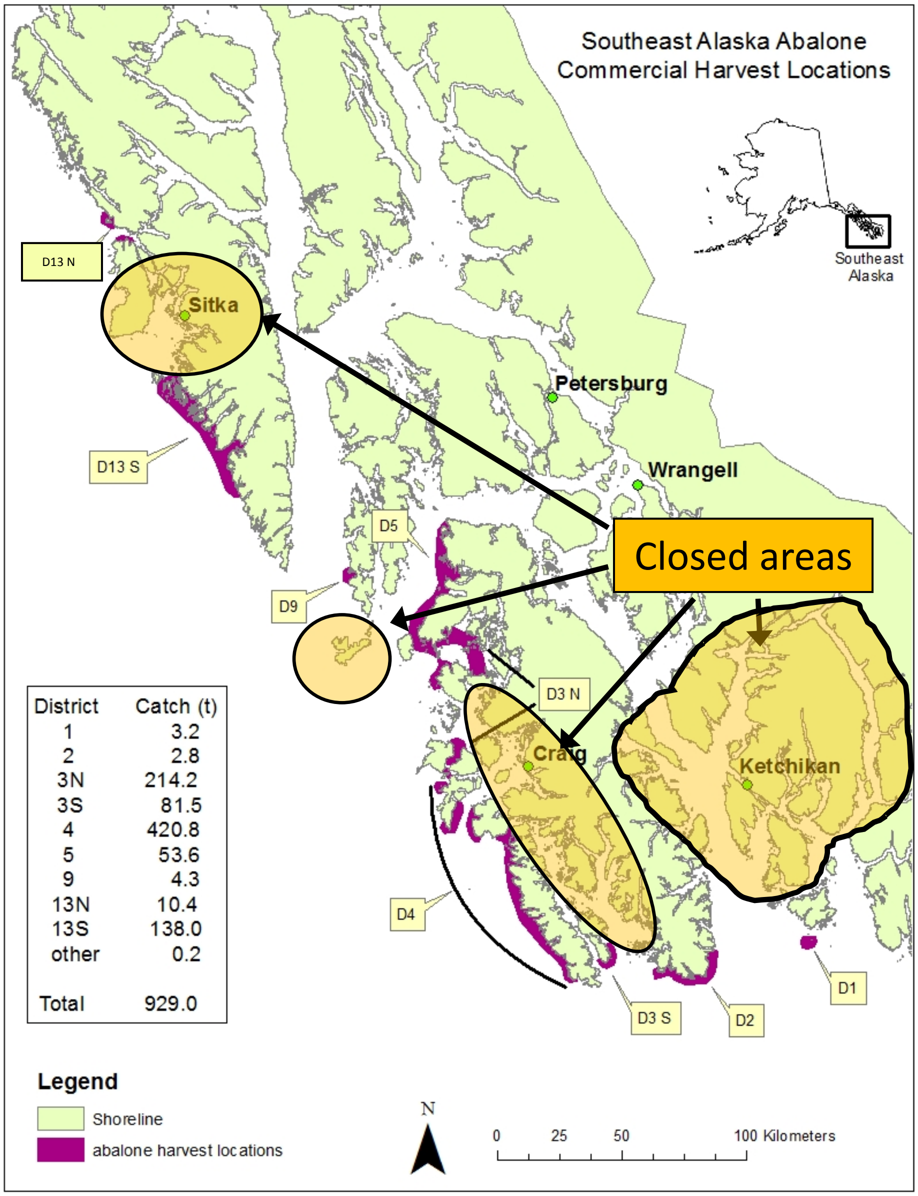


Figure 5. Catch (metric tons) and catch per unit effort (kg per diver day) for the commercial pinto abalone dive fishery in Southeast Alaska. Bars represent catch and line represents catch per unit effort (source Woodby *et al.* 2000).

Figure 6. Pinto abalone commercial harvest locations in Southeast Alaska including four closure areas that were put in place to enhance the subsistence, sport, and personal use fisheries (adapted from K. Hebert and S. Walker presentation, March 2014).



District	Catch (t)
1	3.2
2	2.8
3N	214.2
3S	81.5
4	420.8
5	53.6
9	4.3
13N	10.4
13S	138.0
other	0.2
Total	929.0

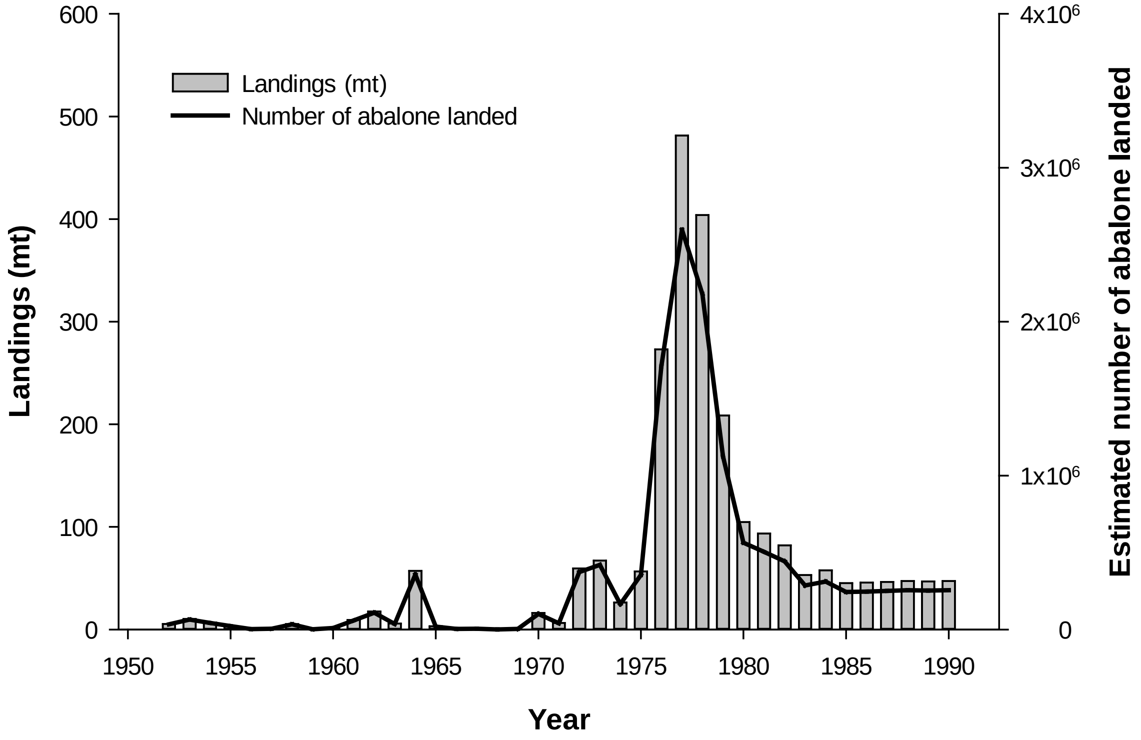


Figure 7. Biomass (mt) and estimated number of pinto (aka northern) abalone landed in the British Columbia commercial dive fishery from 1952–1990. Estimated number of individual abalone landed are based on the predicted mean weight of a legal-sized northern abalone of 159.7 g from 1952–1976 (≥ 90 mm SL) and 185.3 g from 1977–1990 (≥ 100 mm SL) (Quayle 1971, Fedorenko and Sprout 1982, Sloan and Breen 1988, Campbell 1997).

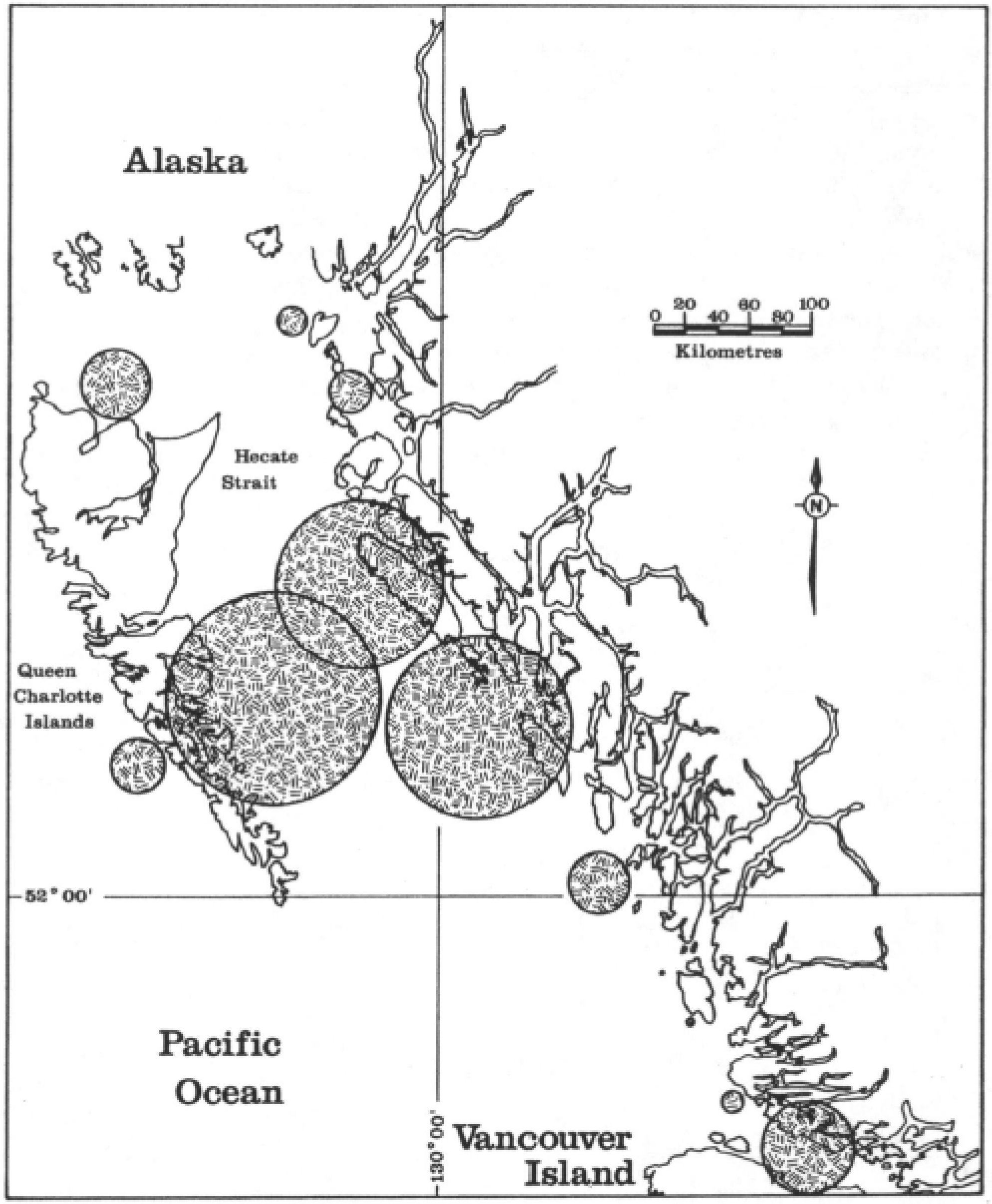
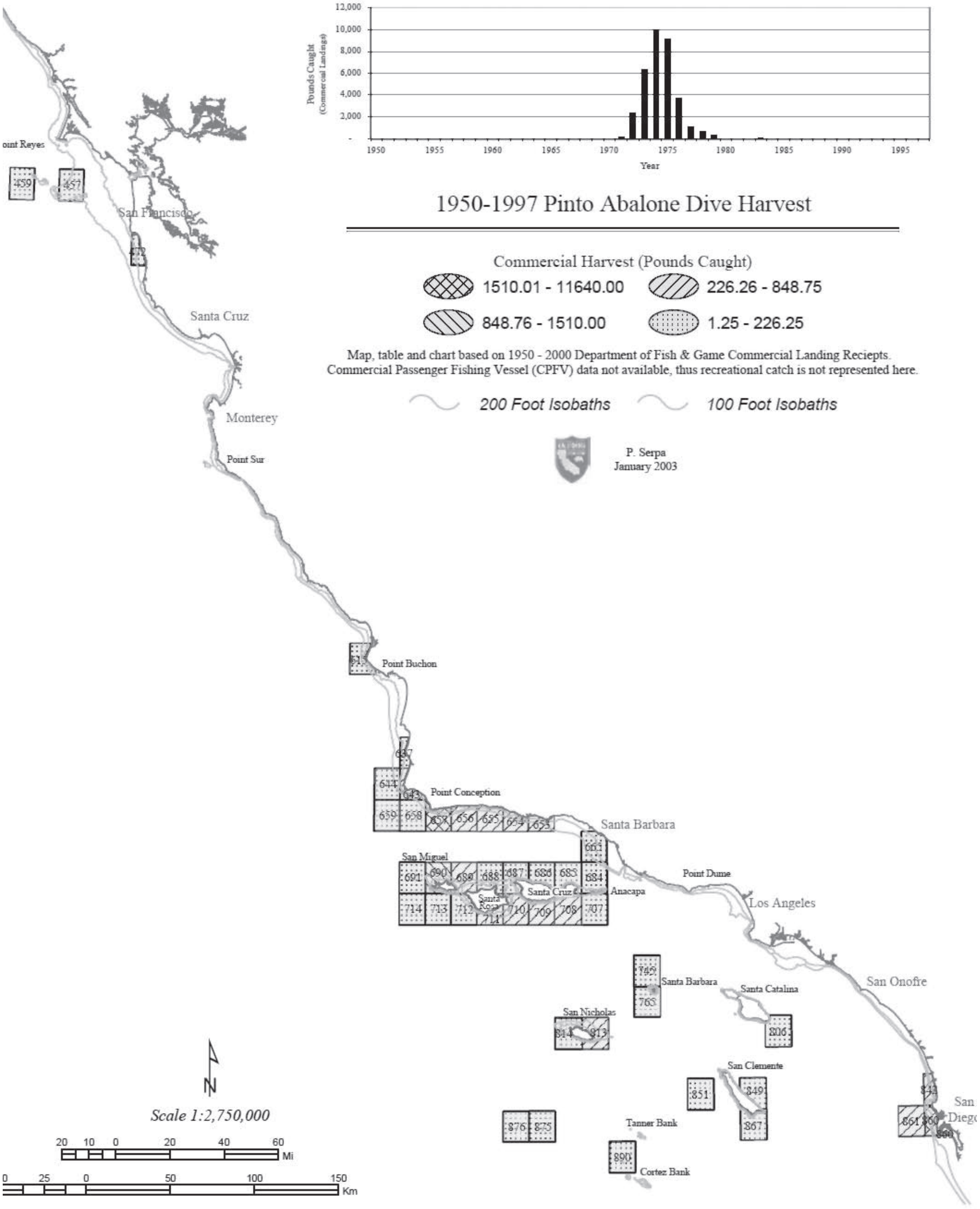


Figure 8. Map of northern British Columbia coast depicting the major areas where pinto (aka northern) abalone were landed during the peak of the commercial fishery during 1977–1979. Areas of circles are proportional to catches as reported by fishers. Copied from Breen (1986).

Figure 9. Abalone landings data recorded by the California Department of Fish and Wildlife 1950-1997 (CDFW 2005).



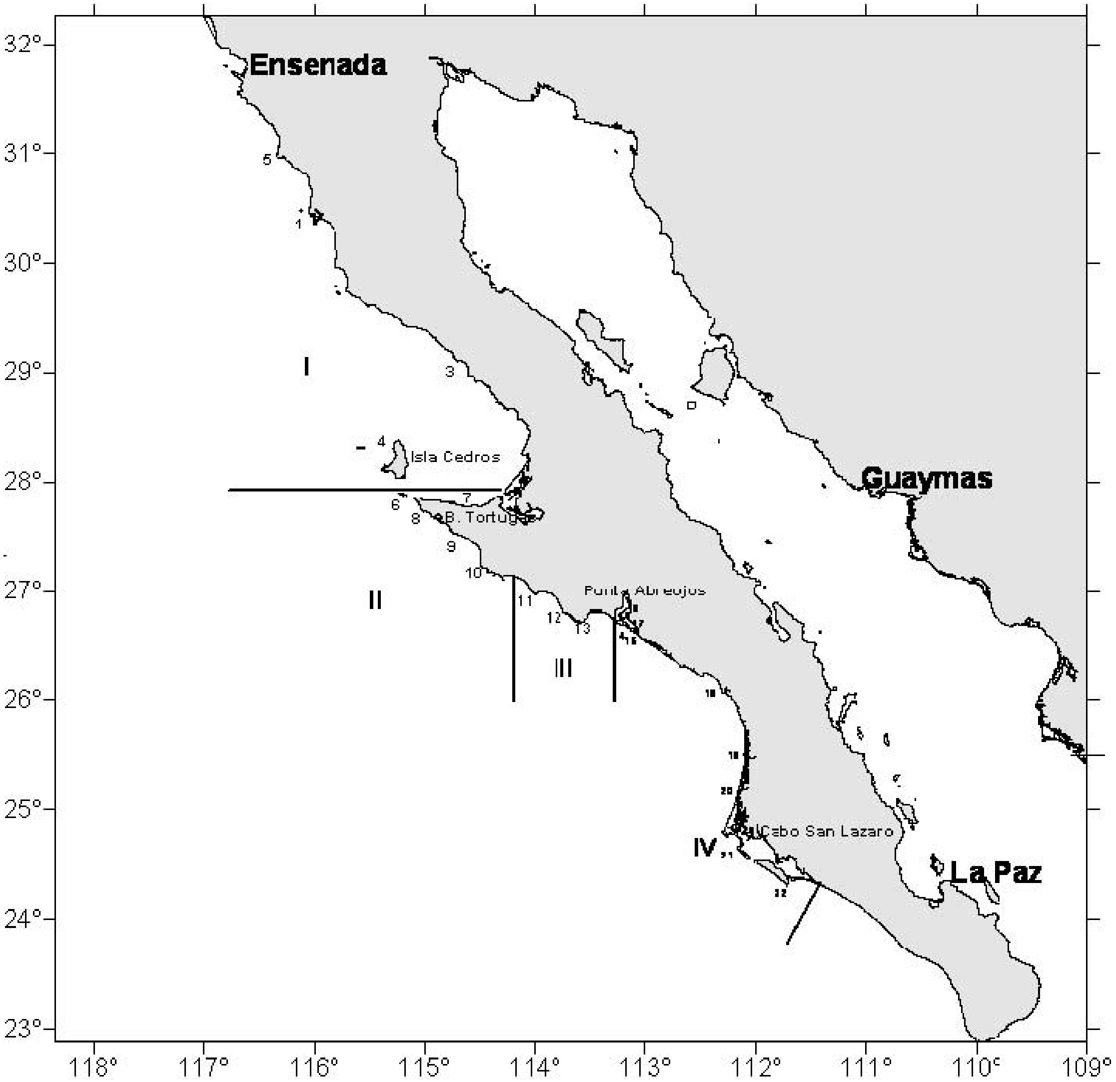


Figure 10. Four abalone fishery management zones (I-IV), encompassing 22 fishing cooperatives (1-22), along the Pacific coast of the Baja California Peninsula, Mexico. Adapted from Sierra-Rodriguez *et al.* 2006.

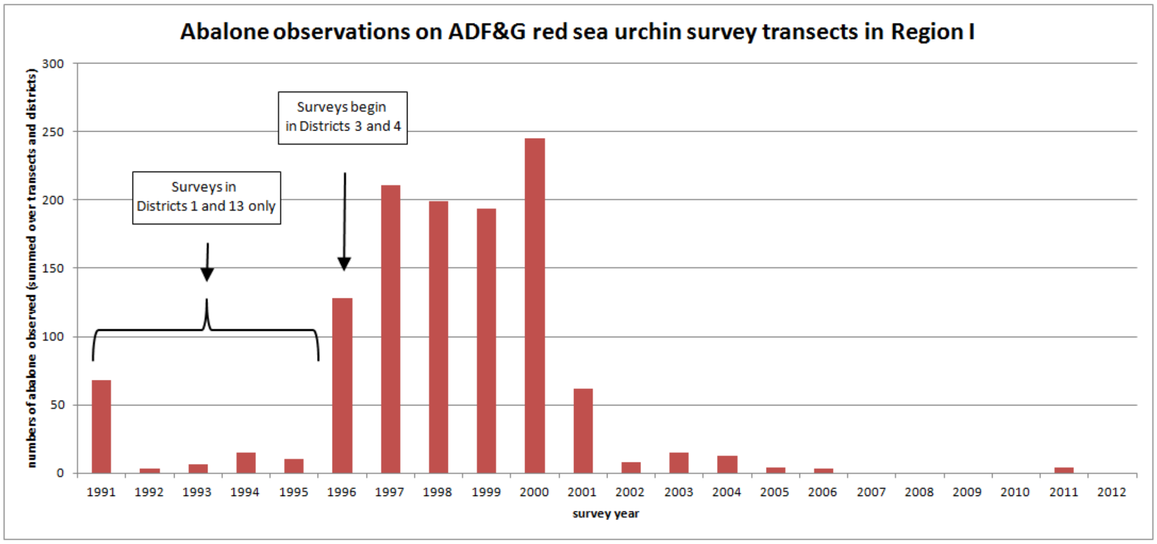


Figure 11. Observations of abalone recorded during red sea urchin surveys, combined for all Alaska Department of Fish and Game (ADF&G) Subdistricts surveyed 1991-2012. Data was obtained by chance encounters with abalone, was collected during surveys designed to estimate red sea urchin density, and was recorded on a volunteer basis by survey divers. Therefore, results should be considered as a low quality index of abalone abundance. However, abalone and red sea urchins occupy very similar habitats and it is believed that the lower frequency of abalone encountered during urchin surveys over the past decade is indicative of much lower abalone abundance in Southeast Alaska than in prior years (ADF&G abalone observations 1991-2012; ADF&G comments to NMFS, 17 January 2014).

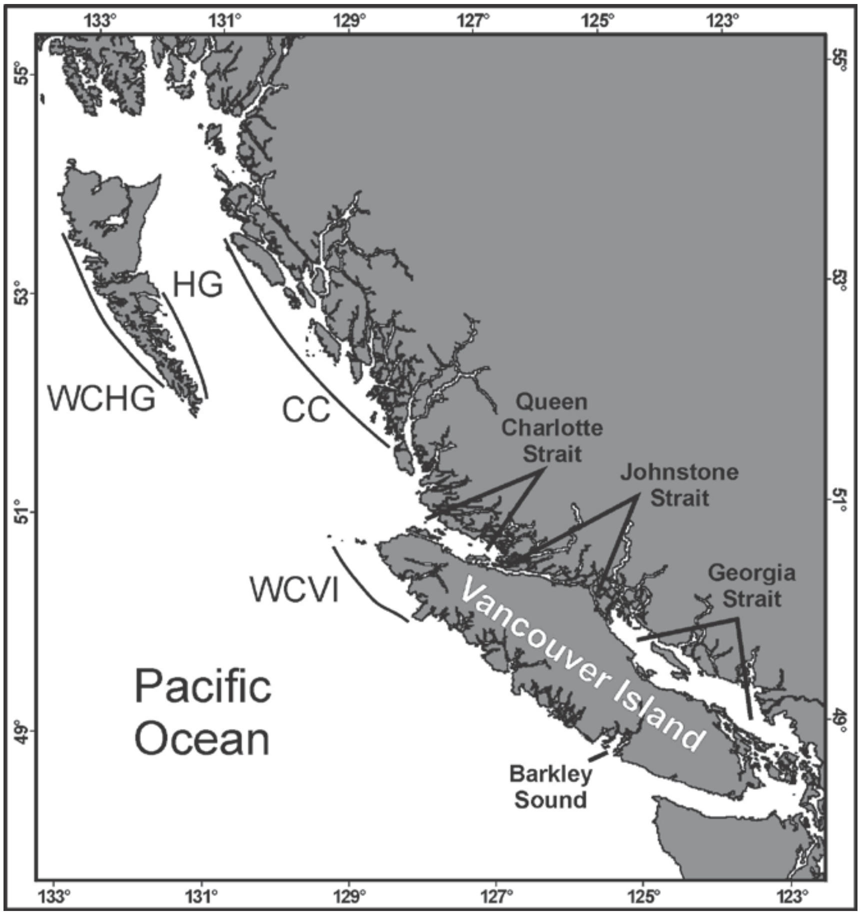


Figure 12. Map of coastal British Columbia, Canada showing pinto abalone (aka northern abalone) index survey areas (J. Lessard, pers. comm.). WCVI, West Coast Vancouver Island; CC, Central Coast; HG, southeastern Haida Gwaii; WCHG, West Coast Haida Gwaii.

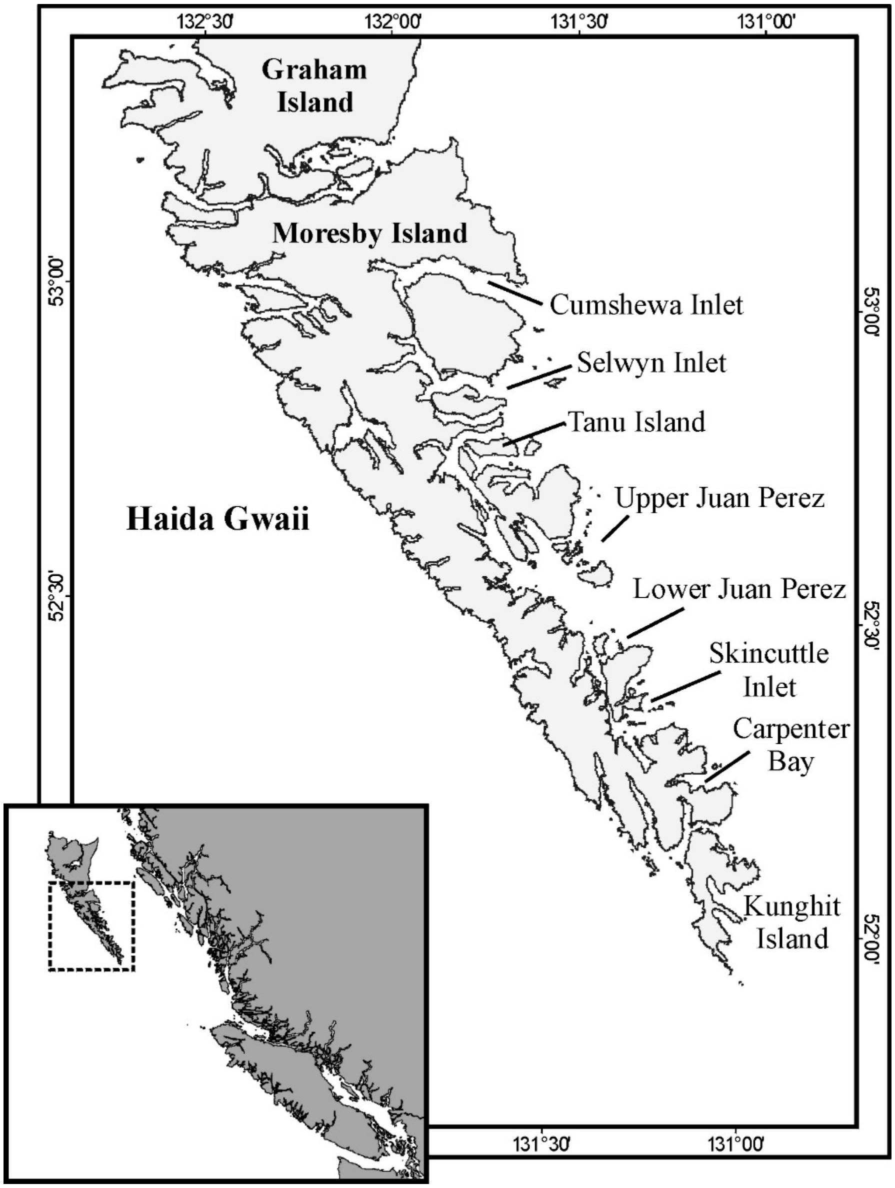


Figure 13. Map of Haida Gwaii showing pinto abalone (aka northern abalone) survey areas. Copied from Hankewich *et al.* (2008).

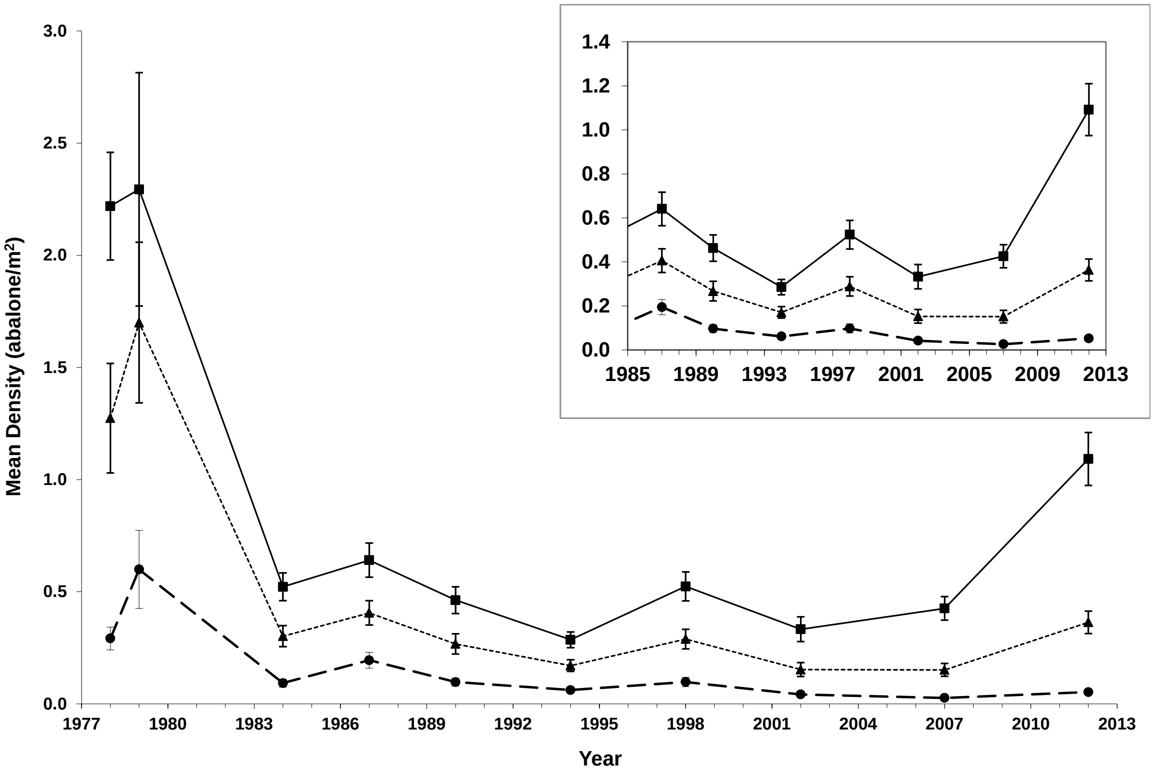


Figure 14. Mean density (abalone/m^2) (± SE) of “all sizes” of abalone (solid line), mature abalone (≥ 70 mm SL) (dotted line), and large adult abalone (≥ 100 mm SL) (dashed line) from all 10 surveys (1978–2012) in southeastern Haida Gwaii. All sites surveyed are included. Inset graph displays greater resolution of densities for survey years after 1985. (J. Lessard, pers. comm.).

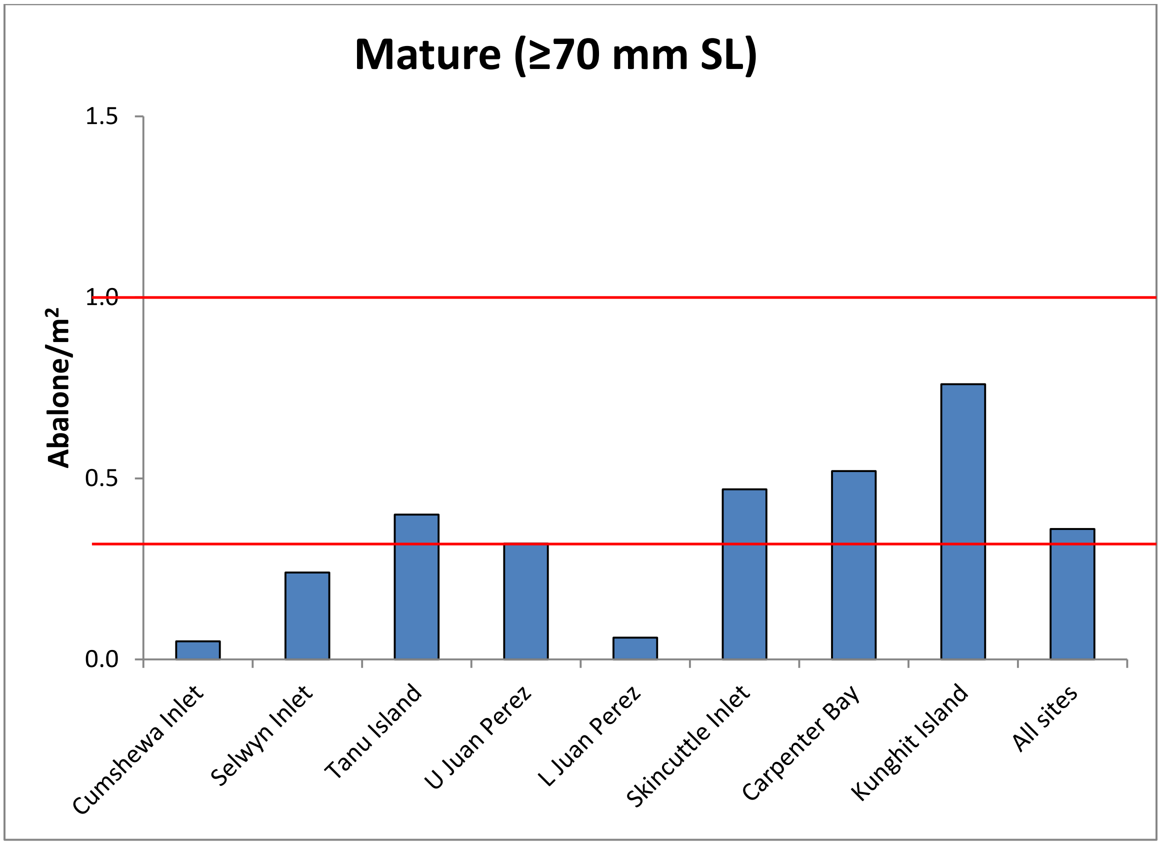


Figure 15. Bar graph depicting density (abalone/m^2) of mature (≥ 70 mm SL) pinto abalone (aka northern abalone) at eight survey index areas in Southeast Haida Gwaii in 2012. The top red line indicates one spawner/m^2, which is a self-sustaining level and the density needed to be considered recovered. The bottom red line indicates a density of 0.32 adult abalone/m^2, which is the mean recovery strategy density objective for the Haida Gwaii. (J. Lessard, pers. comm.).

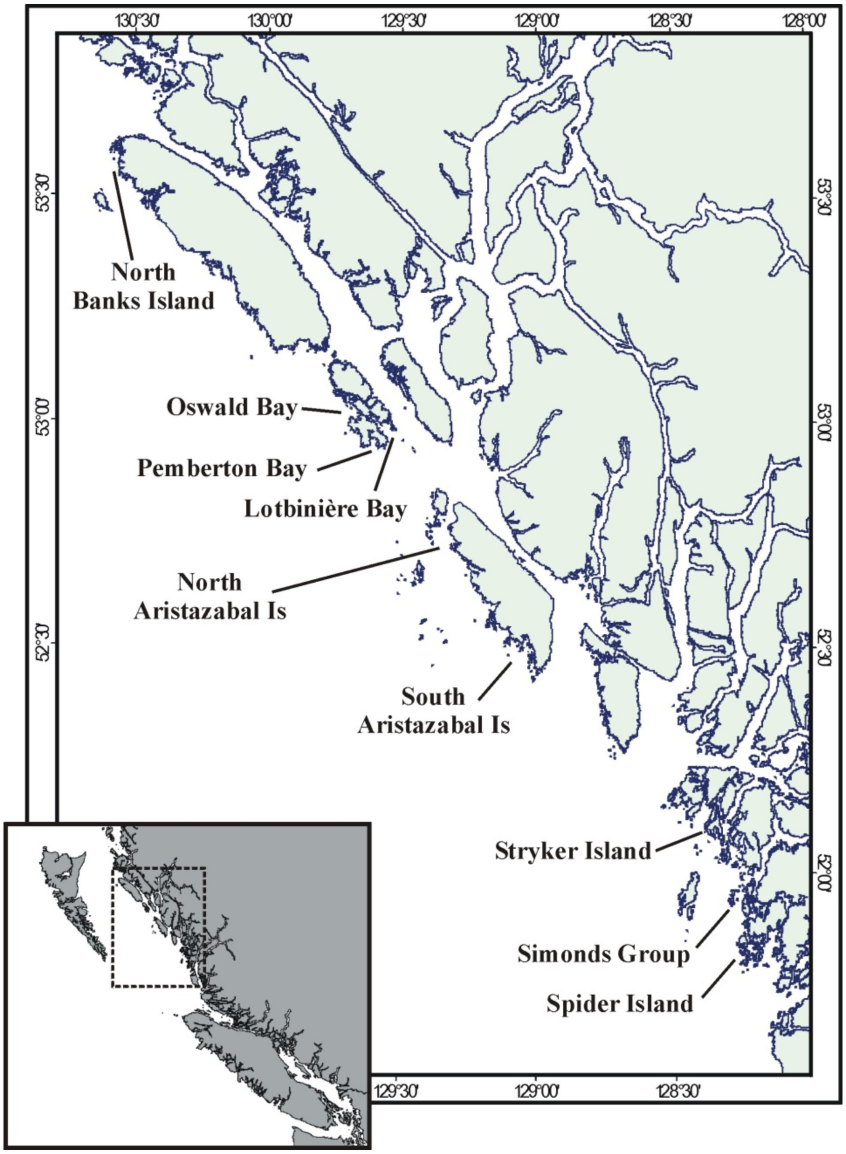


Figure 16. Map of Central Coast of British Columbia showing pinto abalone (aka northern abalone) survey areas. Copied from Lessard *et al.* (2007).

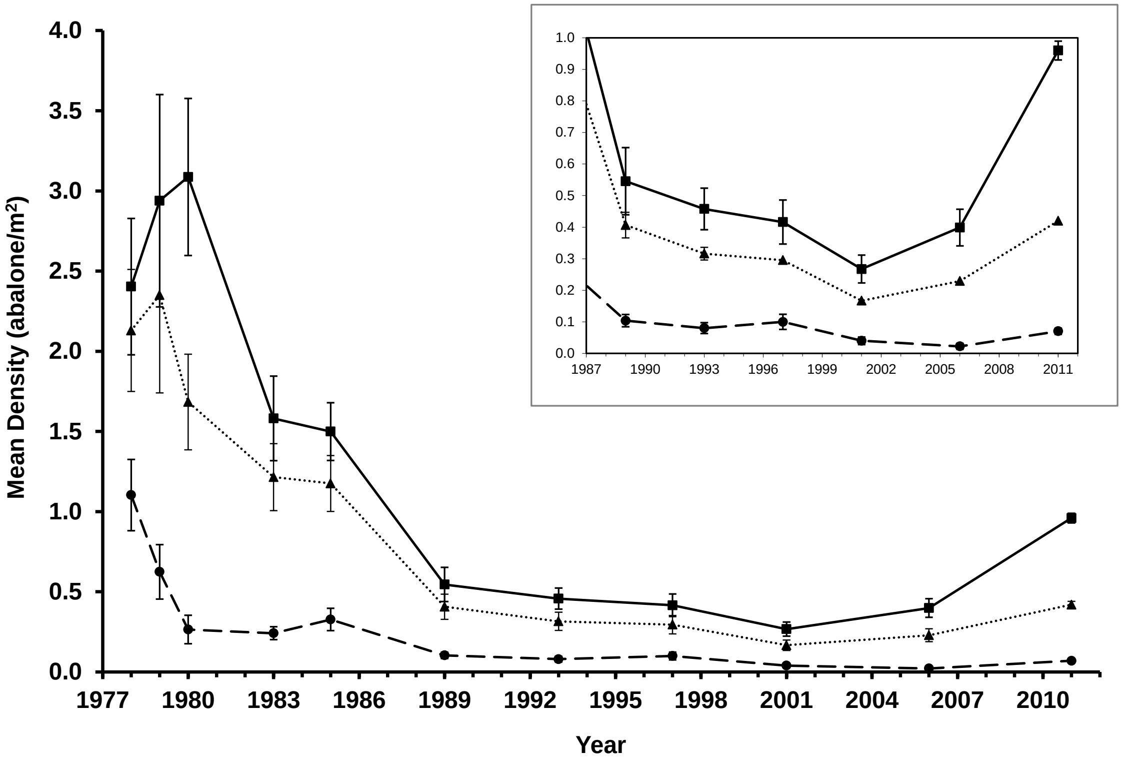


Figure 17. Mean density (abalone/m^2) (± SE) of "all sizes" of abalone (solid line), mature abalone (≥ 70 mm SL) (dotted line), and large adult abalone (≥ 100 mm SL) (dashed line) from all 10 surveys (1978–2011) in on the Central Coast. All sites surveyed are included. Inset graph displays greater resolution of densities for survey years after 1987. (J. Lessard, pers. comm.).

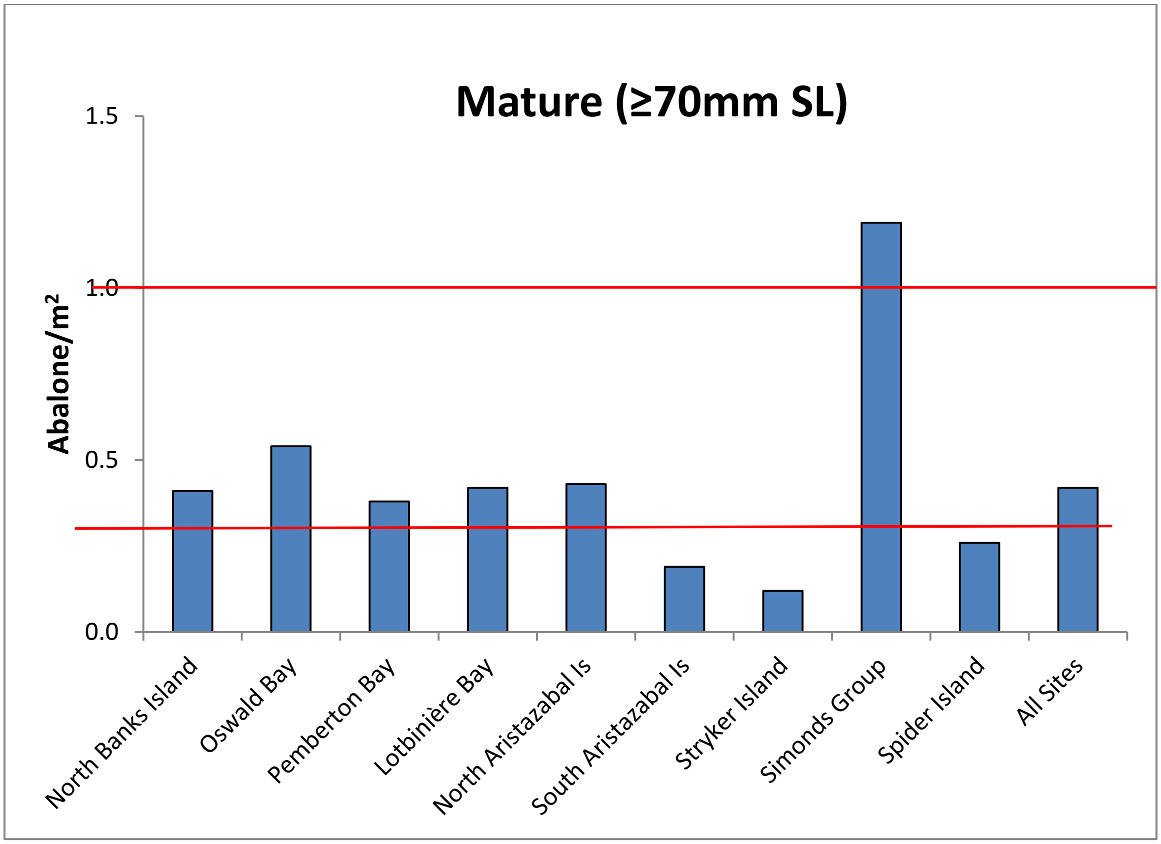


Figure 18. Bar graph depicting density (abalone/m^2) of mature (≥ 70 mm SL) pinto abalone (aka northern abalone) at nine Central Coast survey index areas in 2011. The top red line indicates one spawner/m^2, which is a self-sustaining level and the density needed to be considered recovered. The bottom red line indicates a density of 0.32 adult abalone/m^2, which is the mean recovery strategy density objective for the Central Coast. (J. Lessard, pers. comm.).

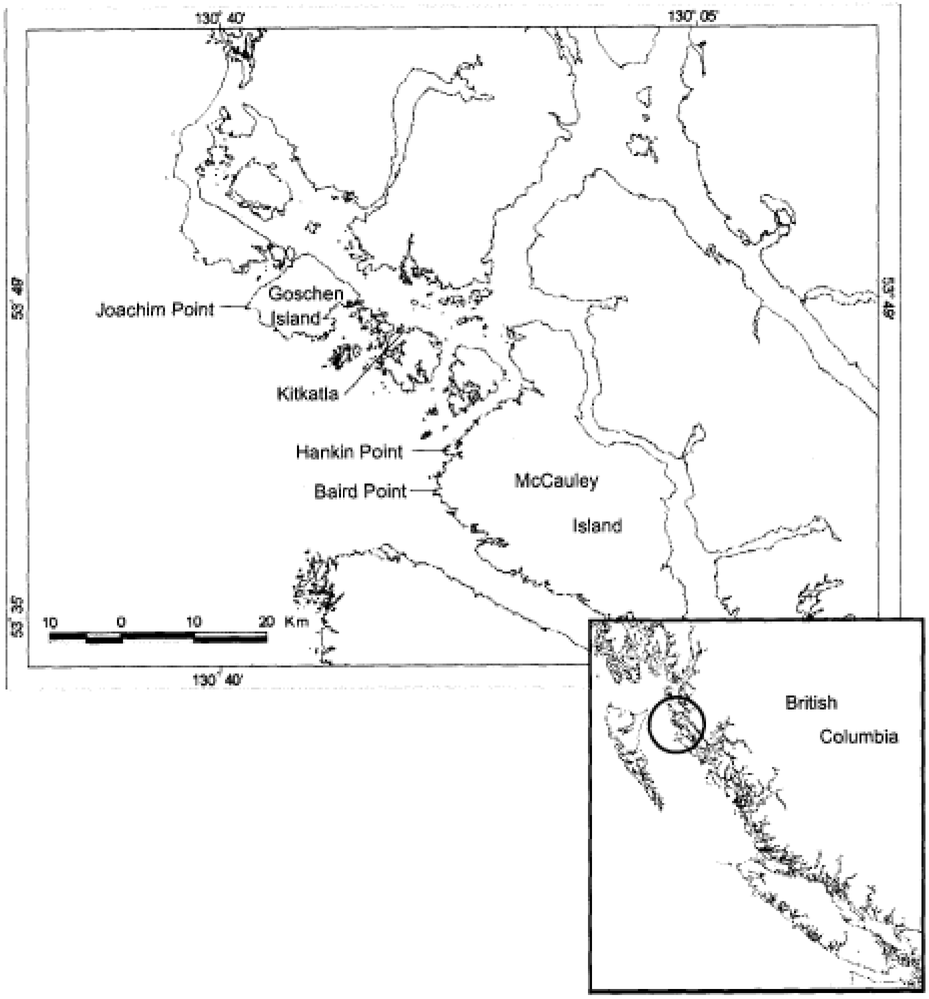


Figure 19. Map of North Coast British Columbia showing pinto abalone (aka northern abalone) survey areas near Kitkatla, British Columbia. Copied from Lucas *et al.* (2002b)

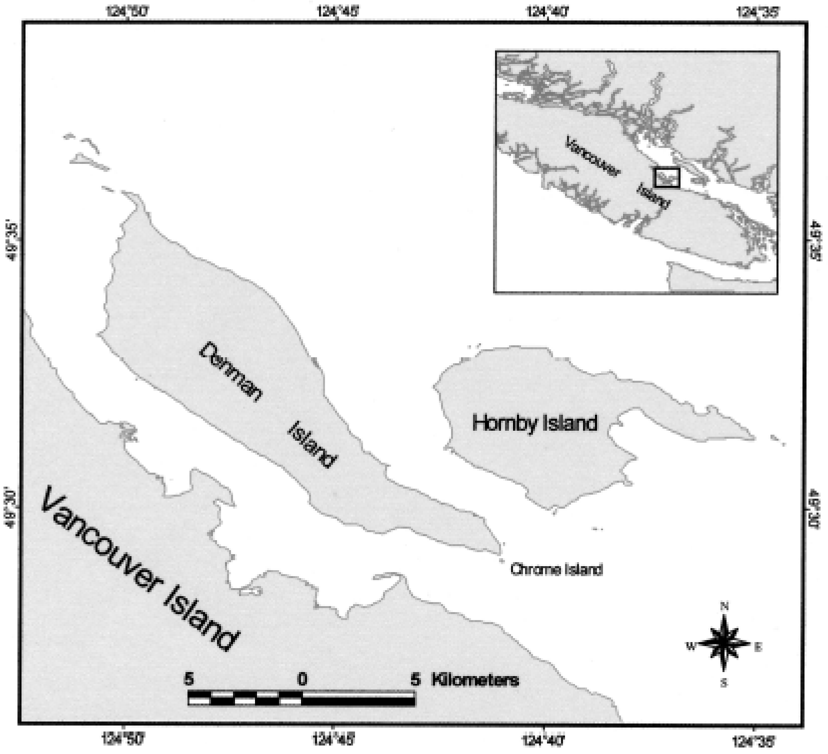


Figure 20. Map of Denman and Hornby islands in the Strait of Georgia showing the pinto abalone (aka northern abalone) survey areas. Copied from Lucas *et al.* (2003d).

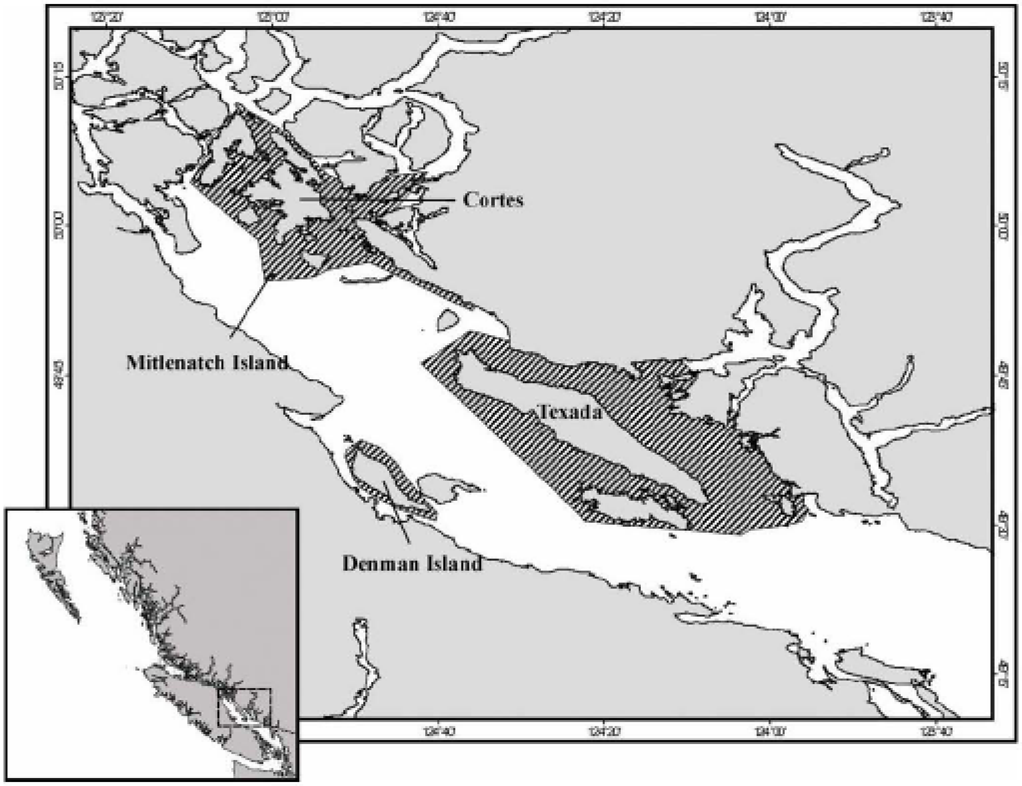


Figure 21. Map of northern Strait of Georgia showing the two pinto abalone (aka northern abalone) survey areas. Copied from Egli and Lessard (2011).

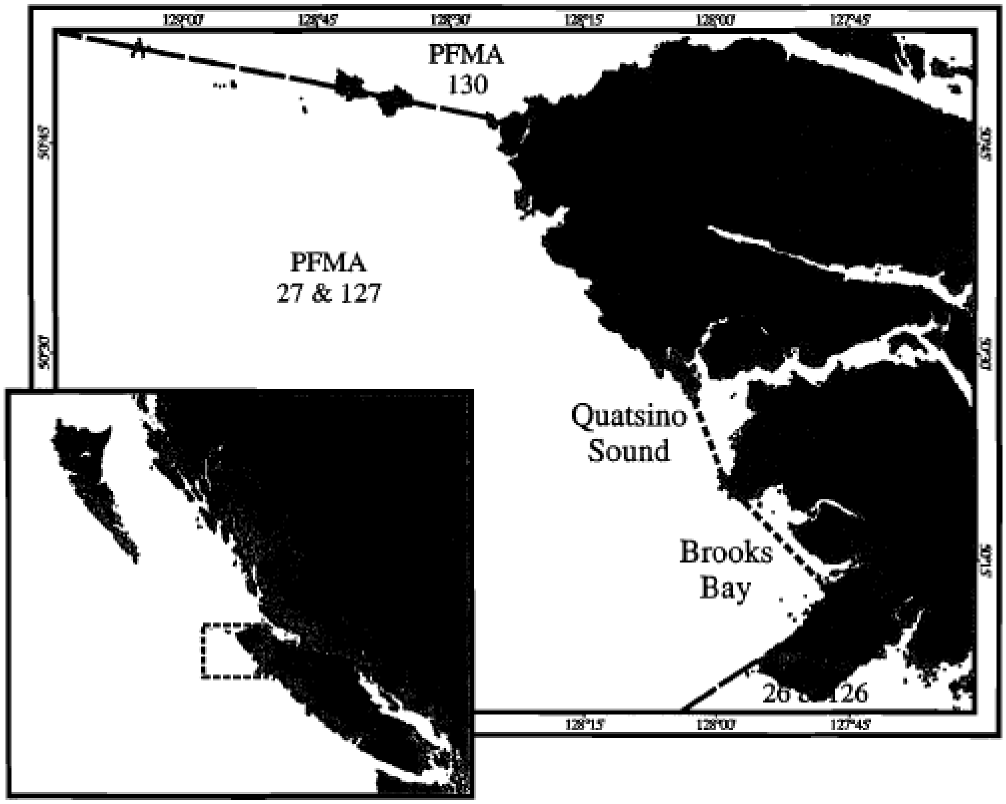


Figure 22. Map of northwest coast of Vancouver Island showing pinto abalone (aka northern abalone) survey areas. Copied from Atkins and Lessard (2004).

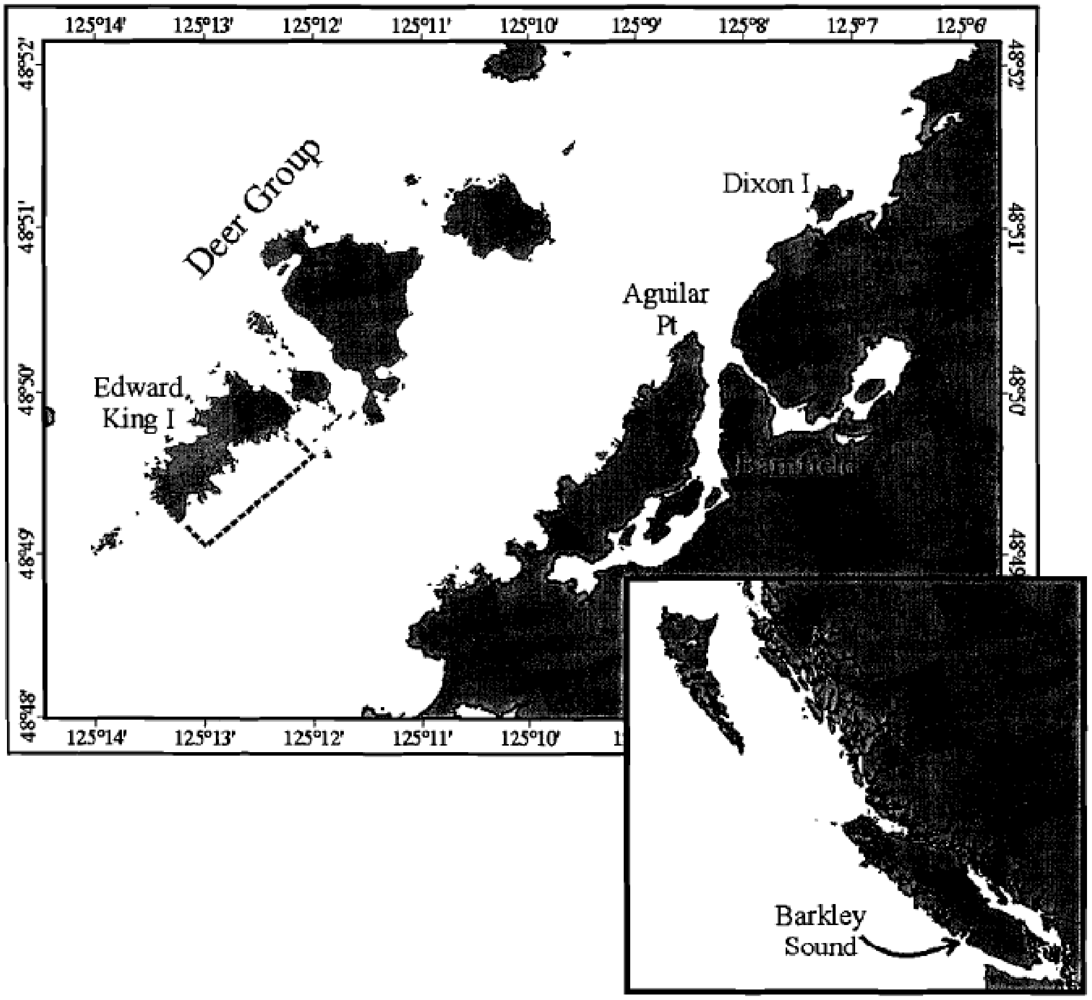


Figure 23. Map of Bamfield area in Southeast Barkley Sound on Vancouver Island showing pinto abalone (aka northern abalone) survey areas. Copied from Lessard *et al.* (2004).

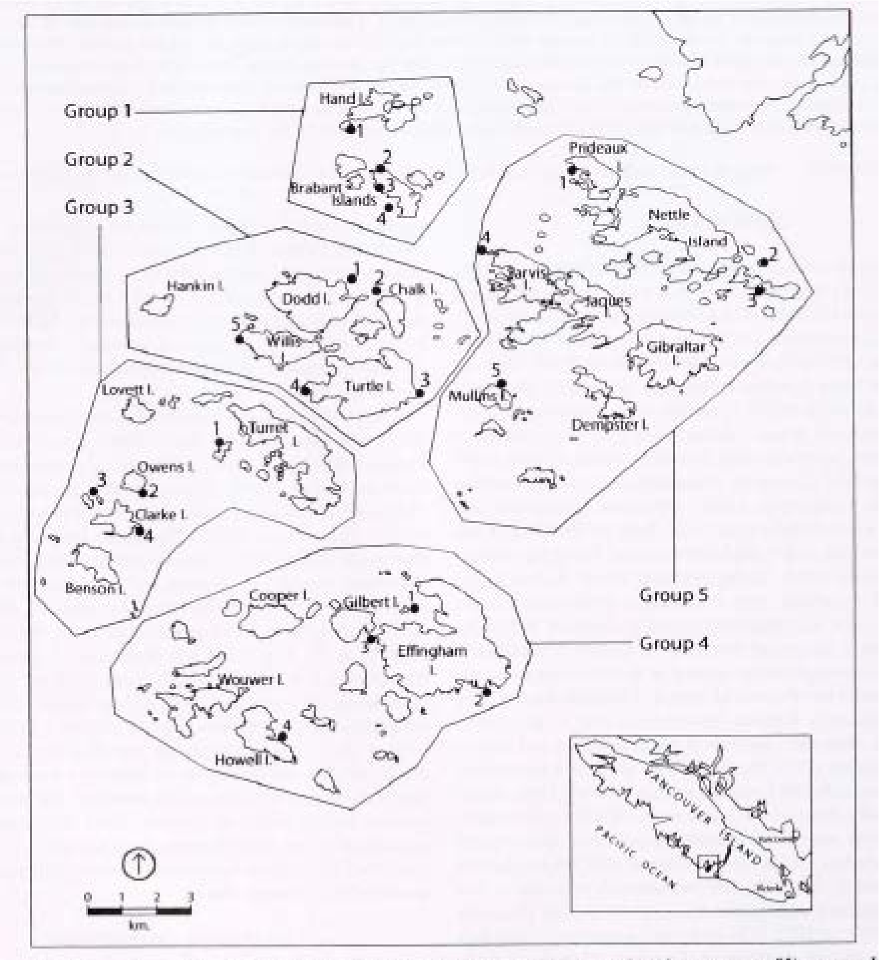


Figure 24. Map of Broken Group Islands in Barkley Sound on Vancouver Island showing island groups and numbered survey locations for pinto abalone (aka northern abalone). Copied from Tomascik and Holmes (2003).

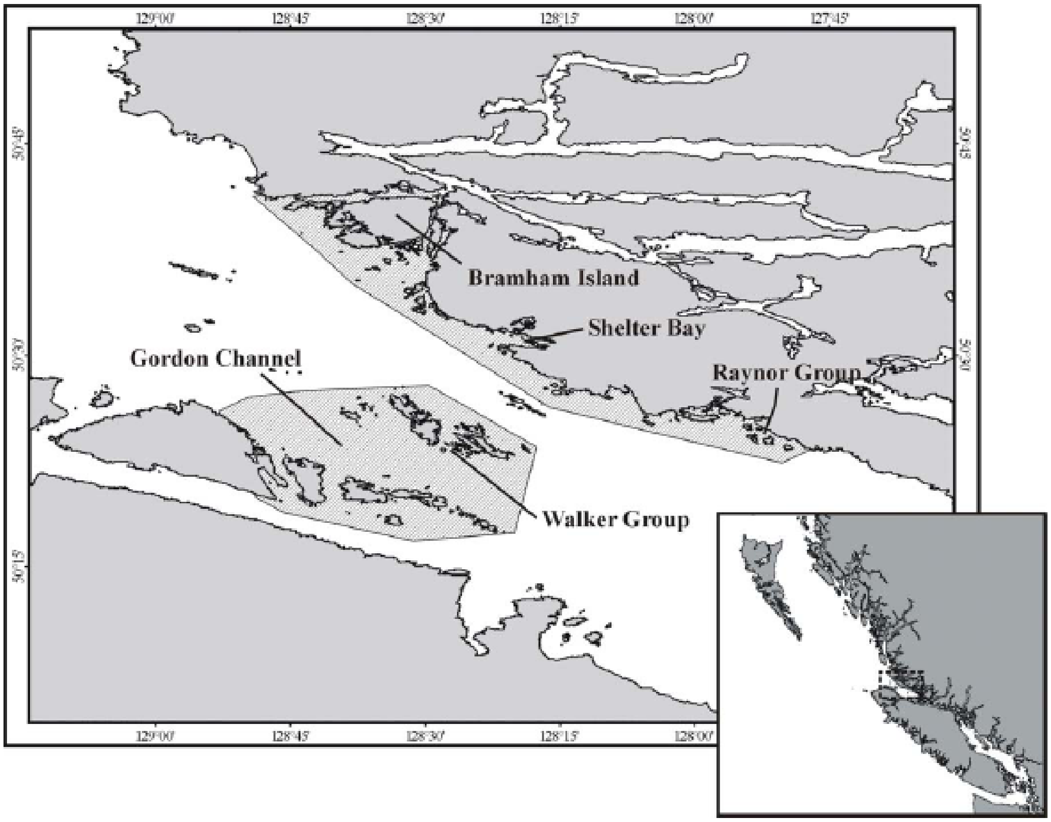


Figure 25. Map of Queen Charlotte Strait showing pinto abalone (aka northern abalone) survey areas. Copied from Lessard and Egli (2011).

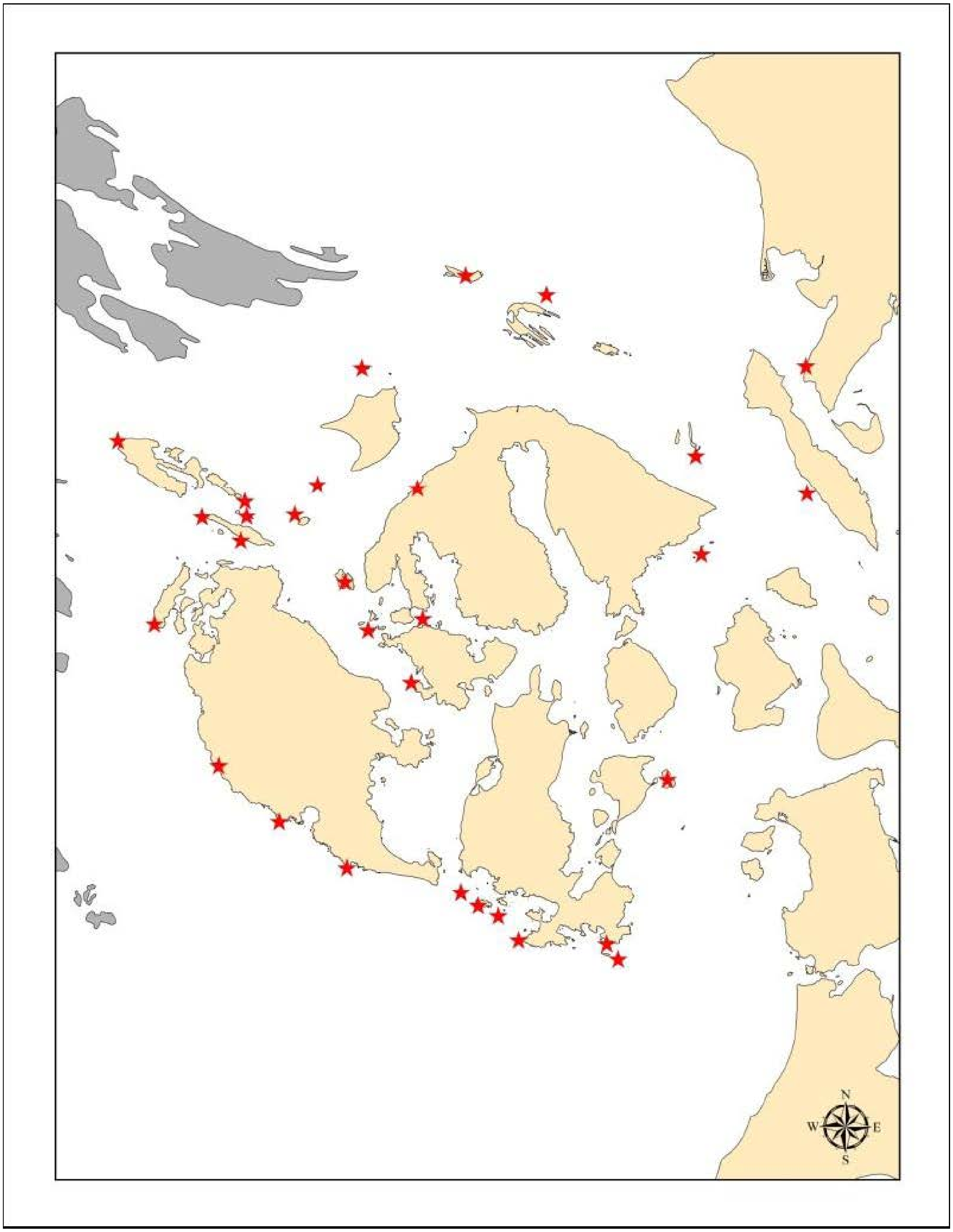


Figure 26. Locations of pinto abalone timed swim surveys conducted in 1979–1981 by WDFW in the San Juan Islands Archipelago. Copied from WDFW (2014).

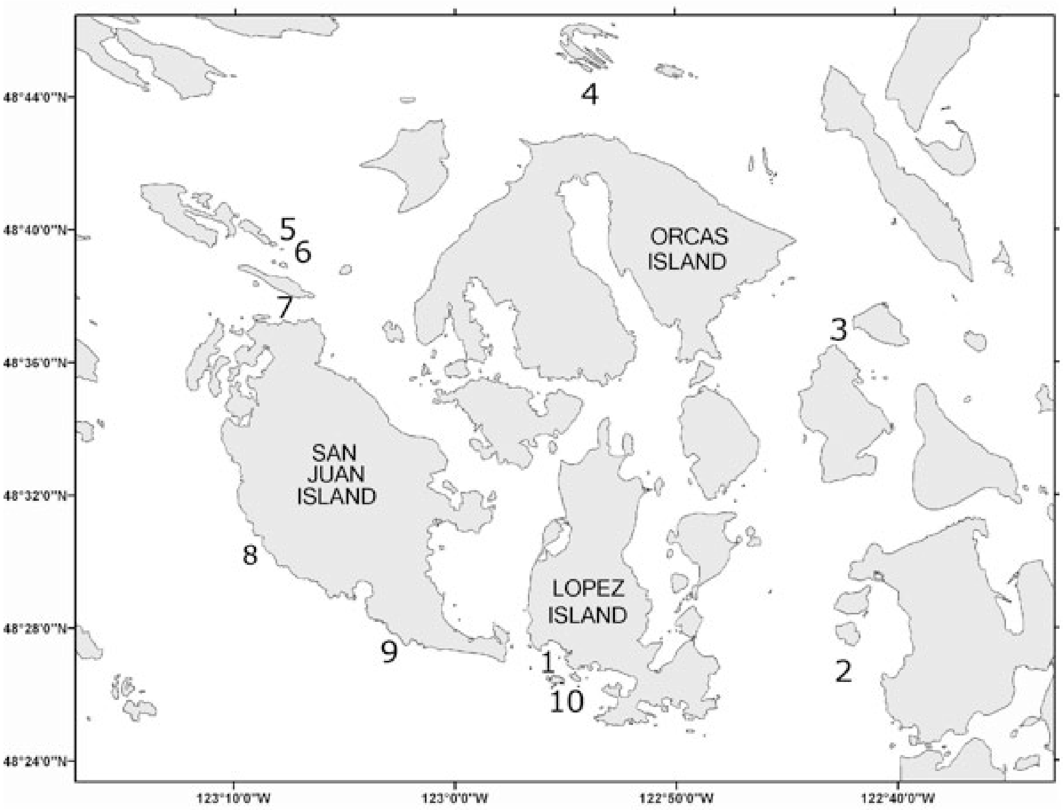


Figure 27. Location of 10 WDFW index survey sites for pinto abalone in the San Juan Islands Archipelago, Washington: 1) Long Island West; 2) Williamson Rocks; 3) North Cypress Island; 4) Parker Reef; 5) Ripple Island; 6) Big Cactus Island; 7) Spieden Island; 8) Deadman's Bay; 9) Old Eagle Point; 10) Long Island East (WDFW 2014).

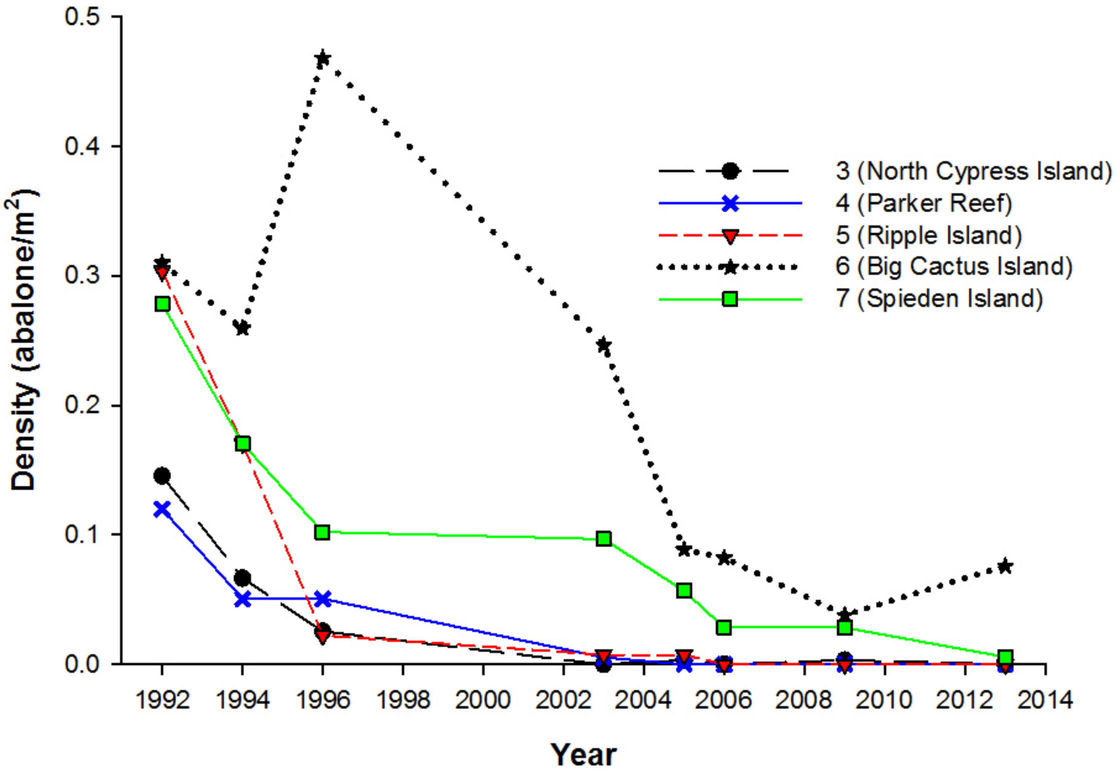


Figure 28. Density (abalone/m^2) of pinto abalone from 1992 to 2013 at 5 index sites in the northern San Juan Islands Archipelago. Some index stations were surveyed in 2004 and some in 2005; however, these data are presented as a single data point for 2005, as described in WDFW (2014). Site numbers correspond with those in Figure 27. Data from WDFW public comment submission Excel file: 13July29_1992_2013_Index_Station_Summary_Data (revised 12/31/2013).

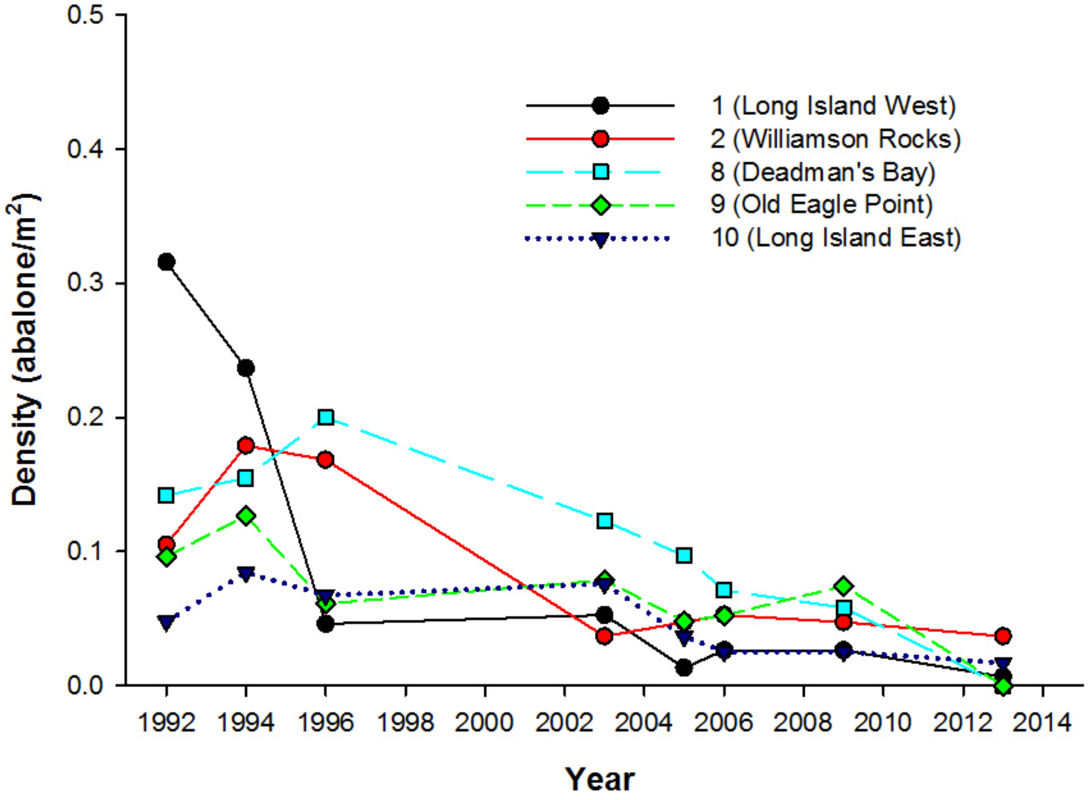


Figure 29. Density (abalone/m^2) of pinto abalone from 1992 to 2013 at 5 index sites in the southern San Juan Islands Archipelago. Some index stations were surveyed in 2004 and some in 2005; however, these data are presented as a single data point for 2005, as described in WDFW (2014). Site numbers correspond with those in Figure 27. Data from WDFW public comment submission Excel file: 13July29_1992_2013_Index_Station_Summary_Data (revised 12/31/2013).

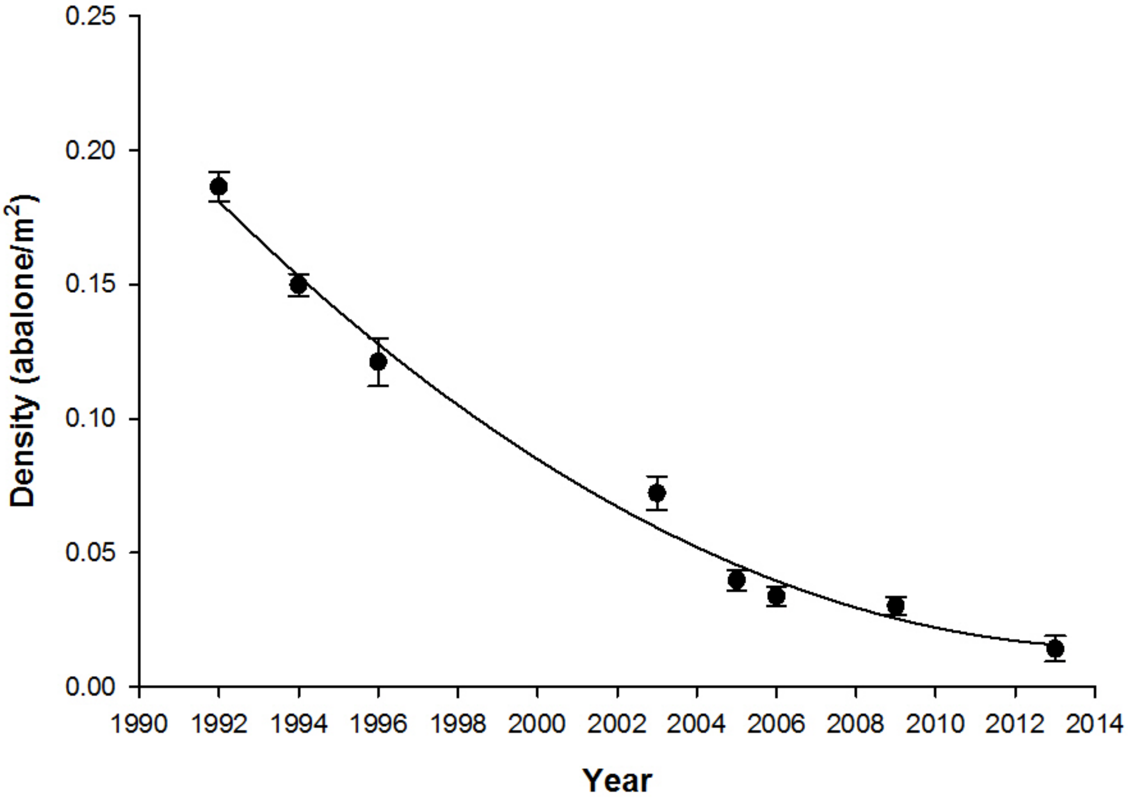


Figure 30. Mean density (abalone/m^2) of pinto abalone from 1992–2013 at 10 index sites in the San Juan Islands Archipelago (see Figure 27). Half of the index stations were surveyed in each year 2004 and 2005; however, these data are presented as a single data point (2005) as described in WDFW (2014). Error bars represent the standard error of the mean density. Data from WDFW public comment submission Excel file: 13July29_1992_2013_Index_Station_Summary_Data (revised 12/31/2013).

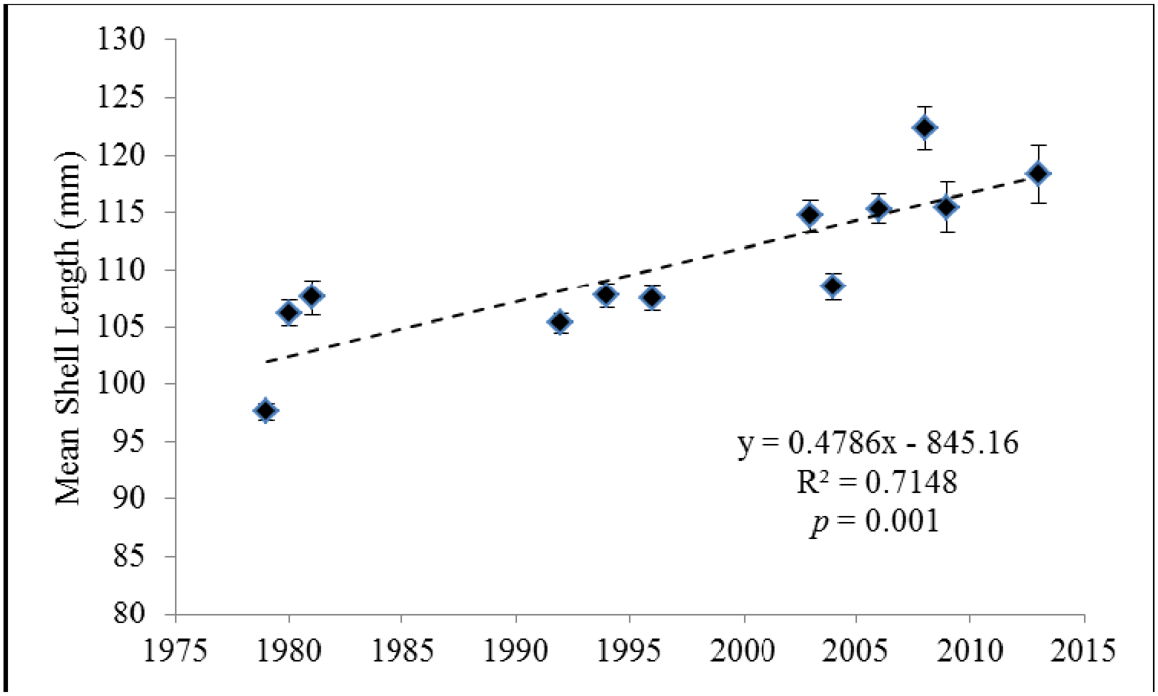


Figure 31. Pinto abalone mean (± SE of the mean) shell length on timed survey transects and index station surveys in the San Juan Islands Archipelago, Washington. Based on shell length measurements of 2,581 pinto abalone measured during timed-swim surveys during 1979–1981 and index site surveys during 1992–2013. Copied from (WDFW 2014).

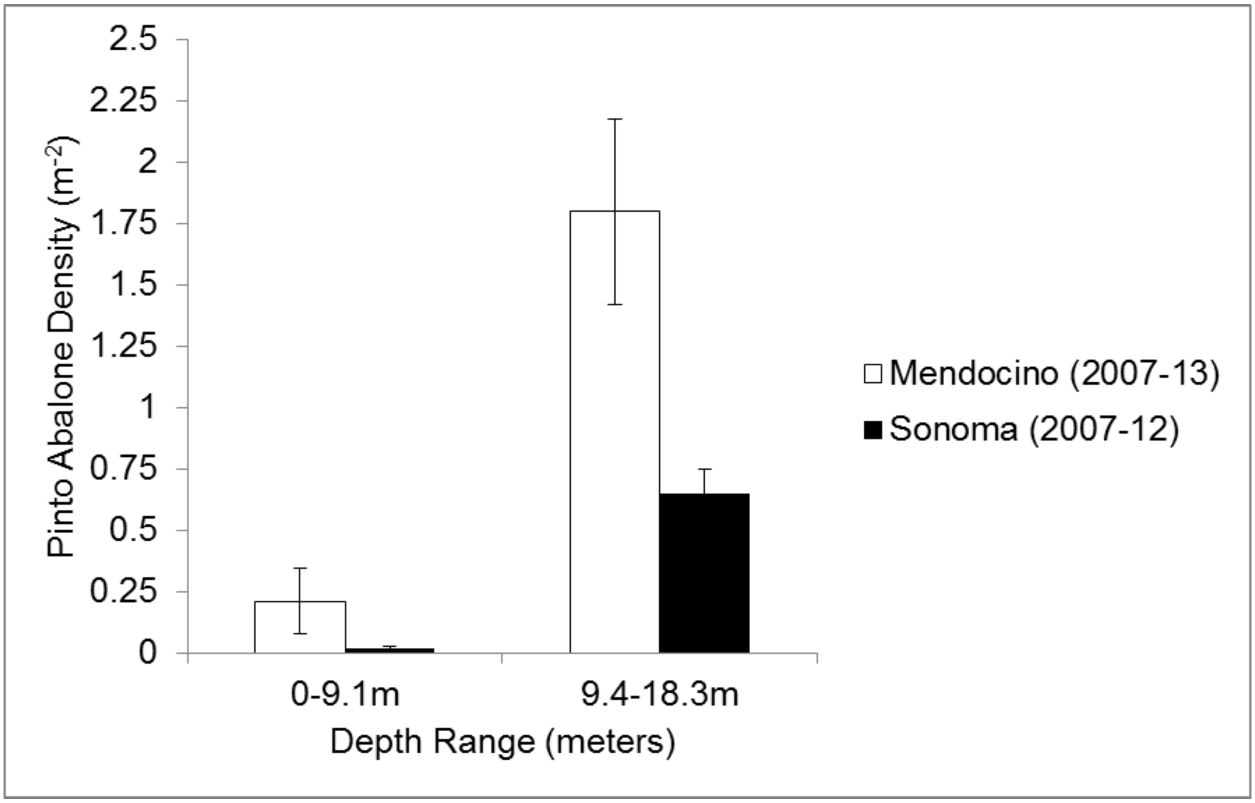


Figure 32. Pinto abalone mean (± SE of the mean) densities recorded during diver survey transects in Mendocino and Sonoma Counties, CA at depths from 0-9.1 m and 9.4-18.3m (Rogers-Bennett, CDFW, unpublished data).

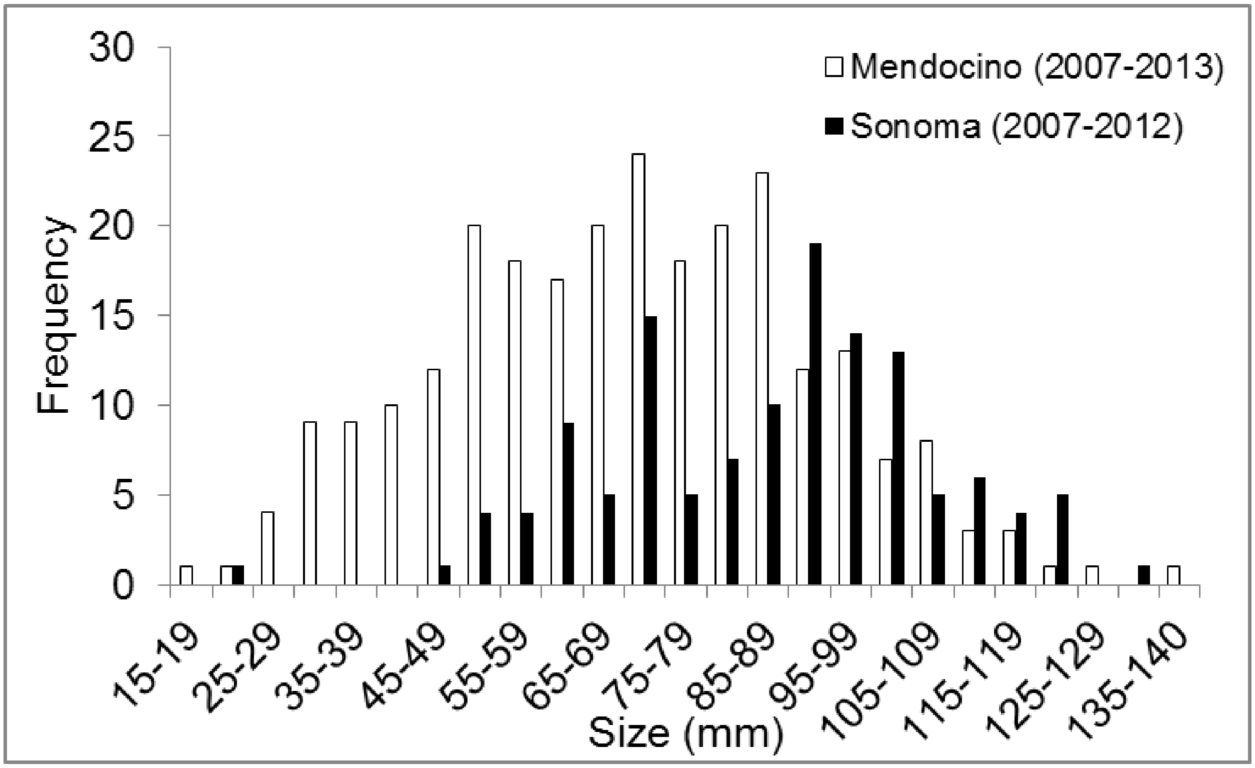
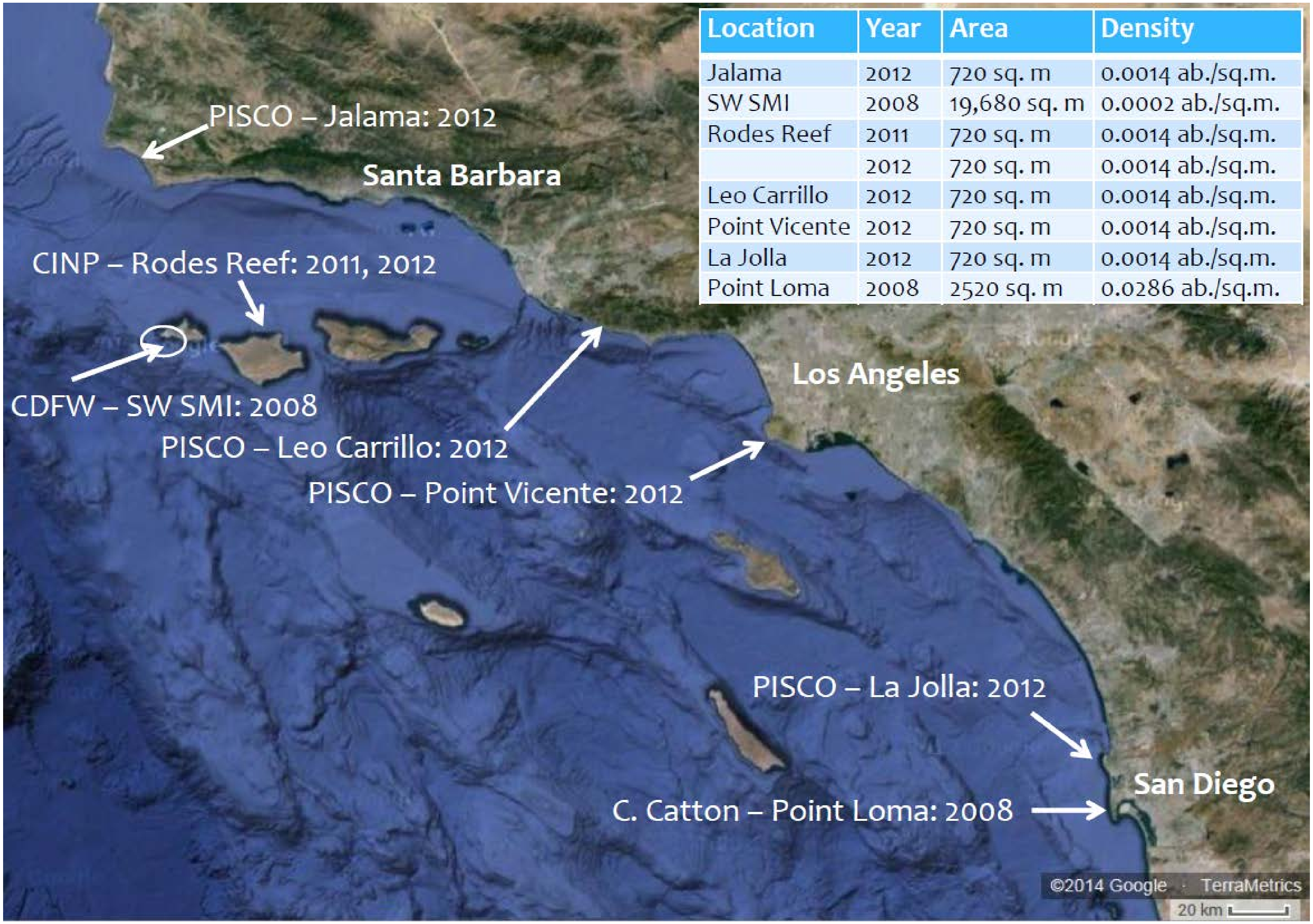


Figure 33. Pinto abalone shell lengths recorded during diver survey transects in Mendocino and Sonoma Counties, CA (Rogers-Bennett, CDFW, unpublished data).



Location	Year	Area	Density
Jalama	2012	720 sq. m	0.0014 ab./sq.m.
SW SMI	2008	19,680 sq. m	0.0002 ab./sq.m.
Rodes Reef	2011	720 sq. m	0.0014 ab./sq.m.
	2012	720 sq. m	0.0014 ab./sq.m.
Leo Carrillo	2012	720 sq. m	0.0014 ab./sq.m.
Point Vicente	2012	720 sq. m	0.0014 ab./sq.m.
La Jolla	2012	720 sq. m	0.0014 ab./sq.m.
Point Loma	2008	2520 sq. m	0.0286 ab./sq.m.

Figure 34. Locations in southern California where pinto abalone were observed and densities recorded during dive surveys conducted in appropriate abalone habitat from 2006-2012 (Taniguchi, CDFW, unpublished data).

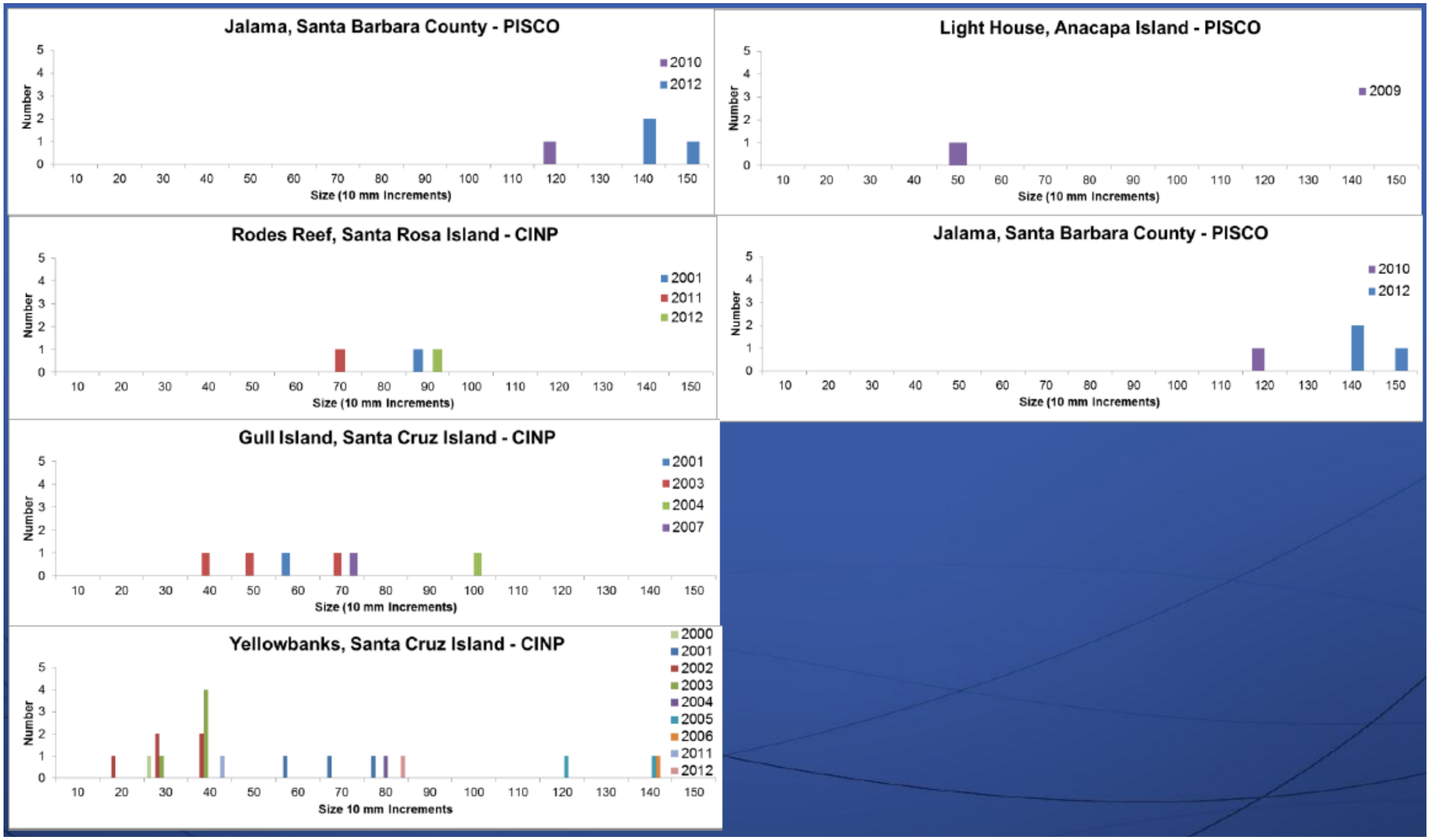


Figure 35. Size frequency information for pinto abalone measured at a variety of locations in Santa Barbara and Ventura Counties, 2000-2012 (Taniguchi, CDFW, unpublished data).

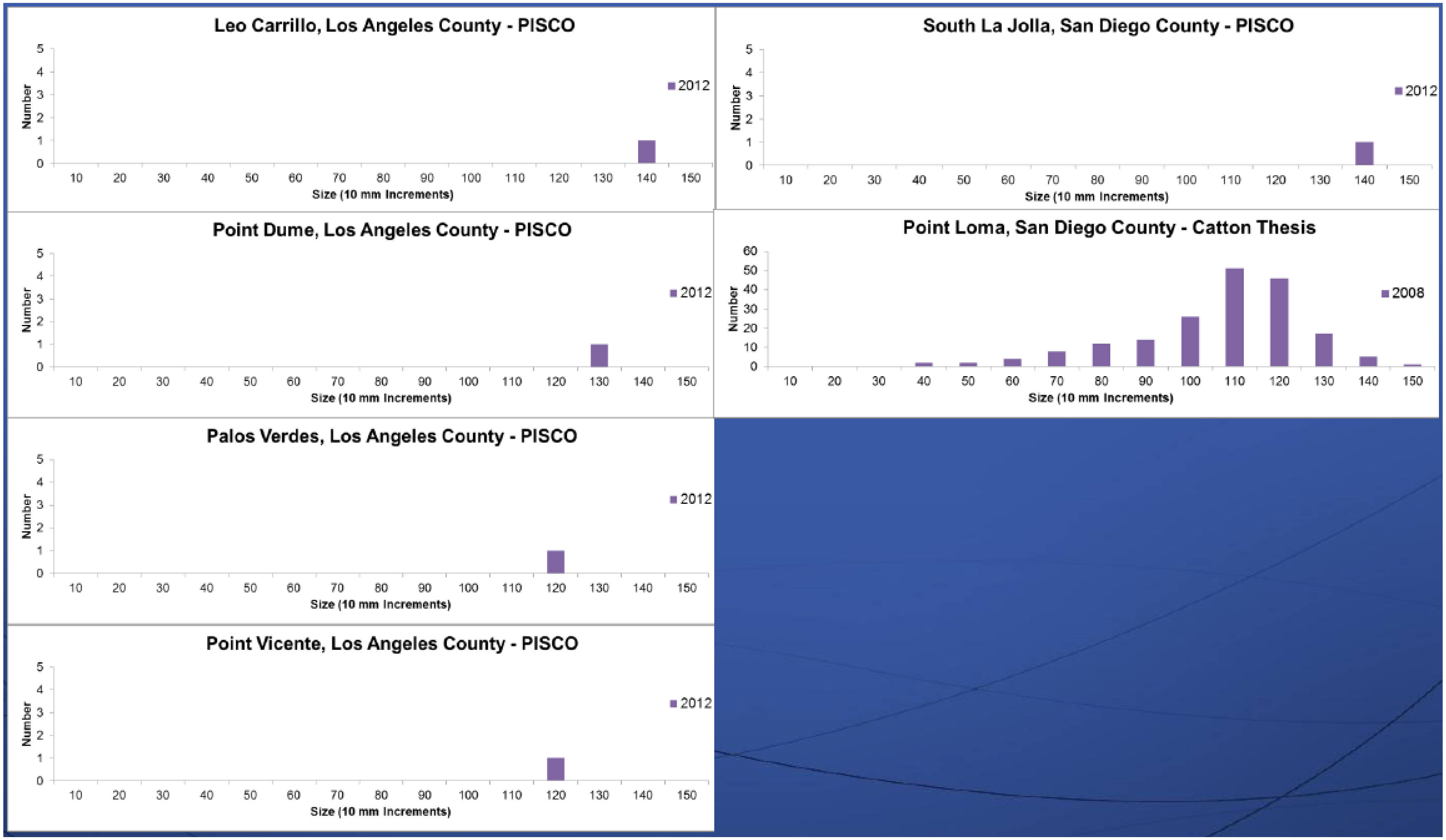


Figure 36. Size frequency information for pinto abalone measured at a variety of locations in Los Angeles and San Diego Counties, 2000-2012 (Taniguchi, CDFW, unpublished data).

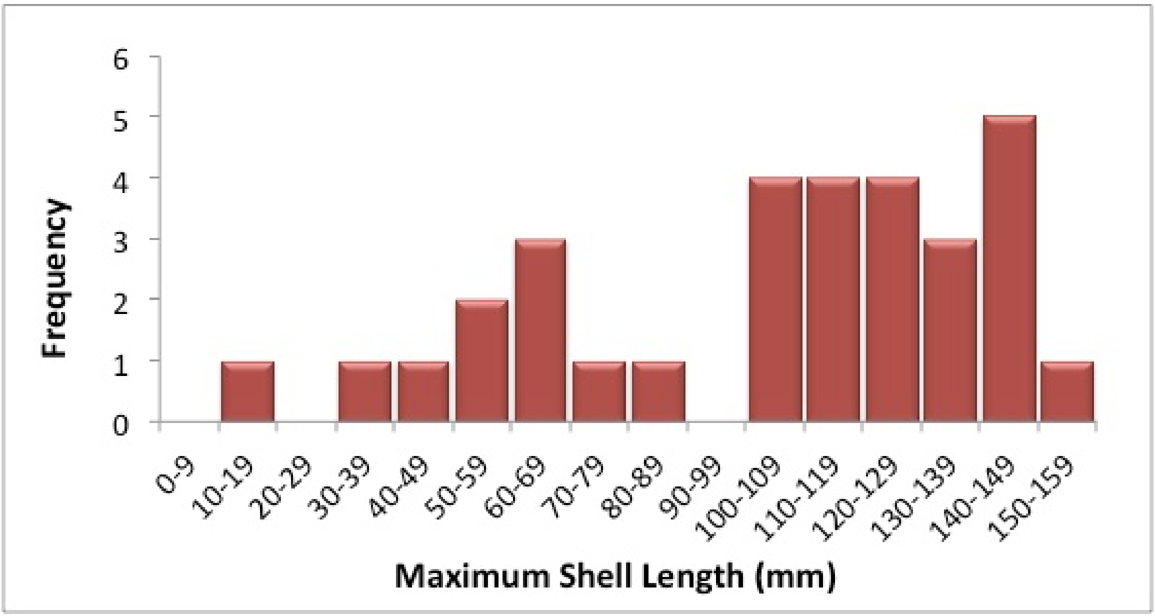


Figure 37. Size frequency distribution of pinto abalone (n=38) observed during demographic surveys of pinto abalone in nearshore San Diego kelp beds (A. Bird, 2014, unpublished data).

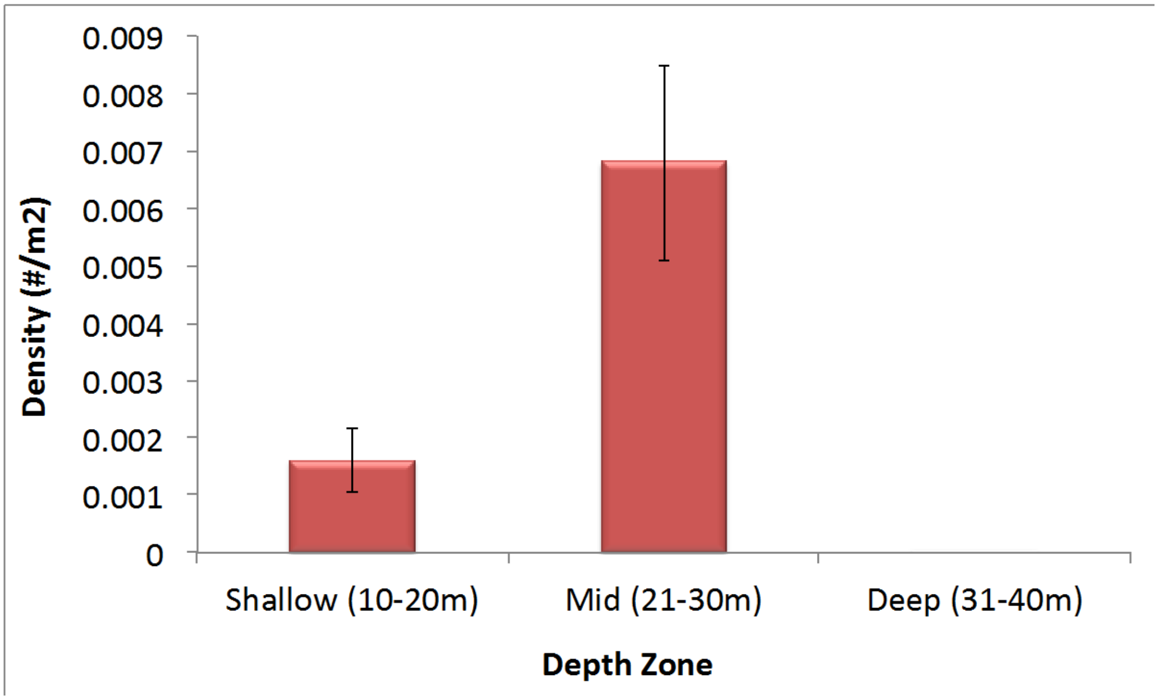


Figure 38. Average density (#/m^2) +/-SE of pinto abalone for all transects (Shallow (n=30); Mid (n=8); Deep (n=0)) and depth zones in Point Loma and La Jolla, CA. nd = no data.

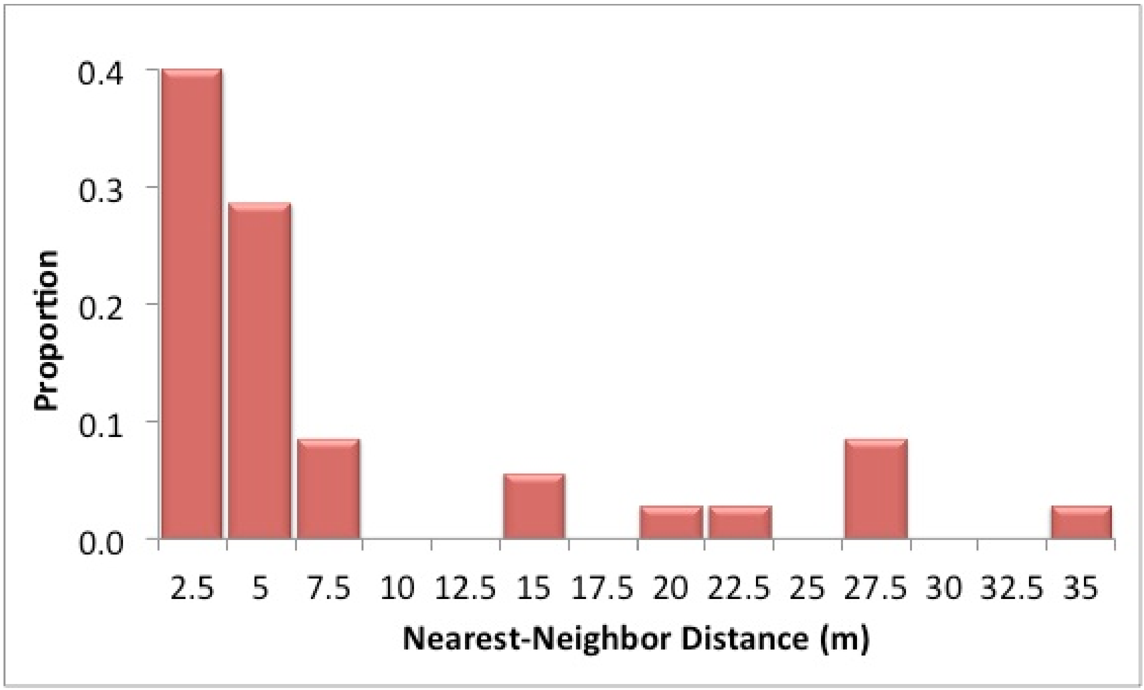


Figure 39. Pinto abalone nearest-neighbor distances (NND) for all individuals in Point Loma (n=34) and La Jolla (n=1) in transects that had two or more animals. Average NND for threaded abalone is 6.7m +- 9.1m.

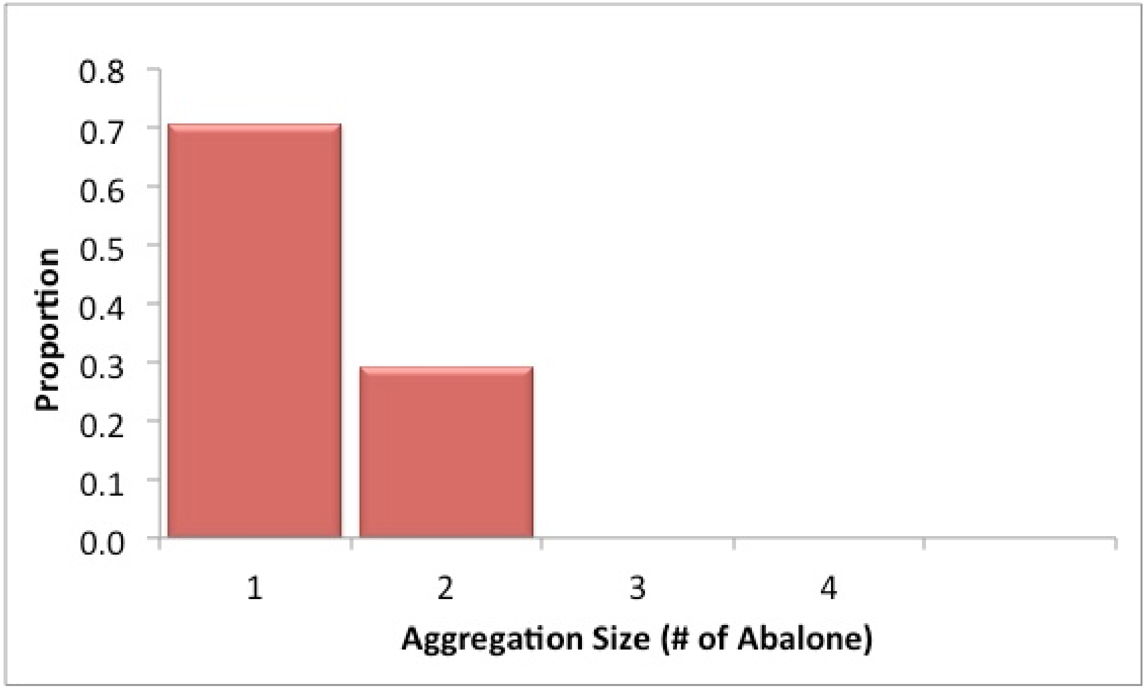


Figure 40. Aggregation sizes for all pinto abalone in Point Loma (n=40) and La Jolla (n=1) for all transects (n=38) and depth zones.

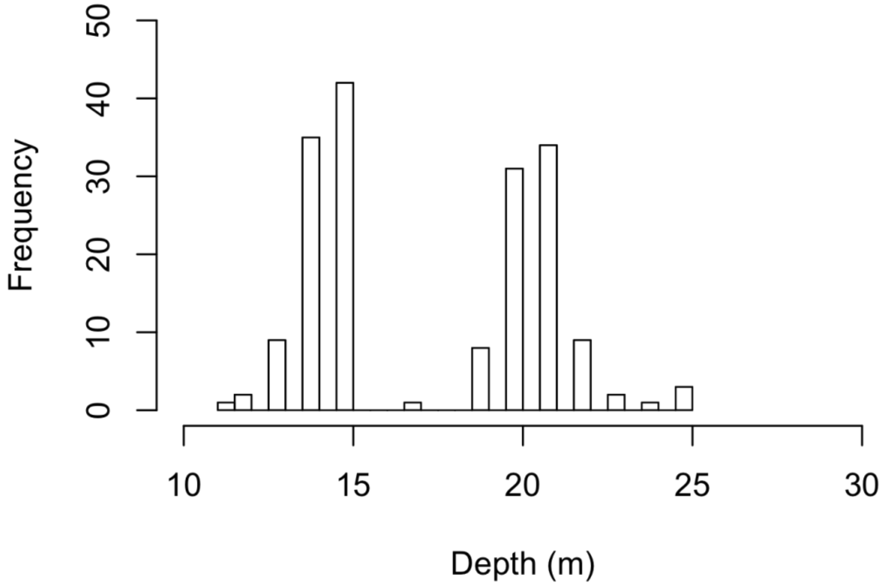


Figure 41. Depth distribution of *Haliotis kamtschatkana assimilis/sorensen*i found in El Rosario, Baja California, Mexico. Total depth distribution of n=178 abalone found during the survey (note: all depths were not equally sampled). Adapted from Boch *et al.*, 2014.

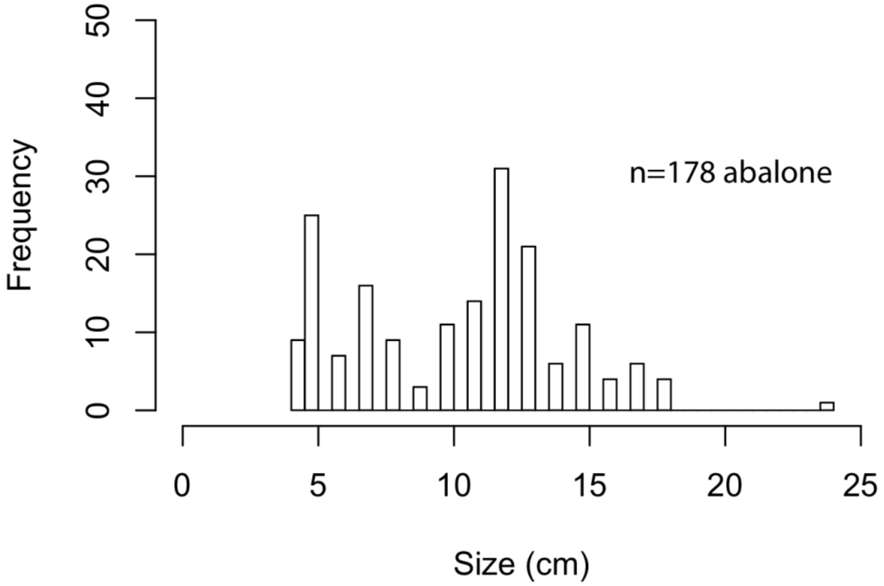


Figure 42. Size distribution of *Haliotis kamtschatkana assimilis/sorensen*i found in El Rosario, Baja California, Mexico. Total size (cm in diameter) distribution of n=178 abalone found during the survey. Adapted from Boch *et al.*, 2014.

Figure 43. Subsistence harvest of Northern sea otters in Southeast Alaska from 2005-2013 (USFWS, unpublished data).

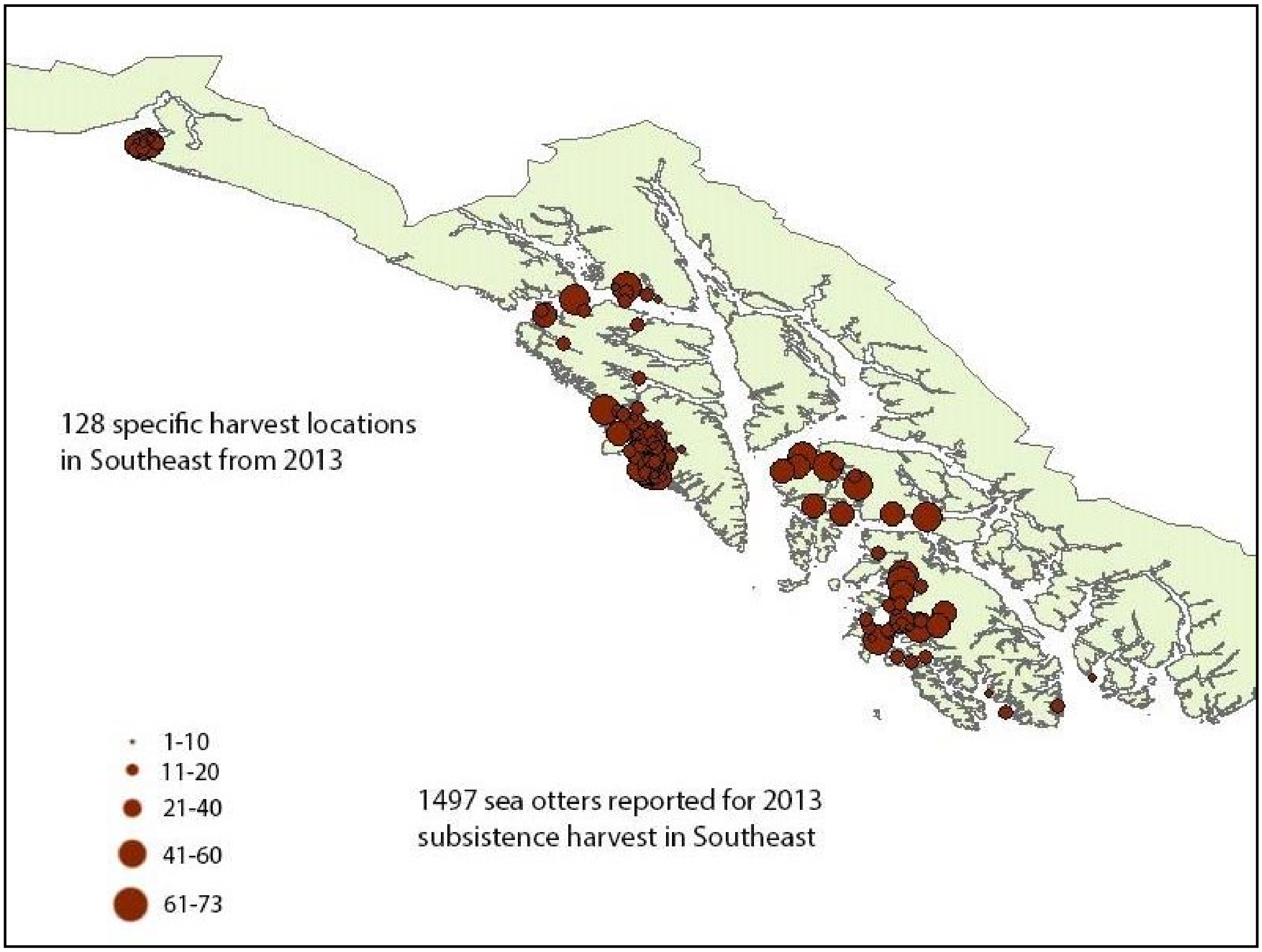


Figure 44. The locations of sea otters reported harvested in Southeast Alaska in 2013 (USFWS unpublished data).

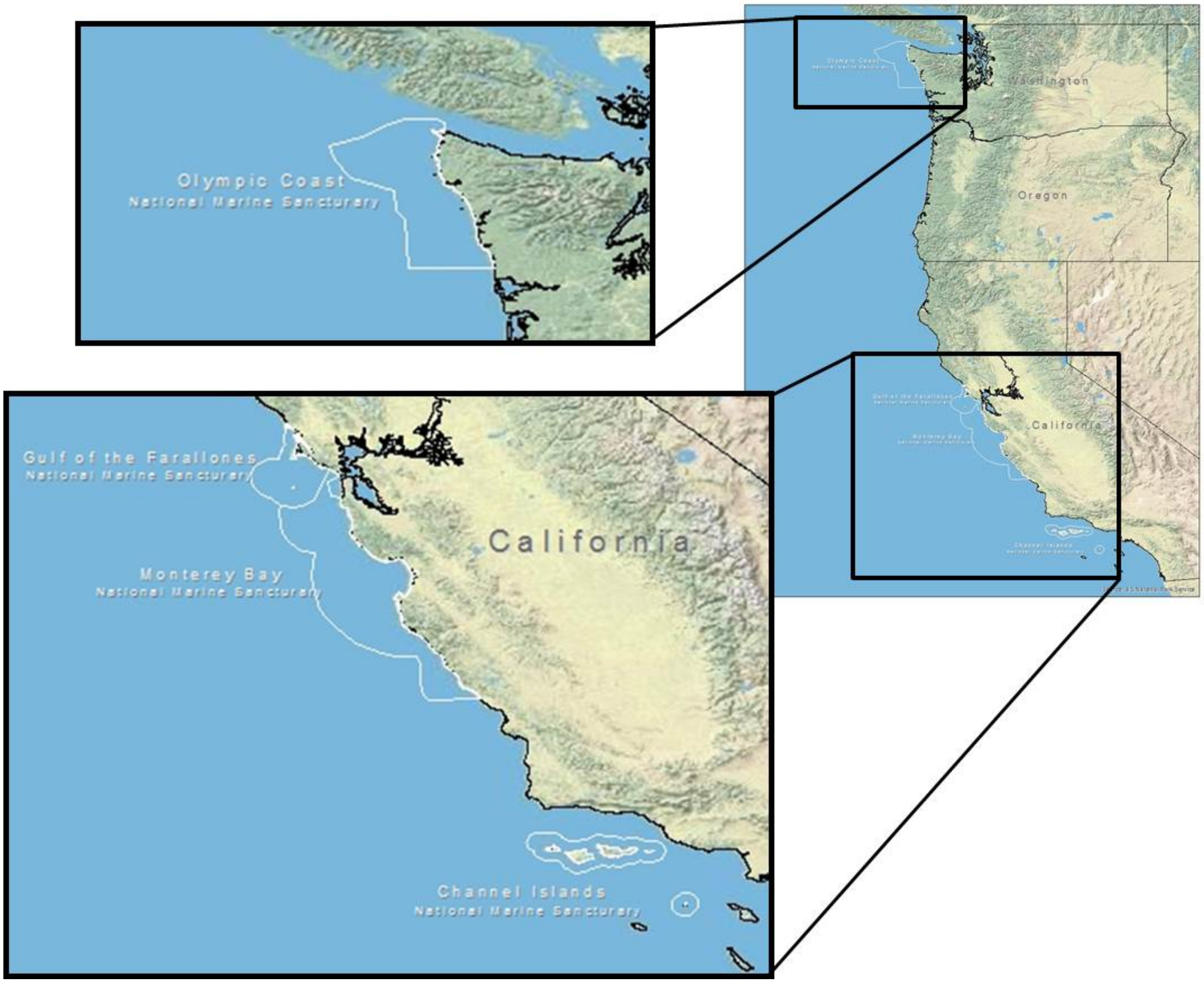


Figure 45. Four National Marine Sanctuaries along the West Coast of the United States that contain pinto abalone: the Olympic Coast , Gulf of the Farallones, Monterey Bay, and Channel Islands.

Figure 46. Threats assessment for the wild population of pinto abalone in the USA, Mexico, and Canada. The scope and severity of the stressor and the data sufficiency were rated as VH = very high, H = high, M = medium, or L = low. Threat persistence refers to the relative time frame(s) over which the threats were/are/will occur: H = historical, C = current, and F = future. The overall threat level for each source was rated as VH = very high, ◯; H = high, ◯; M = medium, ○; or L = low, ∘; based on the scores for scope, severity, threat persistence, and data sufficiency. The coefficient of variation (CV) was calculated for the overall source rating and rated as: VH = very high, ┼ ; H = high, ┼ ; M = medium, + ; or L = low, + .

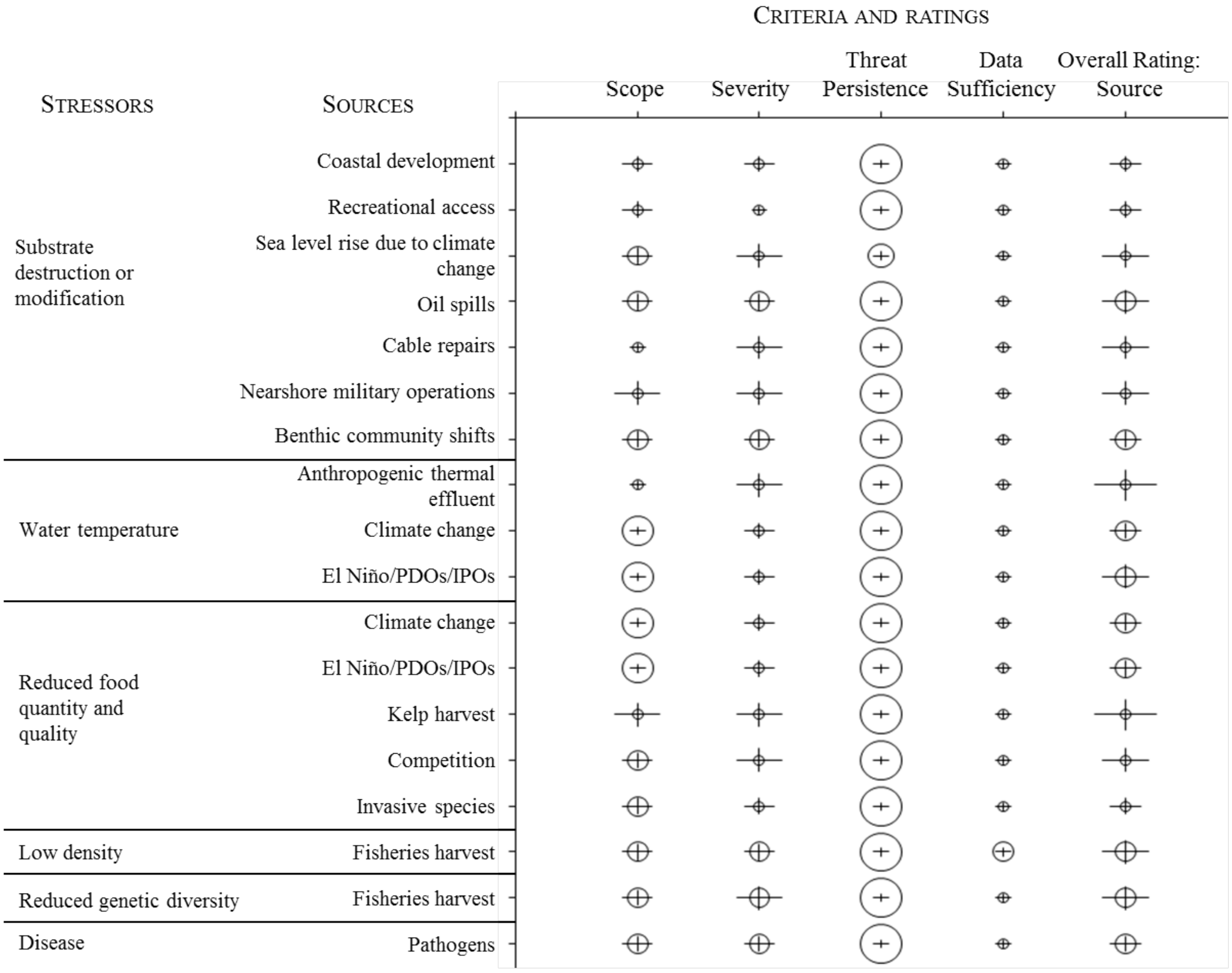
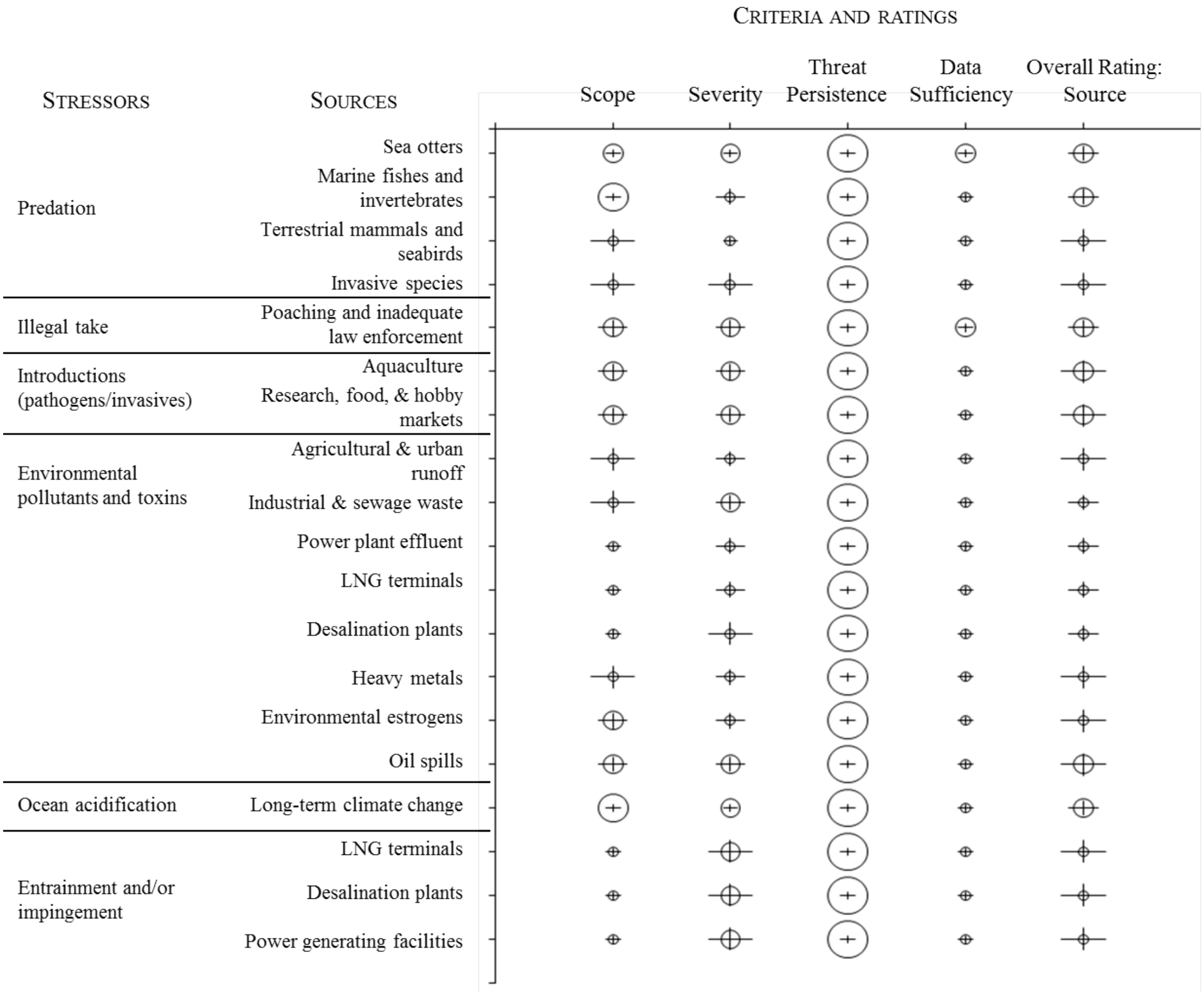


Figure 46. Continued.



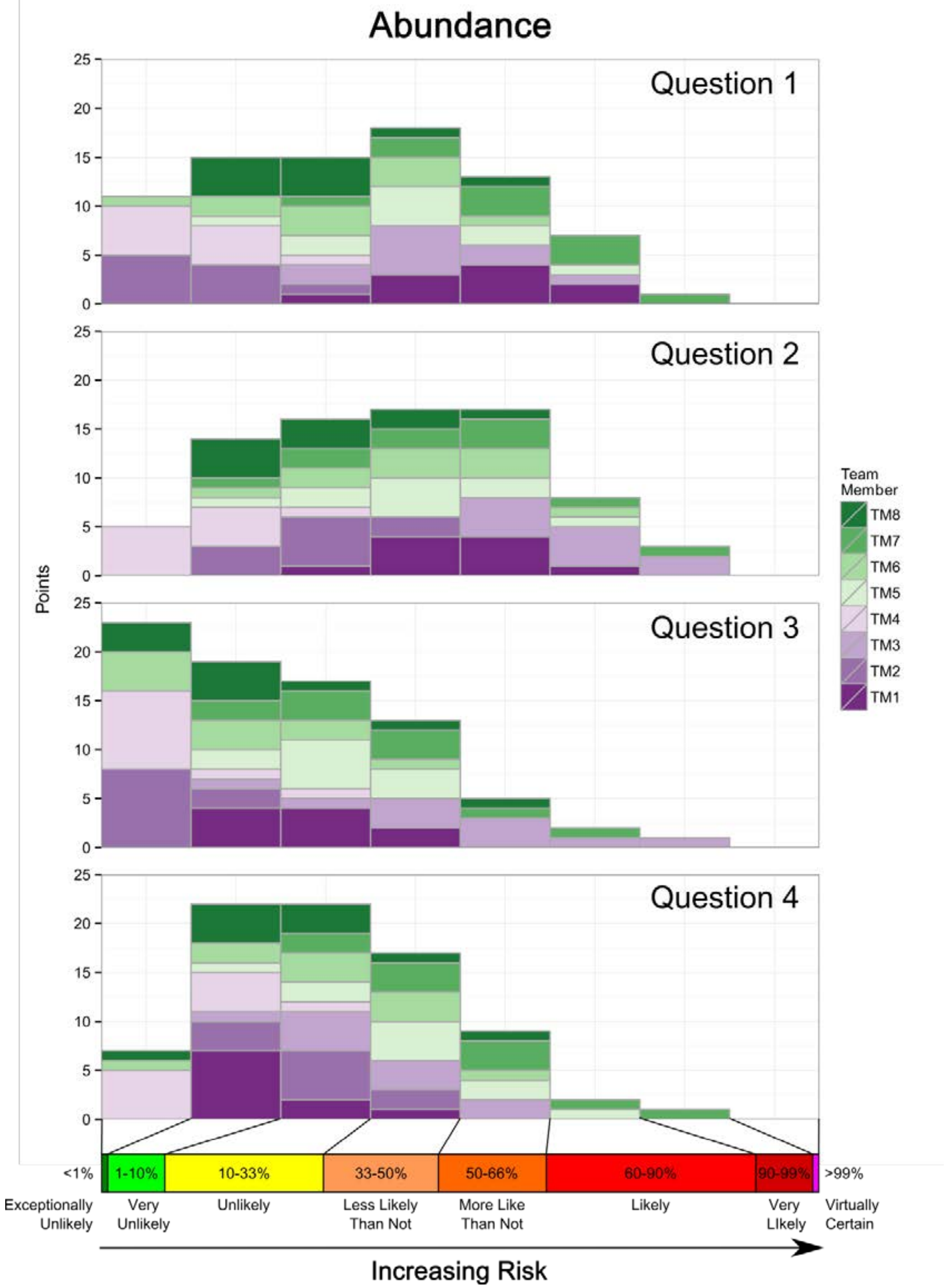


Figure 47. Number of risk points allotted by each voting status review team member (TM1-8) to each likelihood bin for the four abundance risk questions: Question 1) is the species' abundance so low that it is at risk of extinction due to environmental variation or anthropogenic perturbations (of the patterns and magnitudes observed in the past and expected in the future); Question 2) is the species' abundance so low, or variability in abundance so high, that it is at risk of extinction due to depensatory processes; Question 3) is the species' abundance so low that its genetic diversity is at risk due to inbreeding depression, loss of genetic variants, or fixation of deleterious mutations; and Question 4) is a species' abundance so low that it is at risk due to demographic stochasticity?

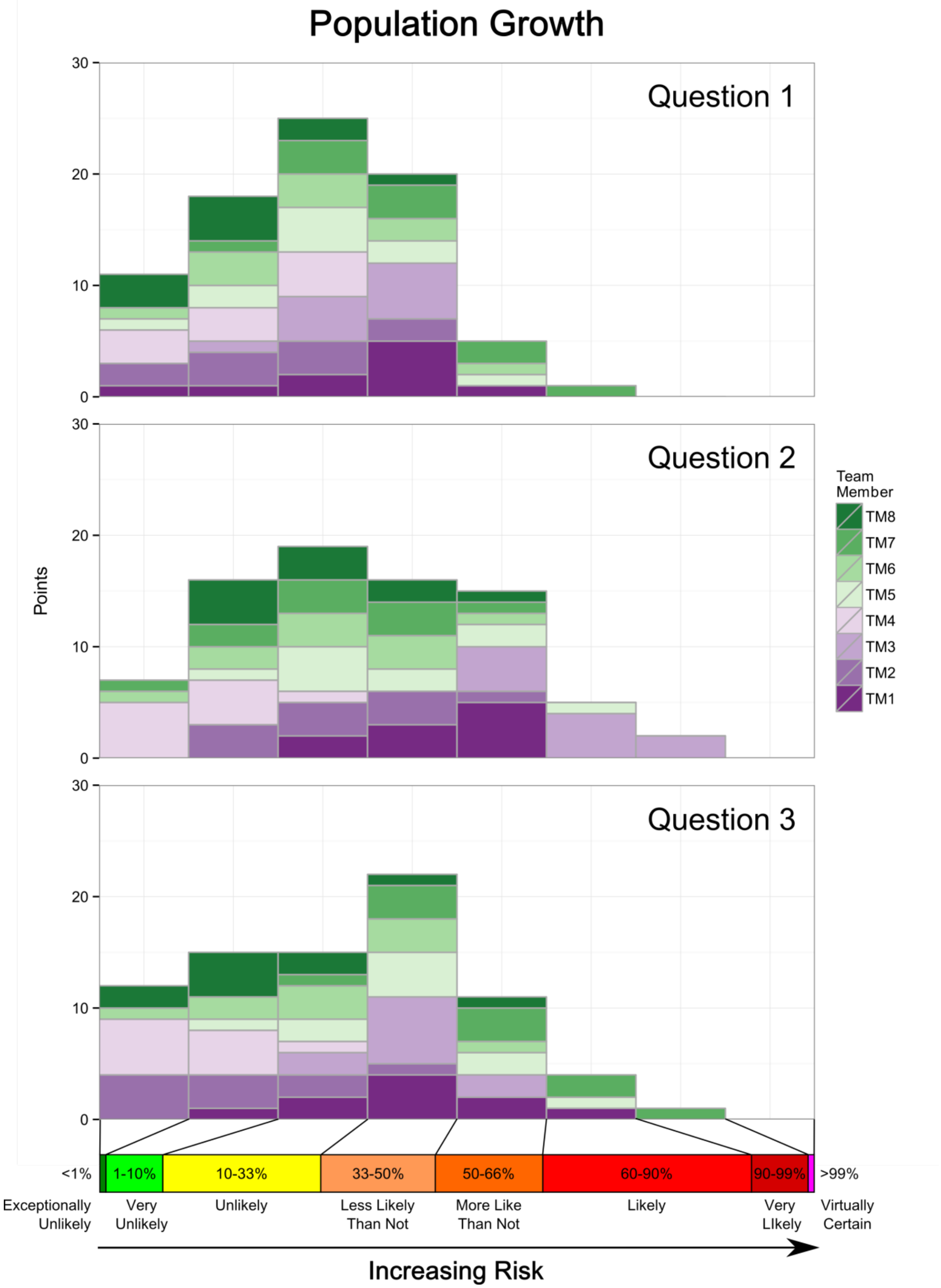


Figure 48. Number of risk points allotted by each voting status review team member (TM1-8) to each likelihood bin for the three population growth risk questions: Question 1) is a species' average population growth rate below replacement and such that it is at risk of satisfying the abundance conditions described in Figure 44; Question 2) is the species' average population growth rate below replacement and such that it is unable to exploit requisite habitats/niches/etc. or at risk due to depensatory processes during any life-history stage; and Question 3) does the species exhibit trends or shifts in demographic or reproductive traits that portend declines in per capita growth rate which pose risk of satisfying any of the preceding conditions?

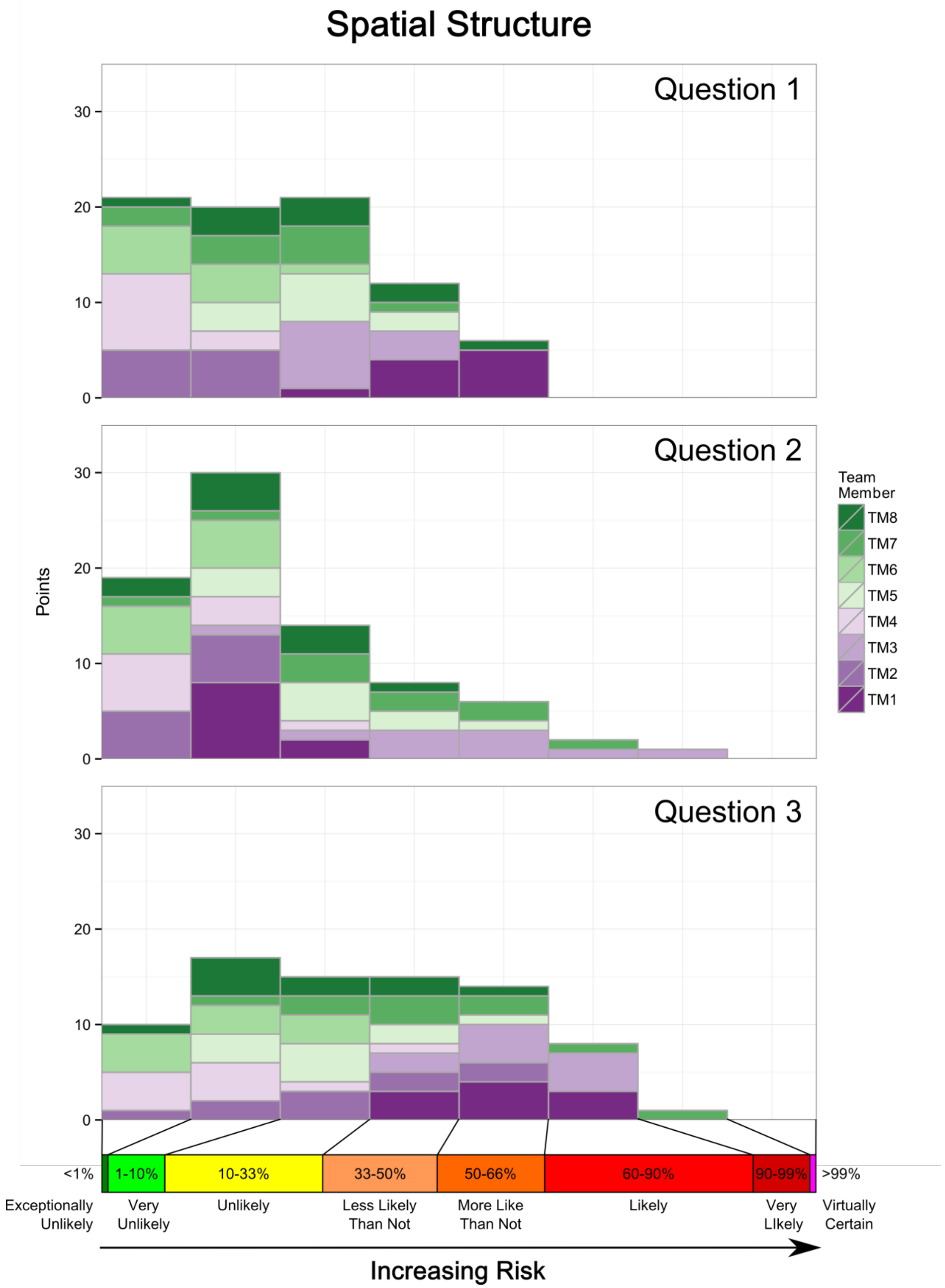


Figure 49. Number of risk points allotted by each voting status review team member (TM1-8) to each likelihood bin for the three spatial structure risk questions: Question 1) are habitat patches being destroyed faster than they are naturally created such that the species is at risk of extinction due to environmental and anthropogenic perturbations or catastrophic events; Question 2) are natural rates of dispersal among populations, metapopulations, or habitat patches so low that the species is at risk of extinction due to insufficient genetic exchange among populations, or an inability to find or exploit available resource patches; and Question 3) is the species at risk of extinction due to the loss of critical source populations, subpopulations, or habitat patches?

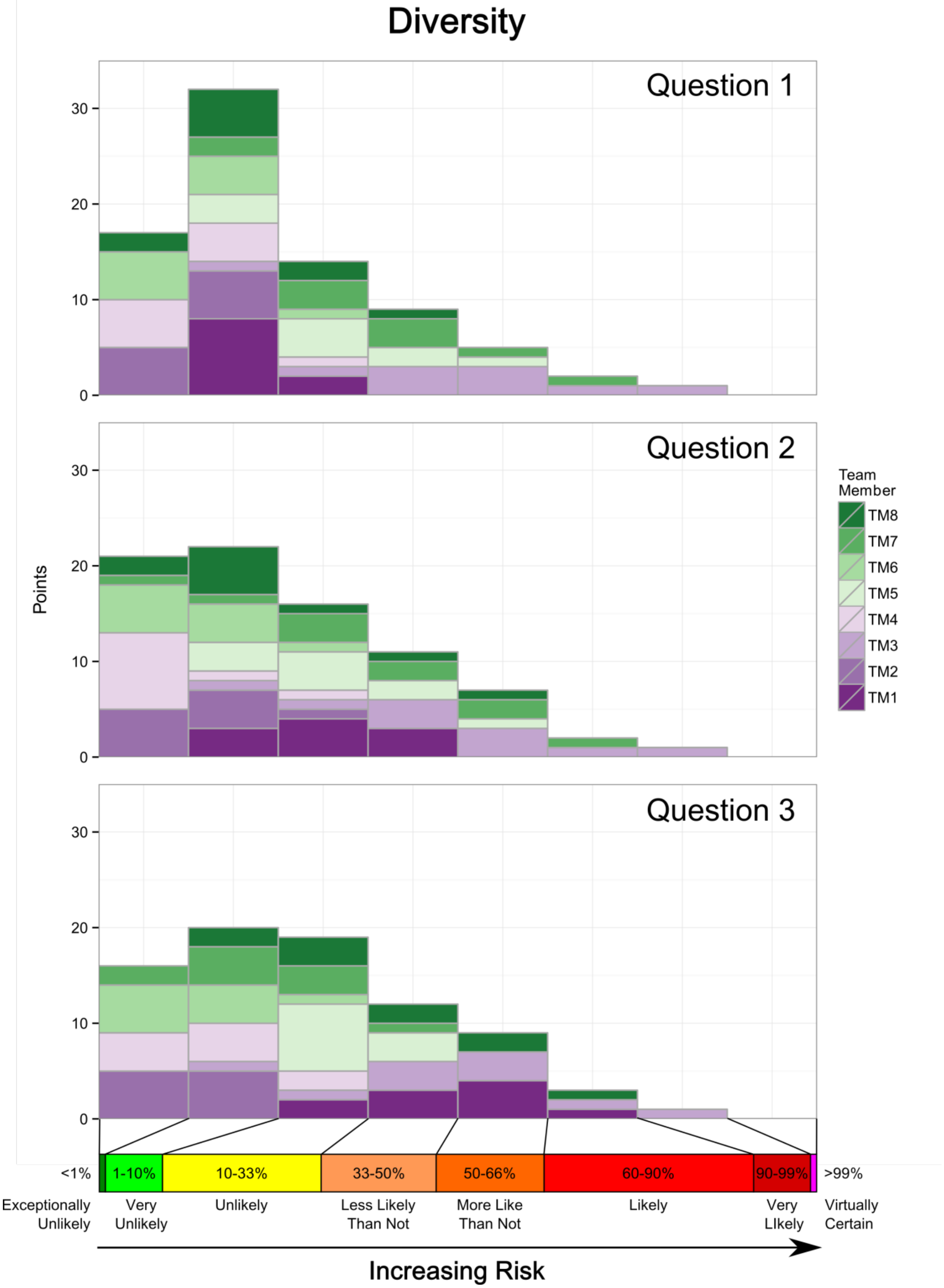


Figure 50. Number of risk points allotted by each voting status review team member (TM1-8) to each likelihood bin for the three diversity risk questions: Question 1) is the species at risk due to a substantial change or loss of variation in life-history traits, population demography, morphology, behavior, or genetic characteristics; Question 2) is the species at risk because natural processes of dispersal, migration, and/or gene flow among populations have been significantly altered; and Question 3) is the species at risk because natural processes that cause ecological variation have been significantly altered?

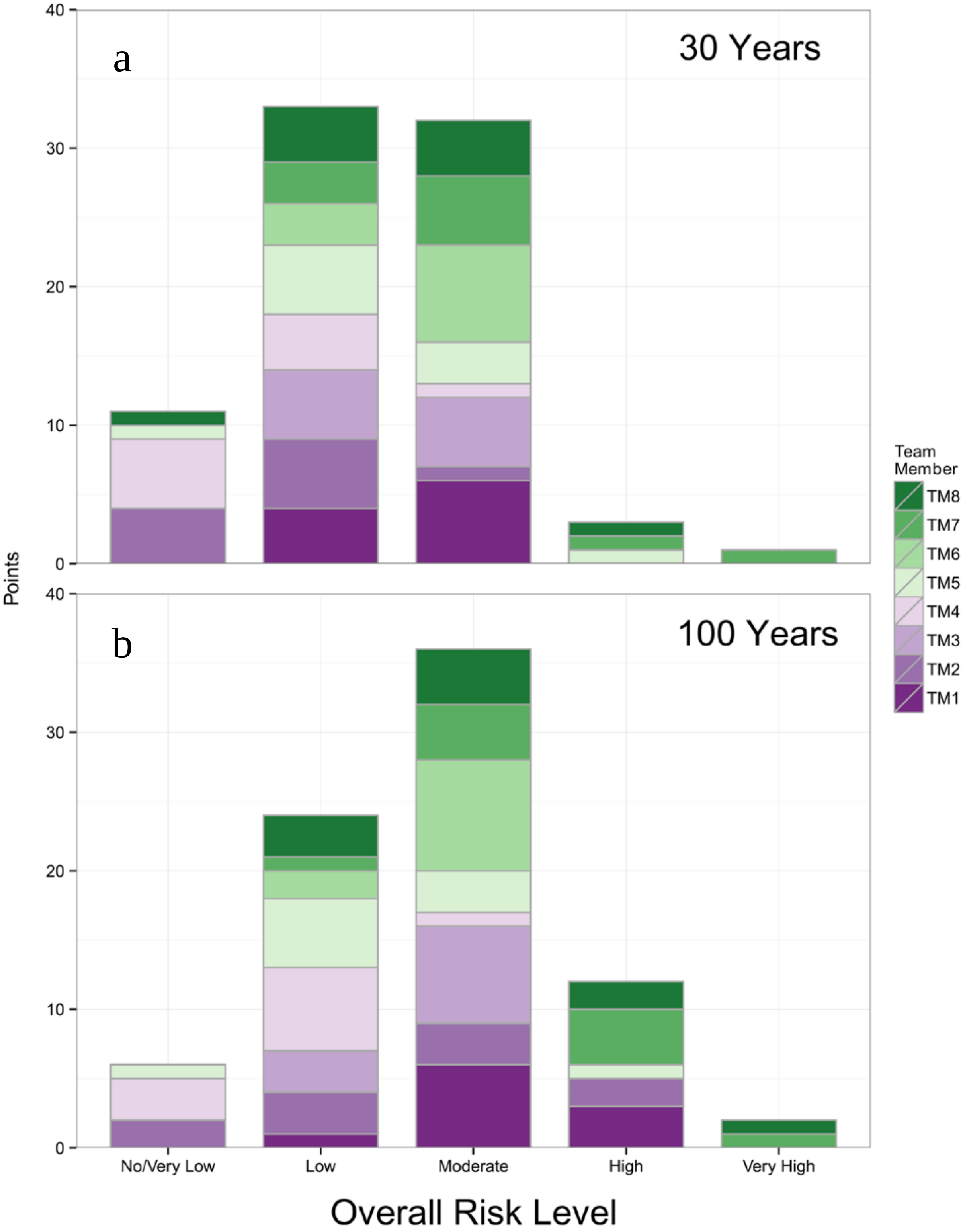


Figure 51. Overall level of extinction risk to pinto abalone now and in the foreseeable future, defined as (a) 30 years and (b) 100 years. The stacked bars show the total votes across all SRT members for each of 5 extinction risk levels, with votes by individual team members (TM 1 – TM 8) represented by different colors. Note: only 8 of the 9 SRT members participated in the overall extinction risk analysis.

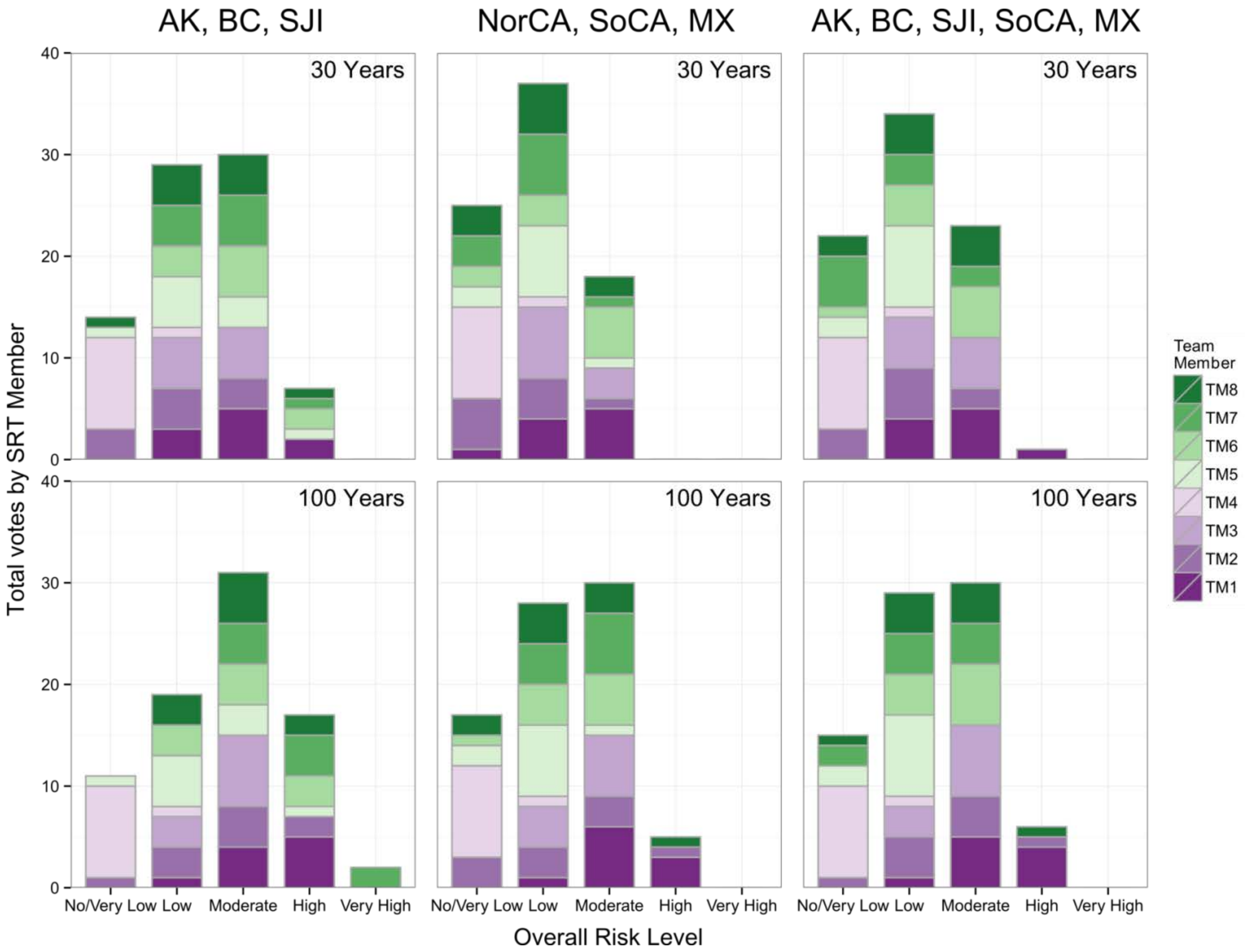


Figure 52. Overall extinction risk assessment results for the three potentially significant portions of the species' range (SPR): the Northern portion (Alaska, British Columbia, San Juan Islands Archipelago; AK, BC, SJI), the Southern portion (Northern California, Southern California, and Mexico; NorCA, SoCA, MX), and a portion encompassing the whole range excluding Northern California (AK, BC, SJI, SoCA, MX). The stacked bars show the total number of likelihood points allotted by each voting SRT member to the five extinction risk levels, with votes by individual team members (TM 1 – TM 8) represented by different colors. The SRT considered the overall extinction risk of the species now and within a foreseeable future of 30 years (top row of plots) and 100 years (bottom row of plots). Note: only 8 of the 9 SRT members participated in the overall extinction risk analysis for the three potential SPRs.