BEFORE THE SECRETARY OF COMMERCE

PETITION TO LIST THE PINTO ABALONE (*HALIOTIS KAMTSCHATKANA)* UNDER THE ENDANGERED SPECIES ACT

Center for Biological Diversity

August 1, 2013

NOTICE OF PETITION

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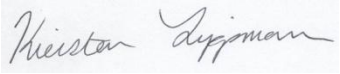

Date: August 1, 2013

Kiersten Lippmann
Center for Biological Diversity

Pursuant to Section 4(b) of the Endangered Species Act ("ESA"), 16 U.S.C. § 1533(b), Section 553(3) of the Administrative Procedures Act, 5 U.S.C. § 533(e), and 50 C.F.R. § 424.14(a), the Center for Biological Diversity ("Petitioner") hereby petitions the Secretary of Commerce and the National Oceanographic and Atmospheric Administration ("NOAA"), through the National Marine Fisheries Service ("NMFS" or "NOAA Fisheries"), to list the pinto abalone (*Haliotis kamtschatkana*) as a threatened or endangered species and to designate critical habitat to ensure its survival and recovery.

The Center for Biological Diversity (Center) is a non-profit, public interest environmental organization dedicated to the protection of native species and their habitats through science, policy, and environmental law. The Center has nearly 475,000 members and online activists in Alaska, throughout the United States and internationally. The Center and its members are concerned with the conservation of endangered species and the effective implementation of the ESA.

NMFS has jurisdiction over this petition. This petition sets in motion a specific process, placing definite response requirements on NMFS. Specifically, NMFS must issue an initial finding as to whether the petition "presents substantial scientific or commercial information indicating that the petitioned action may be warranted." 16 U.S.C. § 1533(b)(3)(A). NMFS must make this initial finding "[t]o the maximum extent practicable, within 90 days after receiving the petition." Id. Petitioner needs not demonstrate that the petitioned action is warranted, rather, Petitioner must only present information demonstrating that such action may be warranted. While Petitioner believes that the best available science demonstrates that listing the pinto abalone as threatened or endangered is in fact warranted, there can be no reasonable dispute that the available information indicates that listing this species as either threatened or endangered may be warranted. As such, NMFS must promptly make a positive initial finding on the petition and commence a status review as required by 16 U.S.C. § 1533(b)(3)(B).

The term "species" is broadly defined under the ESA to include "any subspecies of fish or wildlife or plants and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." 16 U.S.C. §1532 (16). Petitioners ask that the Secretary of Commerce list the pinto abalone as a threatened or endangered species because the continued existence of this species is threatened by one or more of the five listing factors.

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EXECUTIVE SUMMARY

Highly valued for its edible muscular foot and its mother-of-pearl shell, the pinto abalone has declined significantly in recent decades and faces extinction unless it is protected under the Endangered Species Act. The pinto abalone is a marine gastropod found in scattered patches in rocky areas of the intertidal zone off North America's west coast from Alaska to California. This easily accessible species once supported commercial, recreational, and aboriginal fisheries along the West Coast of North America including Canada and Alaska. Like many other abalone species worldwide, pinto abalone populations dropped precipitously over the last few decades, mainly due to poorly regulated commercial harvest. Closures of all commercial fisheries, complete bans on harvest in Canada and west coast states, and restricted harvest by recreational and subsistence users in Alaska, have done little to halt population declines. The pinto abalone has virtually disappeared from its historical range in Northern California and is declining in its Southern California range. The species appears to be experiencing zero recruitment in Washington State despite the closure of all fisheries there in 1994, and is rare to unknown in Oregon.

Poaching and low recruitment caused by low spawner densities are the most serious threats to pinto abalone. Poachers target large abalone, which means that the removal of these individuals is especially harmful, as extraction of highly reproductive mature adults reduces the fecundity of a population significantly more than the removal of other age groups. Additional factors that threaten the pinto abalone are environmental change, especially ocean acidification and ocean warming, increased storm activity, and disease and predation processes. Pinto abalone are part of the kelp forest ecosystem, a sensitive habitat that has been disrupted from its natural state by human activities for hundreds of years, beginning with the near-extirpation of sea otters for the fur trade, and continuing with over-harvest of marine invertebrates.

Greenhouse gas emissions and associated ocean acidification and sea surface temperature rise pose a major emerging threat to pinto abalone. Warmer sea temperatures may limit suitable pinto abalone habitat and also have a wide range of impacts from increased risk of disease to higher metabolic rates. Ocean acidification may affect pinto abalone directly by hindering calcification processes and increasing mortality of larval young and also through the indirect effects of reducing the availability of the abalone's kelp and algal food sources. Scientists have predicted that the pinto abalone will not survive without immediate and active intervention.

This petition summarizes the natural history of the pinto abalone, the population trend and status data available on the species, and the threats to the species and its habitat. The petition then shows that, in the context of the ESA's five statutory listing factors, the severely depleted

population status of the species and the ongoing threats to its continued existence merit listing under the ESA.

PART I. SPECIES ACCOUNT

1. INTRODUCTION AND SPECIES DESCRIPTION

The pinto abalone (*Haliotis kamtschatkana*), also commonly known as the Japanese or northern abalone, is a marine gastropod mollusk occurring in scattered patches of benthic habitat from Sitka, Alaska, to Turtle Bay, Baja California (IUCN 2011, ADFG 2013). Adult pinto abalone prefer rocky kelp-reef habitats, from the low intertidal zone to roughly 10 meters deep, where they graze on attached and drift algae (Sloan 2004, Lessard and Campbell 2007b). Because intertidal areas are easily accessible to humans, pinto abalone were readily harvested for their meat and shells, and are considered a delicacy (CDFW 2013). In North America, and especially Alaska, the pinto abalone has experienced a boom-bust cycle in population, with the boom following the near extirpation of sea otters, and the bust following poorly regulated commercial harvests in both Alaska and British Columbia (ADFG 2013). Pinto abalone populations dropped by 90% from 1979 -1996 in Alaska and by 88.6% from 1979 -2001 in the Queen Charlotte Islands of British Columbia (IUCN 2011). At present, pinto abalone densities are too low for successful recruitment in many areas, and the species is failing to show any signs of recovery despite strict closures of all commercial harvest in 1996 (Bouma 2007, Rothaus et al. 2008). Poaching continues to be a persistent problem and is likely to continue, due to the lack of enforcement capabilities along the remote Alaska and British Columbia coastlines, and the lure of the lucrative Asian market (Pynn 2009). Pinto abalone qualify for listing under the Endangered Species Act (ESA) based on continued decline in populations, failed recruitment from low density populations (Allee et al. 1949, Fisheries and Oceans Canada 2012, Chadès et al. 2012), and emerging threats including ocean acidification, sea level rise, warming sea temperatures (Vilchis et al. 2005, Bouma 2007, Kroeker et al. 2013), and disease (Daniels and Floren 1998). Recognizing the threats to the species, Canada listed pinto abalone as endangered in 2009 under its Species at Risk Act. The International Union for the Conservation of Nature (IUCN) also listed the pinto abalone as endangered in 2006. In 2004, NOAA fisheries listed pinto abalone as a "Species of Concern." This petition summarizes the pinto abalone's natural history, its current status throughout its range, and threats to the species and its habitat.

A. TAXONOMY AND DESCRIPTION

Abalone belong to the gastropod genus *Haliotis*, which includes seven abalone species native to the west coast of North America. Pinto abalone are divided into a northern and southern subspecies, with the northern population, *H. kamtshatkana kamtschatkana* distributed from Alaska south to Point Conception, California, where it merges with the southern subspecies, *H. kamtschatkana assimilis* (common name "threaded abalone"), that has a distribution from Point Concepcion south to Baja California (COSEWIC 2009, Rogers-Bennett et al. 2011). The taxonomic classification of pinto abalone is as follows.

Phylum Mollusca
Class Gastropoda
Order Archaeogastropoda
Superfamily Pluerotomariacea
Family Haliotidae
Genus *Haliotis*
Species *kamtschatkana*

Pinto abalone are a relatively sedentary, herbivorous, single shelled mollusk with a characteristically large muscular foot with which they secure themselves to rocky substrate (Fallu 1991). These gastropods secrete an ear-shaped shell composed of aragonite, with three to six respiratory pores over the mantle cavity that allows for removal of waste material and water from the gills. The shells grow to a maximum length of about 16.5 cm, increasing in length as the mollusk ages (Crim 2010). The exterior color of the shells is typically mottled reddish or greenish with patches of white and blue. The edges of the shell are relatively scalloped. Encompassing the foot, tentacles protrude into the water, aiding the abalone in its search for food and detection of predators (NOAA 2007). The interior of the shell is a pearly-white with a hint of iridescence (COSEWIC 2009).

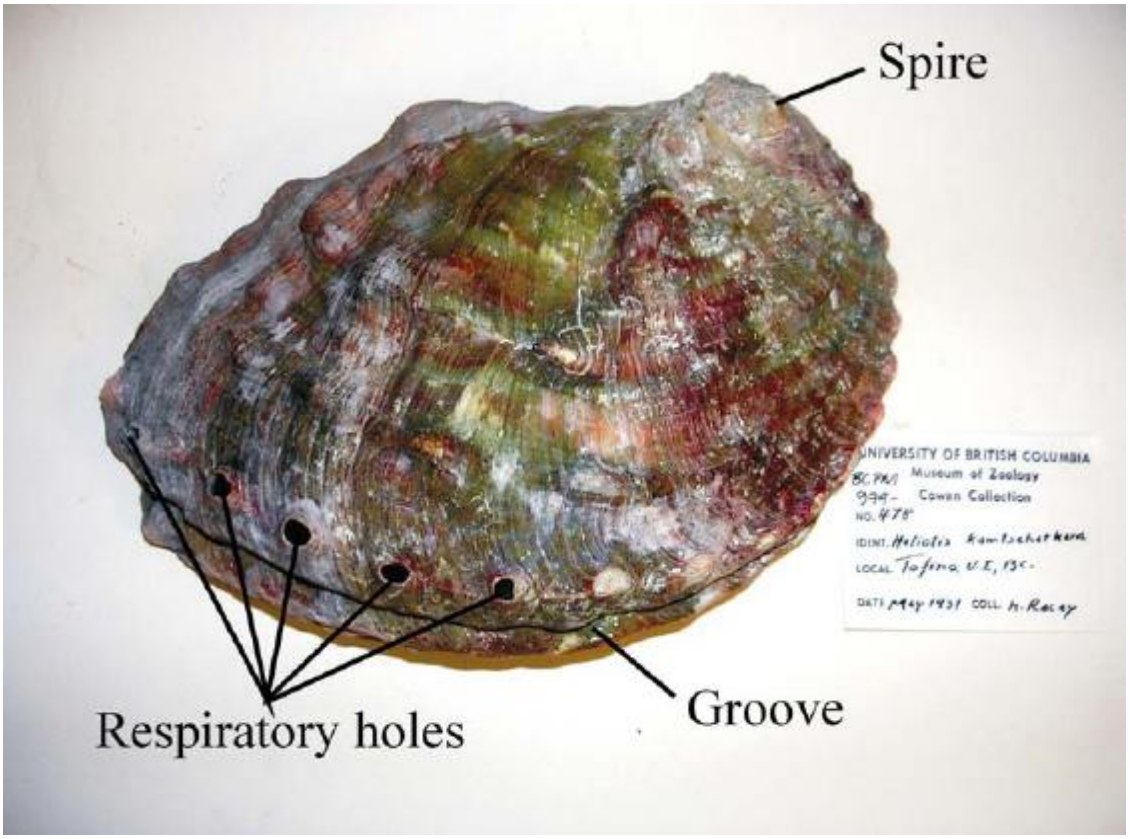

Figure 1. Northern Abalone, *H. kamtschatkana* (COSEWIC 2009; Photo by L. Kirkendale, RBCM, Victoria)

2. DISTRIBUTION, HABITAT USE, AND MOVEMENTA. DISTRIBUTION

The pinto abalone is found in shallow intertidal waters from Sitka Sound, Alaska, to Turtle Bay, Baja California (Lessard and Campbell 2007) (Figure 2). Pinto abalone are the only known abalone species found in the inland waters of the state of Washington (NMFS 2009), with a rare and poorly understood distribution in Oregon. Although records show that the subspecies of threaded abalone were rarely found in Mexican waters in the 1980s, there have been no recent reports of any live individuals, and the species may no longer occur south of California (COSEWIC 2009).

B. HABITAT USE

Pinto abalone are habitat specific, and prefer shallow, rocky sub-tidal habitats with low to medium exposure, scattered boulders, and kelp canopy (Rogers-Bennett et al. 2011). Pinto abalone occur at depths from the intertidal zone to 10-20 m, although juveniles may be found at depths of 100 m (Sloan 2004, Lessard and Campbell 2007, NOAA 2007, Rogers-Bennett et al. 2011). When entering the juvenile stage from the planktonic larval stage, abalone prefer to settle in shallow macroalgal forests with deep boulder environments (Bouma 2007), and in sea urchin barrens where crustose coralline algae levels are high (Bouma 2007, Rogers-Bennett et al. 2011). Urchin and abalone abundance are positively correlated, indicating that abalone may benefit from urchin presence or vice-versa (Tomascik and Holmes 2003). The size and abundance of pinto abalone varies according to the amount of wave exposure and kelp forest cover, with smaller adults found in areas with high wave energy (Sloan 2004, Lessard and Campbell 2007). Pinto abalone density is generally highest in *Pterygophora californica* kelp forests without surface canopy, and lowest in *Macrocystis intergrifolia* kelp forests, with abalone densities in *Nereocystis luetokeana* kelp forests between the two extremes (Lessard and Campbell 2007). Abalone require salinity of >30 ppt, and are rarely found near areas of freshwater input (COSEWIC 2009). Pinto abalone can adapt to a wide range of temperatures, from 2 to 24 degrees C, and appear to be limited in their southern range by warming water temperatures.

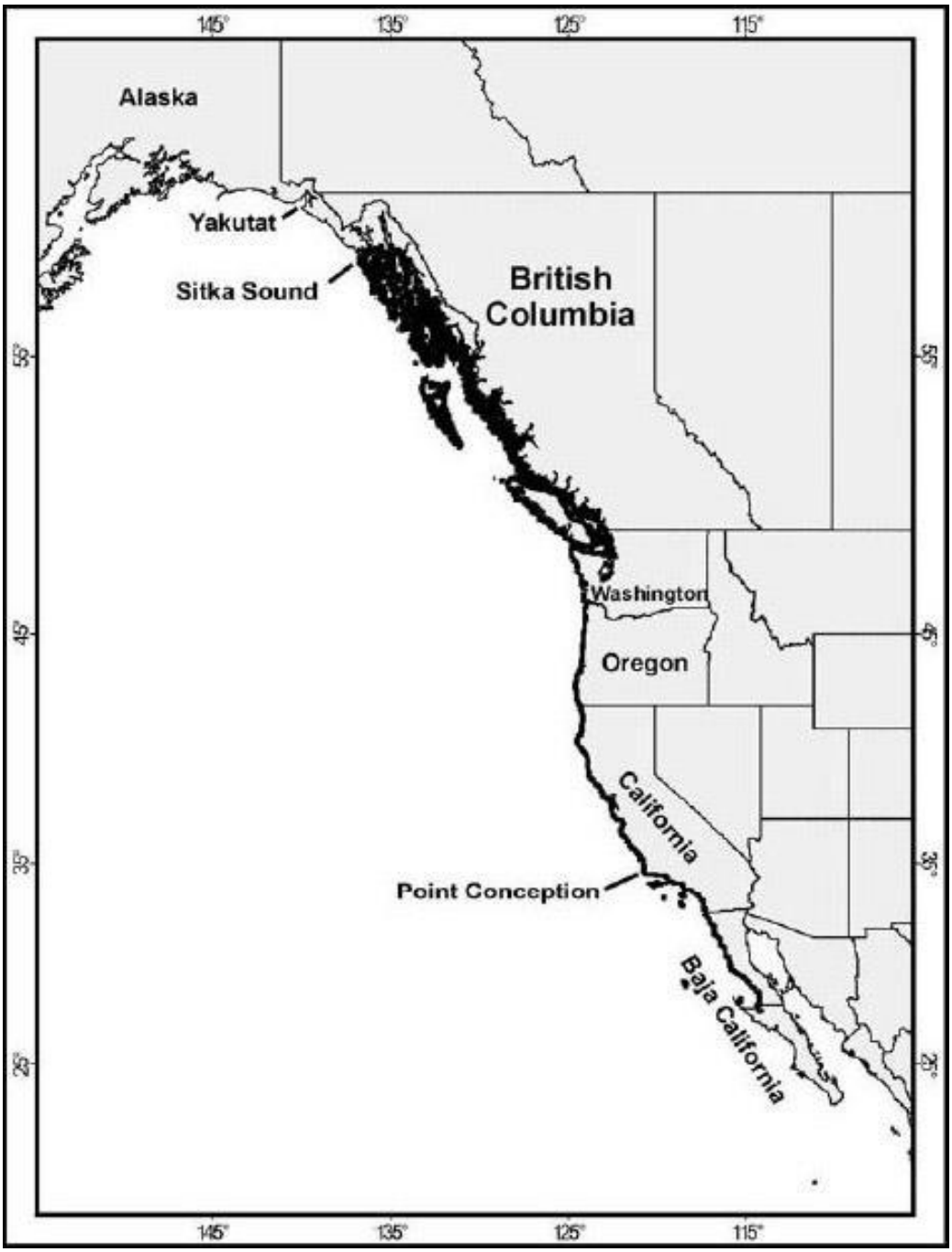

Figure 2. Estimated global distribution of *H. kamtschatkana* along west coast of North America. (COSEWIC 2009)

C. MOVEMENT

Like most snails, pinto abalone use their muscular foot as means of locomotion. Pinto abalone generally do not travel very far from where they first settled as larvae, which means that in order

to successfully spawn, individuals must occur at sufficient densities (Bouma 2007). The snails can travel several meters in a single day, but usually return to the same general vicinity. Evidence of little to no movement over a lifetime are home scars, which are a bare spots on a rock that conforms to the shape of the abalone's shell. Pinto abalone move very little vertically within the water column, with the total movement being less than 50 meters in a year (COSEWIC 2009).

The feet of pinto abalone do not cling well to sand; therefore, they are usually only found on hard substrate including rocks or coral (Figure 3). When an abalone feels threatened, it uses its foot to cling tightly to the substrate, and it is nearly impossible to remove the abalone without a tool (Fallu 1991).

Figure 3: Side view of a juvenile pinto abalone.

3. DIET AND FEEDING ECOLOGY

Pinto abalone are herbivorous. During the free swimming 7-10 day larval period, pinto abalone are lecithetrophic and do not feed. Juveniles consume benthic diatoms, films of bacteria and microalgae (COSEWIC 2009). During this time, they may compete with sea urchins as both eat the same food source. As abalone grow and increase in size, they begin to feed on seasonally available benthic macroalgae, including drift kelp (Rothaus et al. 2008, COSEWIC 2009). Turbulent water acts as a trigger for grazing. Feeding when the water is more turbulent means increased cover for abalone due to drifting seaweed or other detritus, decreasing the risk of predation (Fallu 1991).

Herbivorous grazing by adult abalone in rocky subtidal zones helps to regulate ecosystem dynamics of the benthic community and may promote further settlement and recruitment of juveniles (Bouma 2007). Thus, pinto abalone fill an important ecological role.

4. REPRODUCTION AND GROWTH

Pinto abalone are broadcast spawners, with pre-spawning male and female adults gathering for synchronous release of gametes into the water column. Spawning events typically take place between April and June (Breen and Atkins 1980). The reproductive strategy of broadcast spawning means that reproductively mature adults must be grouped in close proximity to each other in order to increase the chances of fertilization and reduce dilution, and thus recruitment success is highly density-dependent (Bouma 2007). As the nearest neighbor distance increases, fertilization success declines precipitously, with low adult densities known to result in failed reproduction, also known as the "Allee effect" (Allee et al. 1949, Bouma 2007). Researchers estimate that a minimum population density of 0.15 abalone per square meter or a proximity of 1.0 to 2.0 meters is required for successful reproduction, although pinto abalone may be able to overcome this requirement to some extent by aggregating to reduce nearest-neighbor distance (Berec et al. 2007, Seamone and Boulding 2011).

Once sperm and egg meet and form a zygote, the fertilized egg floats to the surface before sinking back down into the water column (Fallu 1991). Within one to two days after successful fertilization, eggs hatch and the planktonic larvae are released into the water. The ocean-going planktonic phase of the pinto abalone life cycle is typically 7-14 days and is longer with cooler water temperatures (Shepherd et al. 2000), which limits larval dispersal to a relatively short distance (COSEWIC 2009). This means abalone colonies are dependent on locally produced larvae, hindering recovery of highly exploited populations (Bouma 2007).

Larvae survival depends on whether they are able to find suitable substrate (Campbell 2000). Larvae prefer to settle under rocks or in crevices at greater depths than where adults are found, migrating to shallower waters as they mature (COSEWIC 2009). Environmental fluctuations and storms may impact larval settlement and survival, especially depressed salinity and elevated seawater temperatures (Rogers-Bennett 2007). Coralline algae, abundant in pinto abalone habitat, can trigger settlement of larval abalone (Fallu 1991). Juvenile abalone consume films of bacteria or microscopic plants, and are generally cryptic and difficult to observe until they reach a length of 50 mm (Bouma 2007). Pinto abalone are considered juvenile until they reach a shell length of 70 mm (COSEWIC 2009). Survival of larvae to adults may be sporadic from year to year, dependent on environmental conditions and wave activity.

Fecundity of pinto abalone increases exponentially with length. A female with a shell length of 57 mm has a fecundity of 156,985 eggs. Once a female achieves a shell length of 139 mm, she

has huge jump in fecundity to 11.56 million eggs (COSEWIC 2009). This means that large females contribute a substantial amount to the reproductive success of an abalone community, and a high percentage of mature females are important for maintaining a viable population (Campbell 2000, COSEWIC 2009).

Pinto abalone are relatively long-lived, surviving up to four decades (Shepherd et al. 2000), and reaching a maximum shell length of 14 to 16.5 cm (Rothaus et al. 2008). Growth is variable depending on conditions in the marine environment, with a linear growth rate of up to 19.7 mm per year for the first five years, after which growth rates gradually slow down (Shepherd et al. 2000, Bouma et al. 2010). Spawning begins after about three years, or at a length of about 5 cm (Muse 1998). Growth rates vary with water temperatures, amount of shelter in the habitat, and food supply (Campbell 2000). Researchers in Alaska found that abalone in sheltered to semi-exposed habitat in edible kelp forests grew at a faster rate and reached a larger size than abalone in habitats dominated by inedible kelp species and exposed to rougher wave regimes (Shepherd et al. 2000). Abalone in exposed areas of sub-optimal habitat that grow slowly and never reach maximum length are referred to as “surf” abalone (Muse 1998).

5. CAUSES OF MORTALITY

A. NATURAL MORTALITY

Pinto abalone are subject to natural mortality from numerous sources including predation, disease, changing environmental conditions, and parasites.

Young and larval abalone are especially vulnerable, and mortality of larval and newly settled pinto abalone in the first year is very high and thought to exceed 98% (CDFW 2013). As pinto abalone mature, the mortality rates generally decrease with increasing size (Read et al. 2013). River otters (*Lontra canadensis*), octopi (*Enteroctopus dofleini*), lobsters, sea stars (*Pycnopodia helianthoides*), crab (*Cancer* spp.), fish, and other abalone predators primarily take smaller abalone, while sea otters (*Enhydra lutris*) will take abalone of any size (COSEWIC 2009). Annual natural mortality rates of mature pinto abalone are estimated to range between 0.15 and 0.27, or 20% a year, with sporadic survival from year to year (Breen and Sloan 1988, Muse 1998).

Shell parasites, including the boring clam and sponges, may weaken abalone shells. Mortality from these parasites is especially high in older abalone (CDFW 2013). During storm events, abalone weakened by parasites may be washed away. Storms may also remove the pinto abalone’s primary algal food source, resulting in lower food resources and higher mortality rates (CDFW 2013).

Interspecific competition is another source of natural mortality. Pinto abalone and sea urchins have overlapping niches. Both organisms consume drift macroalgae and occupy kelp forests and may compete with each other for limited food resources (COSEWIC 2009).

Warm waters during El Niño events and due to climate change may increase pinto abalone mortality in a number of ways discussed in more detail in Part III, and may already have limited the southern range of the pinto abalone. Warm water is nitrogen-poor, which hinders kelp productivity and reduces food resources for the abalone. At the same time warm water may also speed up the abalone's metabolism, leading to energy imbalance. Warm water also may reduce larval survival, further restricting the species' range and fecundity.

Ocean acidification also contributes greatly to pinto abalone mortality (Crim et al. 2011, Li et al. 2013). As ocean waters become more acidic, with decreasing aragonite saturation levels, the calcification processes required for pinto abalone to produce and maintain a shell will be disrupted. Impacts to larval development, and to shell strength and development will increase mortality rates. Additionally, ocean acidification may impact the kelp-coralline algal ecosystem on which pinto abalone depend (see further discussion in Section III).

i. Sea Otter Predation

Sea otter predation on pinto abalone is a complex issue, but most researchers agree that restoration of intertidal kelp-forest habitat requires full recovery of sea otter populations because otters increase biodiversity and maintain ecological functioning (Fanshawe et al. 2003). Sea otters are an important keystone species that are associated with kelp forests and are specialist predators of invertebrates. The level of predation on pinto abalone by sea otters is difficult to estimate because the use of intertidal habitats by sea otters may vary among locations depending on environmental conditions, sea otter movement and individual foraging preferences (Butler et al. 2009). Marine ecosystems are highly complex, and the interactions between sea otters and pinto abalone remain poorly understood.

There are no population data for pinto abalone prior to the massive sea otter hunts from the 1700s to 1900s, and historic densities of both species are unknown (Chadès et al. 2012). Historically, sea otters and pinto abalone evolved to share the kelp forest ecosystem with other species, including kelp and sea urchins, and all species likely existed in a state of dynamic equilibrium (Watson 2000). The extirpation of sea otters from most of their historic range resulted in drastic changes in ecosystem structure of kelp forests and intertidal areas and in disruptions to prey population dynamics. The increase in abalone populations after the extirpation of sea otters may have fueled human overharvest, spurring unsustainable harvest limits and resulting in the crash of the abalone fishery (Watson 2000).

Although sea otters are a natural predator of pinto abalone, researchers find that sea otters are not the primary factor inhibiting pinto abalone recovery, and were at such low numbers that the otter certainly played no role in the collapse of the population during the 1990s (Chadès et al. 2012). Instead illegal poaching by humans, with synergistic and compounding effects from climate change, and low recruitment, are regarded as the key reasons for continued decline (Jubinville 2000, Chadès et al. 2012). In areas of Washington state and Canada where sea otters are not present, pinto abalone continue to decline (Rothaus et al. 2008, COSEWIC 2009). Modeling of pinto abalone recovery finds that a decrease in poaching of at least 50% is required to meet any sort of recovery goal, while the removal of sea otters had only a marginal positive effect on abalone population (Chadès et al. 2012). Thus, improving enforcement of poaching should be the highest priority.

B. POACHING

Poaching of pinto abalone continues to be the major impediment to abalone recovery (Campbell 2000, Chadès et al. 2012). Although there have been relatively few apprehensions and even fewer convictions of poachers, population surveys and black market sales indicate that poaching is an ongoing problem and a serious threat to the viability of pinto abalone. For example, pinto abalone stocks at survey sites in Canada dropped an additional 40% following the ban on harvest, (Pynn 2009), indicating a high level of illegal harvest. Because of the lucrative returns for illegal harvest, with pinto abalone reportedly selling for $35 to $55 a pound on the Asian black market compared to just $6 a pound for farmed abalone, poachers likely consider the pay-off to be well worth the risk. Investigators report that the black abalone market is as intricate and lucrative as illegal drug trafficking (Pynn 2009).

Illegal harvest of abalone is generally carried out by residents of coastal communities, especially those with experience as commercial underwater harvesters of other species such as sea urchins (Welch 2012). This is because these individuals have the expertise, equipment, and ability to operate under the radar, often under the premise of harvest of legal species such as sea urchins. Poachers are difficult to apprehend, especially due to the remote and inaccessible nature of North America's rocky and remote coastline.

Between 1997 and 2006, there were approximately 30 abalone poaching convictions in Canada (COSEWIC 2009). A more recent joint U.S.-Canada-led probe into the illegal abalone trade titled "Operation Awabi" resulted in successful prosecution of high-level and large scale abalone poachers and re-sellers, in both California and British Columbia. Despite this effort, fishery enforcement agents believe that 80-90% of poachers are not prosecuted, remain unknown, or are otherwise undetected (Pynn 2009). Future efforts to curb poaching focus on education and

outreach, highlighting the traditional importance of pinto abalone to aboriginal users (Fisheries and Oceans Canada 2012)

In addition to simply removing abalone and reducing population numbers and limiting recovery of the species, poaching further reduces reproductive success by removing large and fecund mature abalone and leaving behind patches of smaller, younger and less fecund abalone that are too far apart to successfully spawn. Poachers selectively harvest larger abalone, due to their increased value at market, and are in this way compounding an already serious problem (COSEWIC 2009).

6. SUBSISTENCE AND TRADITIONAL USE

Abalone have been harvested by humans for thousands of years, and were valued for their large and tasty edible foot and colorful shell (Campbell 2000). Pinto abalone were a traditional food to coastal Alaska natives, First Nations people of Canada, and Native American tribes in Washington, Oregon, and California. They also played an important role in spiritual and cultural society.

In Canada, all harvest or possession of pinto abalone has been illegal since 1990, including subsistence harvest by aboriginal people (COSEWIC 2009).

In Alaska, abalone harvest for subsistence use is allowed year-round with a daily bag limit of 10 abalone of at least 3.5 inches in size, and a 30 abalone annual limit. This limit was reduced from a previous subsistence daily limit of 50 abalone (Bowers et al. 2012). Reported subsistence harvest has dramatically decreased in many areas of Southeast Alaska, with an average drop in harvest for subsistence use of 98% from 1972 to 1978 according to surveys in the communities of Craig, Klawock, and Hydaburg (Bowers et al. 2012).

Subsistence use is also allowed in Washington and California, but is relatively rare.

7. ECOLOGICAL IMPORTANCE

Scientists believe that sea urchins and pinto abalone perform similar ecological functions by controlling algal density as an integral part of intertidal kelp forest ecosystems (Lessard and Campbell 2007). Pinto abalone are considered ecosystem engineers because they modify their surrounding habitat through their grazing to promote colonization by other species. In benthic ecosystems, pinto abalone function as both herbivore and prey (COSEWIC 2009). Both juvenile and adult abalone consume micro-algae and kelp, and recovery of the pinto abalone may be linked to the abundance and health of kelp forests (Rogers-Bennett et al. 2011).

8. ABUNDANCE AND POPULATION TRENDS

The pinto abalone has experienced extreme population declines throughout its range entire range from California to Alaska. The decline of pinto abalone is quantified through both fishery-related data and research surveys, with minimal or no data available for many areas.

A. ALASKA

The commercial fishery for pinto abalone in Alaska was short lived and peaked from 1978 through 1982, after which it declined sharply (Campbell 2000, Rumble and Hebert 2011). The large jump in harvest of pinto abalone occurred in the 1978-79 season, and was accompanied by a three-fold increase in effort. Next season, 1979-80, harvests increased to an all-time high of 378,685 lbs. This peak exceeded Alaska Board of Game's quota of 250,000 lbs for the 1980 season, resulting in the first emergency closure of the fishery.

Above-quota harvest continued through the 1981-82 season when harvest exceeded 371,000 lbs despite a reduced quota of 125,000 lbs, and a shorter fishing season. By the 1984-85 season, the serious depletion of pinto abalone was finally realized when the fishery failed to reach the 86,000-lb quota, despite 151 days of fishing. A harvest of just 64,000 lbs during the 1990-91 season was the beginning of a second downward trend that continued until the fishery was closed in the 1995-96 season (Rumble and Hebert 2011). Increased harvest and effort was due in part to an increase in sale value of pinto abalone, which rose from $1 per pound in the early 1970s to more than $10 a pound during the last four seasons the commercial Alaska abalone season was open (1992-1995).

In response to decreased harvest rates, and other concerns, the abalone fishery was permanently closed by emergency order on October 16, 1995, to protect the remaining, vastly diminished populations (Woodby et al. 2000, Walker and Pritchett 2006, Rumble and Hebert 2011).

With the closure of Alaskan abalone fisheries and the lack of index sites there are few data to determine the current population status of pinto abalone in Alaska (McDougall et al, 2006). However, the combination of historical fishery data and current index sites in British Columbia likely reflect current conditions in Alaska.

B. BRITISH COLUMBIA

The commercial pinto abalone fishery in British Columbia followed a similar boom-bust pattern of Alaska's commercial fishery (Figure 4). Historical small scale harvesting switched to higher production in the early 1970s (Muse 1998, Jamieson 1999). Initially, in an effort to curb the rapid increase in harvest of pinto abalone, managers restricted licensing, shortened the season, closed specific areas, and put in place size limits for harvest (Muse 1998). Managers continued

to decrease the quota due to the declining population of abalone in the region, but efforts to manage the declining population failed. In 1990, abalone fisheries in British Columbia were closed to harvest by all user groups (Muse 1998).

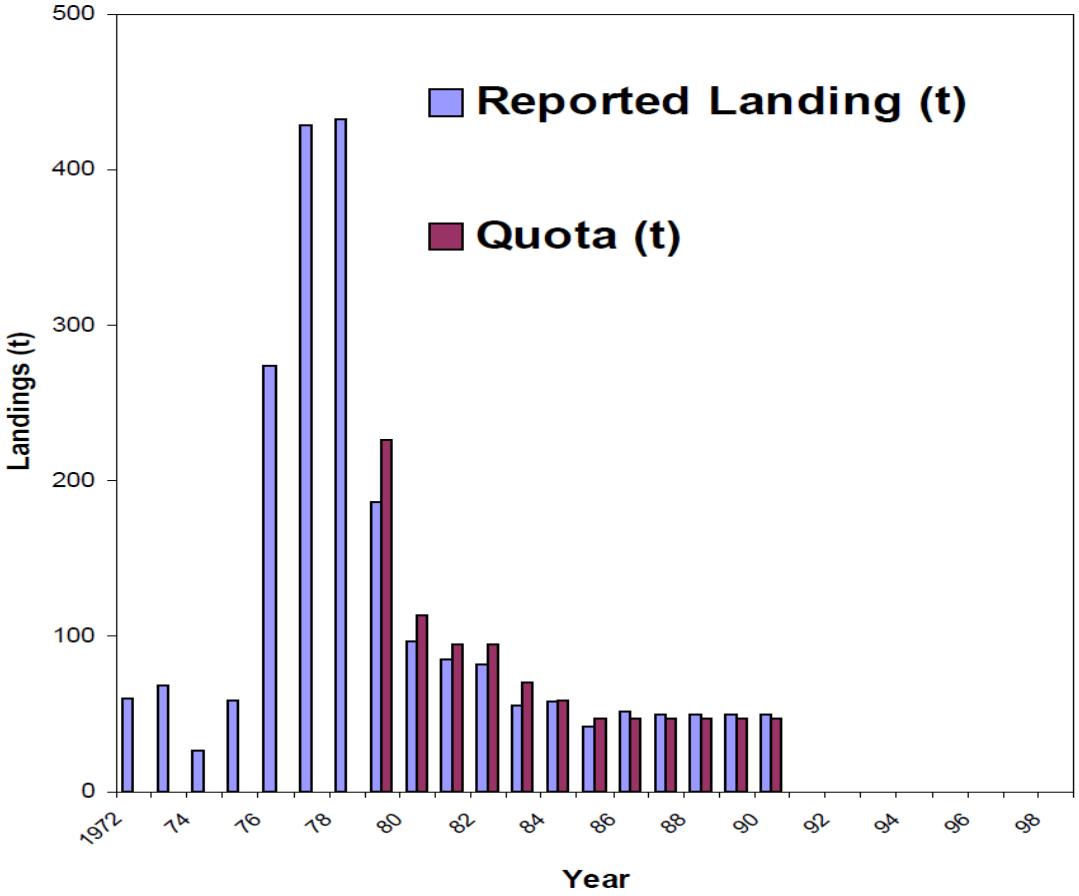

Figure 4: Reported landings and harvest quota in British Columbia from 1972 to 1990. Jamieson 1999.

The closure of pinto abalone commercial fisheries in British Columbia did not lead to recovery of the species. Surveys from index sites in the Queen Charlotte Islands and the Central Coast show that densities of the pinto abalone continue to decline (Sloan 2005, COSEWIC 2009, Egli and Lessard 2011). Anthropogenic factors such as poaching, ocean warming, reduced salinity, dredging and coastal development, and ocean acidification are likely responsible for continued declines (Byrne et al. 2011, Fisheries and Oceans Canada 2012). The populations of pinto abalone are currently well below historic levels due to the lingering after effects of unregulated commercial harvest and compounding environmental and biological influences.

C. WASHINGTON

Pinto abalone are considered functionally extinct in Washington state waters, due to a lack of sufficient spawner densities to effectively reproduce (Bouma et al. 2012). While no commercial fishery ever existed in Washington, recreational harvest was allowed up until 1994 (Rothaus et al. 2008). Despite the closure of the recreational fishery in 1994, Washington continues to see an overall decline in the densities of the abalone population. In the San Juan Archipelago in Washington, 10 index stations where the Washington Department of Fish and Wildlife monitors pinto abalone populations show densities below what is required for successful recruitment, and natural reproduction is largly unsuccessful (Figure 5). Overall shell length of the pinto abalone is also increasing, suggesting a failure in juvenile recruitment (Rothaus et al. 2008).

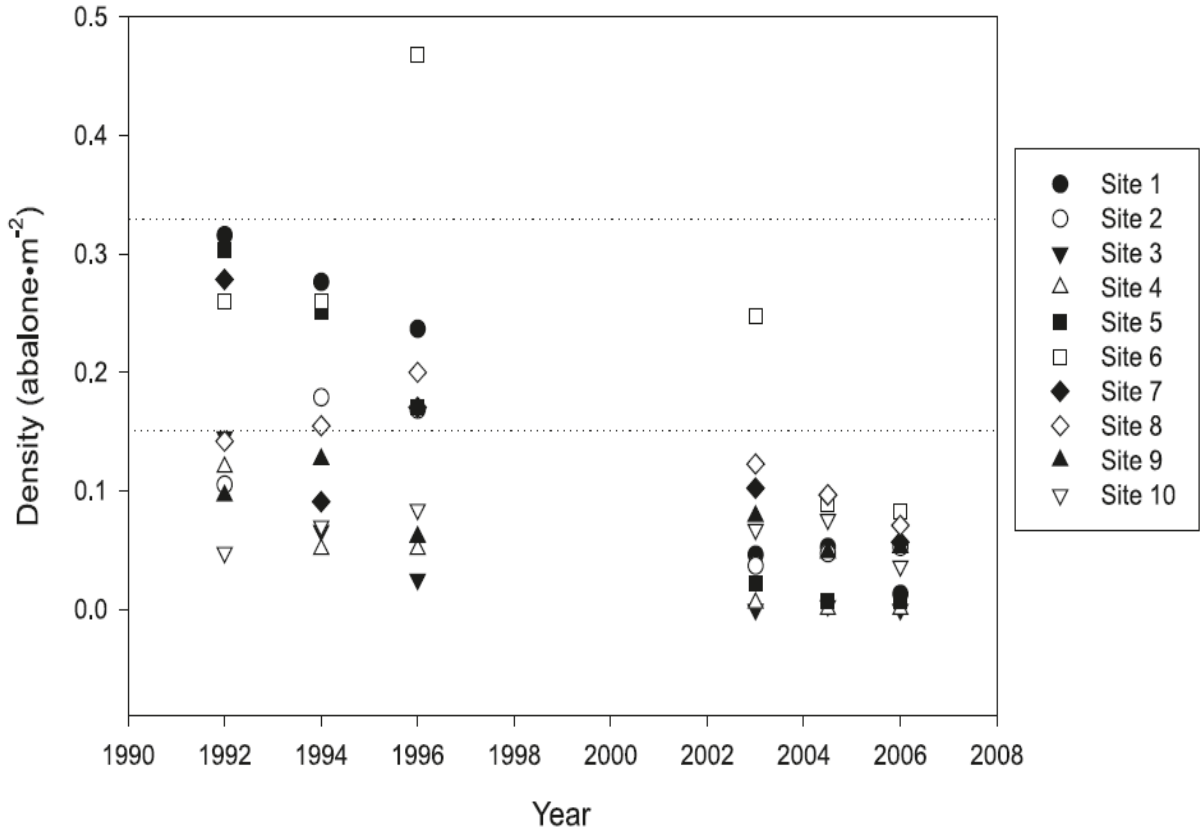

Figure 5: Declining abalone densities and index sites in Washington State (Rothaus et al. 2008).

Washington's aging abalone population is without young recruits and a tipping point has been reached where densities are well below what is conducive for reproduction. Without assistance, the pinto abalone population of Washington state will become locally extinct (Bouma et al. 2012). A large-scale outplanting effort of farm-raised pinto abalone was launched in 2009, and continues to present (Figure 6), but survival results of outplants vary greatly, and long-term benefits to population are uncertain (Stevick 2010, Hester et al. 2011).

Figure 6: Pinto abalone tagged for easier identification before outplanting in Washington state (Photo by Josh Bouma)

C. OREGON

Pinto abalone surveys have never been conducted in Oregon (COSEWIC 2009). Pinto abalone reportedly occur in Oregon, but never in abundances sufficient to support a commercial fishery (NMFS 2009). The recreational fishery in Oregon is currently closed due to continued decline in numbers and size of pinto abalone, in an effort to allow for stock recovery (Washington Department of Fish and Wildlife 2013).

D. CALIFORNIA

Pinto abalone in California are in decline and represent less than 1% of total abalone species currently occurring in California waters (CDFW 2013). The once lucrative commercial abalone fisheries has collapsed (Figure 7), resulting in a moratorium on all abalone fishing in California, except for limited recreational fishing for red abalone in the northern part of the state (CDFW 2013). Once fished commercially, both the black and white abalone are now listed as federally endangered. In the southern portion of their range in California, threaded abalone, the southern subspecies of pinto abalone, are now very rare in areas where they were once common (Rogers-Bennett 2007). Surveys conducted in 2007 found no pinto abalone in central California, where the species was described as “common” in 1966 (Rogers-Bennett 2007). In northern California, pinto abalone declined by ten-fold, suggesting that warmer ocean temperatures are playing an

important limiting role. Overall, the California population of pinto abalone has declined drastically from an estimated baseline abundance of 153,000 in 1971 to 18,000 in 2001 (Rogers-Bennett et al. 2002, CDFW 2013).

Figure 7: Pierce Brothers abalone processing plant, ca. 1933. Photo by Pat Hathaway, Source: Rogers-Bennett et al. 2002.

PART II. THE PINTO ABALONE QUALIFIES AS THREATENED OR ENDANGERED UNDER THE ESA

The Endangered Species Act, 16 U.S.C. §§ 1531 – 1544, allows any species of fish or wildlife or plant to be listed under the provisions of the act. Section 3(8) of the ESA defines "fish or wildlife" to mean "any member of the animal kingdom, including without limitation any mammal, fish, or bird…*mollusk*, crustacean, arthropod, or other invertebrate…" 16 U.S.C. § 1532 (8) (emphasis added). The pinto abalone is a mollusk. The pinto abalone (*Haliotis kamtschatkana*) was formally described as a species in 1845 (Cox 1962). Its taxonomy and validity as a species is uncontested. It qualifies as a "species" under the Act. Petitioners seek protection for the species throughout its range in Alaska, Washington, Oregon, California, Mexico and Canada.

1. PRESENT OR THREATENED DESTRUCTION, MODIFICATION OR CURTAILMENT OF ITS HABITAT OR RANGE

A. ANTHROPOGENIC GREENHOUSE GAS EMISSIONS

Human activities continue to release massive amounts of greenhouse gases into the atmosphere, primarily through the burning of fossil fuels, cement manufacturing and deforestation, with the rate of emissions increasing by 3% each year, well above that predicted under most scenarios (Hansen et al. 2013). The resulting global climate change and ocean acidification processes will impair biological and ecological functions of pinto abalone, with direct impacts to calcification and growth, and indirect impacts to the intertidal kelp forest that is essential pinto abalone habitat (Crim 2010).

Research has found that abalone growth and survival is strongly influenced by environmental variability, and anthropogenic emissions of greenhouse gases will result in warming water temperatures, increasing ocean acidification, shifting ocean circulation patterns, and likely the increasing frequency and intensity of storm and El Niño warming events. As a result, pinto abalone may suffer degradation or loss of habitat, disruption of biogenic calcification processes, low or non-existent larval survival rates, and disruptions to predator-prey dynamics and ecosystem functioning (Crim 2010, Crim et al. 2011, Li et al. 2013).

Climate change is especially harmful to intertidal species, such as the pinto abalone, that tolerate only a narrow zone of environmental conditions (Vilchis et al. 2005, Li et al. 2013), and reductions in the distribution and abundance of intertidal species resulting from climate change are well documented (Harley and Rogers-bennett 2004). Sea level rise will also have significant impacts, inundating substantial areas of the pinto abalone's intertidal habitat, with reductions in salinity further reducing availability of viable habitat. As described below, climate change and ocean acidification will have profound effects on marine ecosystems within this century, with serious impacts to the survival and recovery of the pinto abalone.

i. Ocean Acidification

a. Introduction

Ocean acidification is the one of the greatest threats to marine ecosystems, and one of the most serious threats to the survival and long-term recovery of the pinto abalone. The oceans are a massive reservoir for CO_2 and have absorbed nearly one-third of global anthropogenic CO_2 emissions since the year 1800 (Sabine et al. 2004). While the uptake of CO_2 by the oceans has buffered the effects of climate change, it has resulted in rapid changes in seawater chemistry. Ocean acidification occurs when CO_2 reacts with seawater to generate carbonic acid, which

releases hydrogen ions to form bicarbonate and carbonate ions (Wolf-gladrow et al. 1999, Turley et al. 2007). This increases the concentration of hydrogen ions in seawater and lowers the pH, thus giving rise to the term "ocean acidification." The ocean's absorption of anthropogenic CO_2 has already resulted in about a 30% increase in the acidity of ocean surface waters, at a rate likely faster than anything experienced in the past 300 million years. Ocean acidity is projected to increase by 100-150% by the end of the century if CO_2 emissions continue unabated (Orr et al. 2005, Feely et al. 2009, Hönisch et al. 2012), resulting in a sea water surface pH drop of 0.3-0.4 units (IPCC 2007a, USGCRP 2013).

In addition to reduced pH, ocean acidification reduces the availability of calcium carbonate (CaCO3) for calcifying organisms (Doney et al. 2009). A decrease in the calcium carbonate saturation state stresses calcifying organisms including pinto abalone by negatively impacting the mechanisms, abilities, and energetic costs for calcification, growth, and other essential biological processes including reproduction (Crim 2010, Holcomb et al. 2010), acid-base regulation (Pörtner 2008), respiration (Rosa and Seibel 2008), and tolerances of other stresses (Pörtner 2008, Hutchins et al. 2009). Increased ocean acidity and calcium carbonate undersaturation also negatively affect coralline algae, and kelp species that are important food sources and habitat components for both adult and juvenile pinto abalone (Thresher et al. 2011).

Predictions for the future of calcifying organisms in an acidifying and warming ocean are grim. Feely et al. (2012) report that in the Pacific Ocean there has been a decrease of the saturation state of surface seawater with respect to aragonite and calcite as well as an upward shoaling of the saturation horizon by about 1-2 meters per year on average. Overall, aragonite saturation state has declined 16% since the industrial revolution (Ishii et al. 2011, Feely et al. 2012). The marine regions inhabited by the pinto abalone--the California Current System and the colder, high-latitude waters of the North Pacific--are particularly vulnerable to ocean acidification, as discussed below (Feely et al. 2008, Byrne et al. 2011, Gruber et al. 2012). Decreasing calcium carbonate saturation states have been shown to negatively impact pinto abalone (Crim et al. 2011), and all calcifying marine organisms tested to date have shown at least an initial negative response to decreasing carbonate saturation states (Kroeker et al. 2010, 2013).

The impacts of widespread calcium carbonate undersaturation on marine ecosystems may be very severe and result in massive die-offs of marine organisms. Historical records show mass extinctions of marine taxa during periods of total water column calcium carbonate undersaturation (Zachos et al. 2005). An ocean acidification event, combined with increasing temperatures, on the scale of projected future levels of ocean acidification resulted in extinction of a large proportion of benthic calcifiers 55 million years ago (Zachos et al. 2005). Impacts from this modern ocean acidification event, which would take place over mere decades to centuries, would result in a far more rapid rate of change than the historical event, and this rate of change in ocean acidification levels is unprecedented in the historical record (Hönisch et al. 2012).

b. Waters of the North Pacific are rapidly Acidifying

High latitude waters, including the North Pacific and Bering Sea, are the "bellwether" of ocean acidification because these will be the first ocean regions to become persistently undersaturated with respect to aragonite as a result of greenhouse gas pollution (Fabry et al. 2009, Steinacher et al. 2009). This is critical, as the pinto abalone forms an aragonite shell, and undersaturation with respect to aragaonite may have severe adverse impacts on the species (Kroeker et al. 2013). High-latitude waters have naturally lower carbonate ion concentrations and saturation states due to a combination of cold temperatures, which increase the solubility of CO_2, and ocean mixing patterns (Fabry et al. 2009, Mathis et al. 2011b). Modern-day increases in CO_2 solubility in the Arctic and North Pacific result from a combination of increasingly warmer air and water temperatures, melting ice, and increased concentration of atmospheric CO_2, all of which result in increased absorption of CO_2 by waters in northern latitudes and a hastening of the ocean acidification process (Steinacher et al. 2009). Warmer temperatures also cause a more active hydrological cycle, bringing more low-mineral $CaCO_3$ to the outer-shelf, and increasing the rate of undersaturation (Mathis et al. 2011).

Because of the natural high solubility of CO_2 at northern latitudes, aragonite and calcite thresholds are already very shallow in the North Pacific and Arctic oceans compared to other more temperate ocean areas, and are progressively moving higher as the concentration of anthropogenic CO2 in the atmosphere continues to rise (Guinotte et al. 2006). In the North Pacific, the aragonite saturation horizon is only 50-600 m, compared to 2,000 m in the North Atlantic Ocean (Feely et al. 2009). In the Aleutians the aragonite saturation horizon currently stands at less than 150 m (Guinotte et al. 2006), and the calcite saturation horizon is at just 260 to 440 m (Orr et al. 2005).

Recent observations of calcium carbonate saturation states in the North Pacific and Bering Sea have found that full water column undersaturation of calcium carbonate due to ocean acidification is already prevalent. Mathis et al. (2011b) reported that extensive areas of bottom waters over the Bering Sea shelf are becoming undersaturated with respect to aragonite for at least several months (July to September), and some areas of bottom water were already observed to be undersaturated with respect to calcite (Fabry et al. 2009, Mathis et al. 2011b). Re-mineralization of organic matter exported from surface waters appears to increase bottom water CO_2 concentrations over the shelf in summer and fall, suppressing the calcite and aragonite saturation state (Ω) values. In the surface waters, removal of CO_2 by high rates of phytoplankton primary production increases saturation state values between spring and summer, but these increases are partly counteracted by sea ice melt water and terrestrial river runoff that have low saturation state values and that are increasing with climate warming.

Under existing CO_2 emission rates, models predict that the surface waters of the Arctic Ocean and parts of the North Pacific will be undersaturated with respect to aragonite in the next 50 years, starting as early as 2016 in the Arctic (Figure 8) (Orr et al. 2005). Surface waters of the parts of the North Pacific are already undersaturated with respect to calcite (Steinacher et al. 2009, Mathis et al. 2011b).

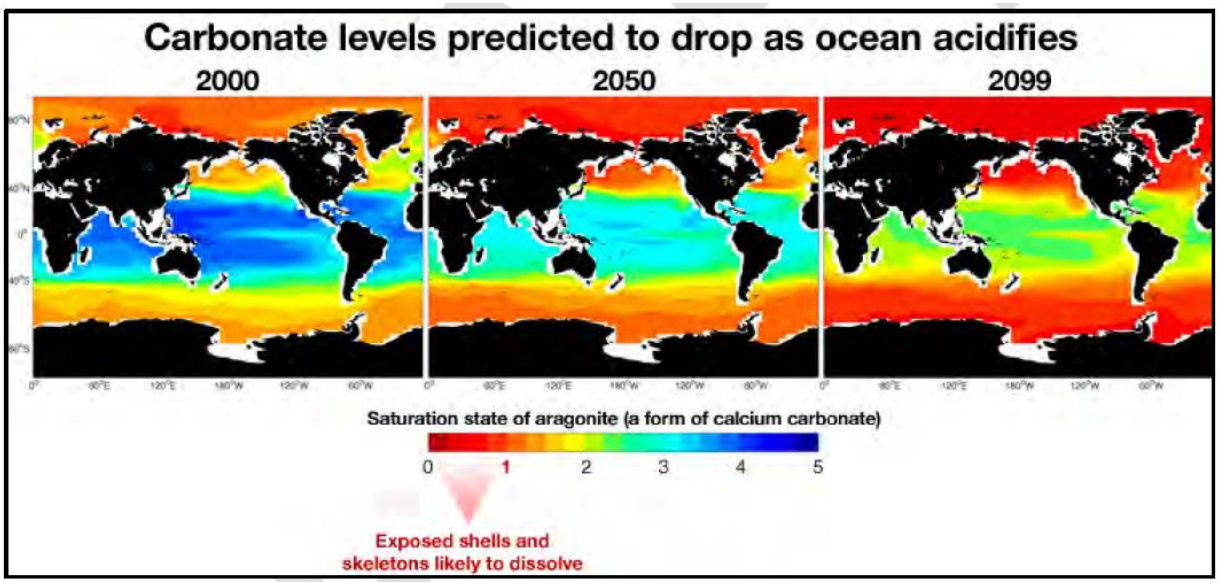

Figure 8: Calculated saturation states of aragonite. Shades of red indicate areas where levels are so low that organisms may be unable to make new shells or skeletons, and where most unprotected aragonite structures will dissolve. By the end of this century, polar and temperate oceans may not longer be conducive for the growth of calcifying organisms such as some mollusks, crustaceans, and corals (Source: Feely et al. 2009).

c. Upwelling

Waters of the Pacific Northwest are strongly influenced by upwelling, which means that pinto abalone may be exposed to the level of ocean acidification experimentally found to have serious adverse effects on larval survivorship and shell development in the near future, and well before the end of this century (Feely et al. 2007). Upwelling is the process by which corrosive deep acidic water is forced up to shallow nearshore habitats as a result of winds moving surface waters offshore. These deep waters are cold, high in dissolved CO_2, and low in dissolved oxygen, which presents three simultaneous environmental stressors to coastal organisms (Barton et al. 2012). The intensity and persistence of upwelling off the Oregon coast is predicted to be a recurring feature of a warming climate (Harley and Rogers-bennett 2004).

Available data indicate that upwelled waters along the Pacific West coast are undersaturated with respect to aragonite, and have a pH of just 7.6 to 7.7 (Feely et al. 2008, Gruber et al. 2012),

which is lower than the pH expected for global oceans within the next century. Models project that the saturation state of nearshore (within 10 km of the coast) waters of the California Current System will drop rapidly, with waters to 60 m deep developing under-saturation within 30 years (Gruber et al. 2012). Within 50 years, more than half of nearshore waters are projected to exhibit year-round undersaturation with respect to aragonite (Gruber et al. 2012).

Manipulated laboratory experiments have observed serious impacts to pinto abalone, especially at young life stages, at a pH of 7.6 or below (Crim et al. 2011). Pinto abalone spawn in late spring to early summer, during the peak upwelling period, exposing vulnerable larval stages to the most extreme states of acidification and undersaturation. Fluctuations in local CO_2 chemistry will occur concurrently with ocean acidification, resulting in increasingly lengthy periods where conditions are unfavorable to mollusks (Barton et al. 2012). Thus, pinto abalone may suffer greater mortality and especially poor recruitment in years with intense upwelling events, which are expected to increase with climate change. This will further exacerbate effects on larval survival and shell morphology.

d. Ocean Acidification Impacts on Pinto Abalone Recruitment and Survival

Early life stages of pinto abalone may be particularly vulnerable to ocean acidification (Kurihara 2008). Ocean acidification has many observed effects on early developmental processes including fertilization, larval growth, larval duration, and settlement (Dupont and Thorndyke 2009), even with minor changes in pH (Crim et al. 2011).

The negative effects of ocean acidification on early life stages have been observed for many abalone as the pH dropped below 7.6, with effects including decreased fertilization and hatching rates, decreased growth rates, and increased malformation rates (Byrne 2011, Li et al. 2013). Crim (2011) observed abnormal shell development in pinto abalone exposed to even minor elevation in CO_2 concentrations. Forty percent of pinto abalone larvae developed abnormal shells at 800 ppm CO_2, with virtually all larvae developing abnormal shells, or lacking a shell completely at 1800 ppm (Crim et al. 2011). Recent research shows that upwelling is already resulting in seawater concentrations of 850 ppm at the continental shelf break off northern California, with higher values inshore (Feely et al. 2008). Larvae that lack a shell or have an abnormal shell are highly susceptible to predation. Similarly, Li et al (2013) found that embryonic development of the Pacific abalone was also negatively affected by reduced pH. At a pH between 7.6 and 7.3, researchers observed prolonged hatching time, an increased malformation rate, and decreased hatching and metamorphosis rates (Li et al. 2013). Abalone develop calcified shells during post-embryonic stages of development, and secrete the more soluble polymorphs of calcium carbonate (amorphous $CaCO_3$ and aragonite) during the larval

stage, meaning abalone larvae are particularly sensitive to reductions in the aragonite saturation horizon (Crim et al. 2011).

Seawater pH can also disrupt chemical signaling, which may decrease the ability of pinto abalone larvae to detect suitable substrate for settlement. Ocean acidification may have especially severe impacts on low density populations of pinto abalone, because survival and recovery of the species hinges on successful recruitment, which will be further limited by the negative consequences of ocean acidification.

In addition to impacts to the juvenile and reproductive life stage, ocean acidification may also produce a stress response in pinto abalone by enhancing their energy metabolism, suppressing the amount of energy available for reproduction and growth (Crim et al. 2011). Additionally, the influence of adult exposure to ocean acidification on larval performance is unknown and may have a significant negative impact.

Experimental results may be misleading and underestimate the negative consequences on ocean acidification. Impacts of ocean acidification on some calcifiers, including oysters, has resulted in population collapses or range shifts well above that which would be indicated by most experimental research results. Rather than undergo a slow decline, a species may simply be unable to survive past a specific and unknown tipping point of pH and carbonate saturation levels (Cooley and Doney 2009). With pinto abalone experiencing zero recruitment and increasing population declines along the west coast of North America, and unknown population dynamics in Alaska's waters, it is possible that pinto abalone are already experiencing serious declines due to ocean acidification and are at or exceeding the unknown tipping point, and immediate action to reduce greenhouse gas emissions and promote recovery must be taken to prevent extinction of this species.

e. Ocean Acidification Impacts to Pinto Abalone Habitat

Coralline algae and kelp forests, especially bull kelp (*Nereocystis* spp.), are crucial components of pinto abalone habitat, and provide important cover, food sources, and areas for the settlement of larvae and juveniles (Lessard and Campbell 2007). Ocean acidification may affect various processes of these species including photosynthesis, growth, calcification rate and competitive ability (Asnaghi et al. 2013). Under acidified conditions, with a pH less than 7.7, coralline algae experience weakened structure, which reduces their ability to resist boring by predators and wave energy, and also experience severe reductions in recruitment rates and growth (Kuffner et al. 2007, Ragazzola et al. 2012). Sea urchins are similarly affected, and act as major grazers in the rocky intertidal habitats inhabited by pinto abalone. Research has found that urchins are susceptible to ocean acidification across all development stages, even with small changes in pH

(Hall-Spencer et al. 2008, Asnaghi et al. 2013), and are absent in areas where the pH drops below 7.8 (Asnaghi et al. 2013). The loss of sea urchins will have complicated impacts on rocky intertidal kelp ecosystems, and on pinto abalone.

Ocean acidification will also impact non-calcifying kelp species, primarily through changes to the predator-prey dynamics. With a decrease in sea urchin density, grazing pressure on kelp and other non-calcifying algae will be reduced. This may result in a loss of biodiversity, due to ocean acidification-caused reductions in coralline algae species, less available areas for invertebrate colonization due to lack of sea urchin grazing, and poor recovery of intertidal communities following disturbance (such as fishing pressure) due to a loss of coralline algae, which promote recovery and complexity in rocky intertidal communities (Asnaghi et al. 2013). These complex ecosystem interactions could result in reduced suitable habitat for pinto abalone, and in an increased susceptibility to predation.

Thus, the loss or reduction in coralline algae, along with a drop in or absence of sea urchins, would have myriad negative impacts on pinto abalone, including lack of or poor success for larval settlement, decreased habitat suitability, diet insufficiencies leading to increased susceptibility to predation, increased mortalities from wave or storm action, and decreased densities. Additional changes in ecosystem dynamics and community structure of pinto abalone habitat due to changes in the abundance of keystone species, such as kelp, are relatively unknown due to a lack of long-term studies, but are likely to adversely affect pinto abalone in similar ways to the well-researched negative impacts observed for sea urchins. Mollusks such as the pinto abalone comprise the bottom or middle trophic levels of benthic ecosystems, and acidification-caused reductions in these species may negatively impact their primary and secondary predators in complex ways, possibly resulting in ecosystem collapse.

* * *

Ocean acidification is a primary threat to the pinto abalone, with severe direct and indirect impacts occurring at a pH of 7.7-7.8 and below. Ocean acidification will limit the ability of pinto abalone to successfully reproduce, or obtain adequate nutrition and inorganic carbon for growth, repair, and other biological processes, especially during the early life stages. Adult abalone will suffer decreased rates of calcification and more energetically costly calcification. This will inhibit the growth and repair of the pinto abalone shells and result in a weaker attachment to the rocky substrate, making abalone more susceptible to predation and removal by wave and storm action. Negative impacts to pinto abalone from ocean acidification are expected to be significant. These impacts may range from decreased growth and reproduction, poorer ability to compete for habitat, food, and other important resources, and increased metabolism to complete die-offs of pinto abalone in many areas, similar to the massive mortalities suffered by oysters along the Pacific Northwest coast (Barton et al. 2012).

ii. Climate Change and Ocean Warming

The earth has warmed more from 1976 to present than it has at any time during the last 1,000 years (Glover and Smith 2003, IPCC 2007a). Global surface temperature has increased by 0.76 °C between the years 1850-1899 and 2001-2005 (IPCC 2007). Warming has also occurred in all major ocean basins at nearly every latitude during the last 50 years from the surface to the deep ocean to at least 2000 m (Levitus et al. 2012). Warming will also occur in the oceans at high latitudes in response to decreased salinity, changing current patterns, and melting sea ice. Models predict large-scale warming in the North Pacific, averaging 2.5 °C, accompanied by a surface air temperature rise of 2°C (Menviel et al. 2012). At the most extreme CO_2 emissions model, sea surface temperatures are projected to increase up to 5-7°C (Rogers-Bennett et al. 2010).

The distribution of pinto abalone is determined largely by temperature, with water temperatures above 24 °C lethal to all life stages, and increased mortalities at temperatures above 21 °C (Bouma 2007). Warming waters may have numerous direct negative impacts on pinto abalone including decreased reproduction rates (Vilchis et al. 2005, Rogers-Bennett et al. 2010), reduced growth (Vilchis et al. 2005), and higher mortality (Harley and Rogers-bennett 2004). Warming ocean temperatures indirectly affect pinto abalone by decreasing the growth and viability of the kelp habitats and food resources the abalone depend upon (Vilchis et al. 2005, Rogers-Bennett et al. 2010).

Direct impacts of seawater warming will affect pinto abalone reproduction, growth and mortality rates (Rogers-Bennett et al. 2011). Abalone already suffer reductions in growth rates during the periodic warming that occurs during El Niño conditions, due to a reduction in food quantity, and global climate change may be increasing the frequency and intensity of El Niño events (Li et al. 2013). Ocean warming also negatively impacts egg and sperm production through decreased food resources and disintegration of sperm at warmer temperatures (Rogers-Bennett et al. 2010). Thus, warming ocean temperatures increase both mortality rates, and result in sub-lethal effects such as reduction in fertility. Increasing temperatures may also create positive feedbacks with other emerging threats such as ocean acidification, discussed below.

Nereocystis kelp species and coralline algae are essential habitat components for pinto abalone, and these species, and the rocky intertidal communities they support, are likely to be negatively affected by warming water because they show a decrease in growth as water temperatures rise (Rogers-Bennett et al. 2011). Corallines, which are used by pinto abalone as cover and as a food source, may chemically cue the settlement of larval pinto abalone. Corallines also enhance larval metamorphosis and survival during the critical settlement period (Steller and Cáceres-Martínez 2009, Walan et al. 2012). Corallines show a decrease in recruitment rates and growth when temperatures rise, and are further limited by ocean acidification (Rogers-Bennett et al. 2011). A

reduction in kelp canopies and coralline algae due to warming waters will make pinto abalone more vulnerable to predation and starvation, and further limit recruitment success.

Abalone species also become more vulnerable to disease, such as Withering Syndrome, with increasing temperatures. The agent causing Withering Syndrome does not produce clinical symptoms in red abalone exposed to cool water, but in warm water, the pathogen caused male abalone to fail to produce mature gametes (Rogers-Bennett et al. 2010). Increased temperatures may provide optimal conditions for bacterial replication and transmission, which may spread the disease north and into the range of pinto abalone (Friedman and Finley 2003).

In sum, temperature-mediated effects on abalone fertility and growth, disease status, and kelp and coralline abundance, indicate population-level threats (Rogers-Bennett et al. 2010). The synergistic impacts of ocean acidification and global climate change across the pinto abalone's range threaten the pinto abalone population.

iii. Ocean Currents and Changes in Salinity

Northern latitude waters are becoming fresher due to inputs from increasing glacier and sea-ice melt and terrestrial run-off, including increasing river outflows, and these freshwater inputs are expected to increase as temperatures continue to rise (Clark et al. 2010, Richter-Menge et al. 2011). This influx of freshwater may slow down the circulation of water and alter current patterns (Curry et al. 2003, Menviel et al. 2011).

Pinto abalone larvae are sensitive to a decrease in salinity, especially when combined with warming waters. Bouma (2007) found that larval abalone were unable to survive at salinities less than 23 psu. Conditions of low salinity and increased temperature are likely to occur in the coastal water inhabited by pinto abalone, with climate change-induced changes in hydrology and increased freshwater input. Combined with a predicted seawater temperature increase of at least 2 to 3 °C by 2055 (IPCC 2007a), suitable habitat for pinto abalone will become increasingly rare, hindering recovery and threatening any existing viable populations.

iv. Sea Level Rise

Global average sea level rose by roughly eight inches (20 centimeters) over the past century, and sea level rise is accelerating in pace (USGCRP 2009). Although the IPCC Fourth Assessment Report projected a global mean sea-level rise in the 21st century of 18 to 59 centimeters (7 to 23 inches), the IPCC acknowledged that this estimate did not represent a "best estimate" or "upper bound" for sea-level rise because it assumed a negligible contribution from the melting of the Greenland and west Antarctic ice sheets (IPCC 2007b). Recent studies documenting the

accelerating ice discharge from these ice sheets indicate that the IPCC projections are a substantial underestimate (Hansen et al. 2008, Pritchard et al. 2009, Rignot et al. 2011). Just 2-3 degree C of warming will likely result in a sea level rise of 6 m within a century (Hansen et al. 2006). Studies that have improved upon the IPCC estimates have found that a mean global sea-level rise of at least 1 to 2 meters is highly likely within this century (Rahmstorf et al. 2007, Pfeffer et al. 2008, Vermeer and Rahmstorf 2009, Grinsted et al. 2009, Jevrejeva et al. 2010), and larger rates of 2.4 to 4 meters per century are possible (Milne et al. 2009). Storms and storm surge also will increase in intensity under warming climate conditions (Meehl et al. 2007) and will exacerbate the effects of sea level rise.

Rising sea levels will eliminate much of the species' intertidal habitat, with serious consequences for the pinto abalone. As the species is relatively sessile and poorly adapted to changing conditions, rapid sea level rise may wipe out suitable habitat, with poor recruitment and poor juvenile survival further limiting the potential for recovery or adaptation.

v. Synergistic and Multiple Effects

Synergistic effects occur when a variety of environmental stressors act simultaneously, and the resulting interactions may result in effects much greater than the individual influence alone. This has resulted in crashes of marine populations when they pass a tipping point. Evidence indicates that such a situation is likely for pinto abalone, and is already observed for other northwestern mollusks, including oysters.

Ocean acidification and ocean warming are intricately linked, and thus it is important to understand the interaction between ocean acidification and other environmental stressors that will change the marine environment due to anthropogenic greenhouse gas emissions. O'Donnell et al. (2008) found that sea urchin larvae raised in more acidic seawater were more susceptible to increased water temperature. Temperature and UV light were found to have different effects on intertidal algae separately than together (Hofmann et al. 2010).

Pinto abalone are susceptible to different aspects of anthropogenic greenhouse gas emissions in the northern and southern parts of their range. In Alaska and northern Canada, abalone are already exposed to seawater with a relatively low pH, with seawater expected to become undersatured with respect to aragonite by the end of this century (Feely et al. 2009). Abalone in the California Current System in Washington, Oregon, and California are already experiencing the upwelling of water undersaturated in aragonite into the nearshore environment (Feely et al. 2008, Gruber et al. 2012). Pinto abalone are limited by warming water temperature in the southern half of their range, with strong evidence of population declines (Rogers-Bennett 2007). Both of these factors will limit the range of the species, resulting in an overall impact from

anthropogenic greenhouse gas emissions that may be greater than that of acidification or warming alone.

The impacts of climate change on marine organisms often interact with non-climatic stressors such as overharvest and predation (USGCRP 2013). For pinto abalone, such interactions are especially important as recovery post-overharvest is increasingly hindered by climate change induced effects such as ocean acidification and seawater warming.

2. OVERUTILIZATION FOR COMMERCIAL, RECREATIONAL, SCIENTIFIC OR EDUCATIONAL PURPOSES

A. COMMERCIAL USE

The serious and long-lasting impacts on pinto abalone from overharvest by commercial fisheries in Alaska and British Columbia is discussed in detail in Part I and incorporated here by reference. Serial depletion by the Alaskan and Canadian commercial abalone fishery (Walker and Pritchett 2006, COSEWIC 2009) lowered the density of fecund pinto abalone adults to levels at which recruitment failure is now highly likely (Rothaus et al. 2008). Density-influenced spawning impacts are a serious threat to overfished pinto abalone populations and have played a significant role in the collapse of other abalone stocks worldwide (Campbell 2000). Abalone fisheries are generally unable to support a sustainable commercial fishery, even with fishery regulations in place due to poor recovery and recruitment. Recovery following commercial harvest is slow to nonexistent, and there is no evidence that pinto abalone populations are recovering to historical densities in any part of their historic range.

Poaching, fueled largely by the economic boom in Asia and resulting demand on the Asian markets for expensive, wild-caught pinto abalone, is a major factor contributing to the continued declines of most pinto abalone populations the United States and Canada. Abalone have a high market value, with an estimated market price of $50 Canadian dollars, mostly on the Chinese market, and poachers are easily able to operate undetected along North America's remote coast (Crim 2010).

Alaska is the only area where legal recreational and subsistence pinto abalone harvest continues to occur, but even with low bag limits, handling mortalities remain a concern, as abalone are prone to mortalities from any cut or laceration, and abalone fishers generally target larger, reproductively important abalone (Muse 1998).

3. DISEASE AND PREDATION

A. PREDATION

Sea otters are a natural predator of pinto abalone, and play an important role in the recovery of kelp forest ecosystems along the west coast of North America (Chadès et al. 2012). The primary predators of juvenile abalone are small decapod crustaceans, such as *Lophopanopeus bellus* and *Scyra acutifrons* (Griffiths and Gosselin 2008). Any areas chosen for artificial aggregations of wild pinto abalone or for reintroduction of captive-bred stock must take the presence and density of abalone predators into consideration, and efforts should be made to introduce pinto abalone into areas with suitable crevices and areas to escape predators. Captive bred abalone have poor long-term survival when outplanted to wild environments, and are more vulnerable to predators than wild abalone, although adjusted rearing techniques may increase survival (Stevick 2010, Read et al. 2013). Additionally, ocean acidification increases the susceptibility of adult and juvenile pinto abalone to predation.

B. DISEASE

Diseases of the pinto abalone are poorly understood. Disease and parasites cause mortality in both wild and cultured individuals of other abalone species, but pinto abalone are only known to succumb to disease in aquaculture environments (Campbell 2000). The protist parasite *Labyrinthuloides haliotides* killed off a large proportion of pinto abalone at an aquaculture facility in Canada, but this parasite has never been found in wild populations. Warming temperatures from climate change along with ocean acidification and diet insufficiency may increase the susceptibility of pinto abalone to diseases.

4. INADEQUACY OF EXISTING REGULATORY MECHANISMS

Existing regulatory mechanisms are woefully inadequate to curb the primary threats to the pinto abalone posed by greenhouse gas emissions and poaching, as discussed below.

A. REGULATORY MECHANISMS ADDRESSING GREENHOUSE GAS EMISSIONS, CLIMATE CHANGE, AND OCEAN ACIDIFICATION ARE INADEQUATE

Greenhouse gas emissions pose a major threat to the continued existence of pinto abalone through impacts from climate change and ocean acidification. However, regulatory mechanisms at the national and international level do not adequately protect the pinto abalone from these impacts, nor do they require the greenhouse gas emissions reductions necessary to protect the pinto abalone from extinction.

NMFS has acknowledged that regulatory mechanisms are inadequate to regulate greenhouse gas emissions to levels that do not threaten species. In its 2010 proposed listing rules for the ringed and bearded seal, NMFS stated that "there are currently no effective mechanisms to regulate GHG emissions, which are contributing to global climate change and associated modifications to [ringed and bearded] seal habitat. The risk posed to [ringed and bearded] seals due to the lack of mechanisms to regulate GHG emissions is directly correlated to the risk posed by the effects of these emissions" (75 Fed. Reg. 77508). Similarly, NMFS acknowledged in its 2012 Management Report for 82 Corals Status Review under the Endangered Species Act that no countries are reducing emissions enough to keep the increase in global temperature below 2 °C; and the top ten emitters including the United States, accounting for over 60% of the global emissions, are performing poorly or very poorly at meeting needed greenhouse gas reductions (NMFS 2012). As detailed below, the continued failure of the U.S. government and the international community to implement effective and comprehensive greenhouse gas reduction measures places the pinto abalone at ever-increasing risk of extinction.

i. Global Greenhouse Gas Emissions are tracking the worst IPCC Emissions Scenario

The atmospheric concentration of CO_2 reached 400 parts per million (ppm) for the first time in human history in May, 2013, compared to the pre-industrial concentration of ~280 ppm (Scripps Institution of Oceanography 2013). The current CO_2 concentration has not been exceeded during the past 800,000 years and likely not during the past 15 to 20 million years (Denman et al. 2007, Tripati et al. 2009). Atmospheric CO_2 emissions have risen particularly rapidly since the 2000s (Raupach et al. 2007, Friedlingstein et al. 2010). The global fossil fuel CO_2 emissions growth rate was 1.0% per year in the 1990s compared with 3.1% per year since 2000, and this growth rate has largely tracked or exceeded the most fossil-fuel-intensive emissions scenarios projected by the IPCC (A1FI and RCP 8.5) since 2000 (Raupach et al. 2007, (Peters et al. 2012). The CO_2 emissions growth rate fell slightly in 2009 due largely to the global financial and economic crisis; however, the decrease was less than half of what was expected and was short-lived (Fiedlingstein et al. 2010). In 2012, global CO_2 emissions rose by the second-highest amount on record,[1]

ii. U.S. Measures to reduce Greenhouse Gas Emissions are Insufficient

[1] http://www.esrl.noaa.gov/gmd/ccgg/trends/

While existing domestic laws including the Clean Air Act, Energy Policy and Conservation Act, Clean Water Act, Endangered Species Act and others provide authority to executive branch agencies to require greenhouse gas emissions reductions from virtually all major sources in the United States, these agencies are either failing to implement or only partially implementing these laws for greenhouse gases. For example, the EPA has issued a rulemaking regulating greenhouse gas emissions from automobiles that will reduce greenhouse emissions emitted per vehicle mile traveled by passenger vehicles in the future, but because the improvements are modest and more vehicles are projected to be driven more miles in the future, the rule will not reduce emissions from this sector overall but will only slow the rate of increase somewhat compared to what it would be without the rule. EPA, Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule, 75 Fed. Reg. 25324 (May 7, 2010). Meanwhile even the government concedes that "these reductions in emissions are not sufficient by themselves to reduce total HD vehicle emissions below their 2005 levels by 2020." NHTSA, Medium- and Heavy-Duty Fuel Efficiency Improvement Program – Final Environmental Impact Statement (June 2011). This means that the vehicle rule is far from achieving emissions goals agreed to by the U.S. in the Copenhagen Accord, which aim to keep global warming below 2˚C.

The EPA has also to date issued only a single proposed rule under the new source pollution standard program for stationary sources of pollution, for electric generating units (power plants). While there is enormous potential to reduce emissions through this program overall and through the power plants rule in particular, the EPA has instead proposed a weak and flawed rule that it admits will not reduce emissions from these sources between now and 2020 compared to what would be expected without the rule. EPA, Standards of Performance for Greenhouse Gas Emissions for New Stationary Sources: Electric Utility Generating Units, 77 Fed. Reg. 22392, 22430-33 (April 13, 2012). Indeed, in the rulemaking the EPA conceded that new power plant rule on greenhouse gas emissions "will not have direct impact on U.S. emissions of greenhouse gases under expected economic conditions." Id. at 22401.

While full implementation of our flagship environmental laws, particularly the Clean Air Act, would provide an effective and comprehensive greenhouse gas reduction strategy, due to their non-implementation, existing domestic regulatory mechanisms must be considered inadequate to protect pinto abalone from climate change and ocean acidification.

iii. International Measures to reduce Greenhouse Gas Emissions are inadequate

International initiatives are also currently inadequate to effectively address climate change. The United Nations Framework Convention on Climate Change, negotiated in 1992 at Rio de Janeiro, Brazil, provides the forum for the international negotiations. In the Framework

Convention, signed and ratified by the United States, the world agreed to take the actions necessary to avoid dangerous climate change. Parties to the Convention also agreed as a matter of fairness that the world's rich, developed countries, having caused the vast majority of emissions responsible for the problem, would take the lead in solving it. It was not until the 1997 meeting in Kyoto, Japan, that the first concrete, legally binding agreement for reducing emissions was signed: the Kyoto Protocol. The Protocol requires the world's richest countries to reduce emissions an average of 5 percent below 1990 levels by 2012, while developing nations also take steps to reduce emissions without being subject to binding emissions targets as they continue to raise their standard of living. The United States has been a major barrier to progress in the international negotiations. After the Clinton administration extracted many concessions from the rest of the world in exchange for the United States signing on in Kyoto, the Senate rejected the equity principles behind the Convention, saying the United States should not agree to reduce its own emissions unless all other countries — regardless of their responsibility or ability — were similarly bound. Citing the same excuses, President George W. Bush repudiated the Kyoto Protocol entirely. Thus the United States is the only industrialized country in the world that has yet to ratify the Kyoto Protocol. The United States negotiating team under both the George W. Bush and the Obama administrations has pursued two primary objectives in the international talks: to refuse any legally binding emissions reduction commitments until all other countries— but particularly China and India — do so, and to push back the date for a new agreement. Not surprisingly, the United States had failed to meet its (never ratified) Kyoto pledge to reduce emissions to 7.2% below 1990 levels by 2012; to the contrary, U.S. emissions have increased by 10.5% since 1990 (EPA 2012).

Moreover, the Kyoto Protocol's first commitment period only sets targets for action through 2012, and there is still no binding international agreement governing greenhouse gas emissions in the years beyond 2012. While the 2009 U.N. Climate Change Conference in Copenhagen called on countries to hold the increase in global temperature below 2°C (an inadequate target for avoiding dangerous climate change), the non-binding "Copenhagen Accord" that emerged from the conference, and the subsequent "Cancún Accords" of 2010 and "Durban Platform" of 2011 failed to enact binding regulations that limit emissions to reach this goal.[2] Even if countries were

[2] The non-legally binding Copenhagen Accord of 2009 and Cancún Accords of 2010 recognize the objective of limiting warming to 2°C above pre-industrial temperatures, but do not enact binding regulations to achieve this goal (http://cancun.unfccc.int/cancun-agreements/main-objectives-of-the-agreements/#c33; unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf). According to the Durban Platform, developed and developing nations agreed to a process to develop a "new protocol, another legal instrument, or agreed outcome with legal force that will be applicable to all Parties to the UN climate convention"; this legal instrument must be developed as of 2015 and will not take effect until 2020 (unfccc.int/resource/docs/2011/cop17/eng/l10.pdf).

to meet their Copenhagen and Cancún pledges, analyses have found that collective national pledges to cut greenhouse gas emissions are inadequate to achieve the 2°C target, and instead suggest emission scenarios leading to 2.5°C to 5°C warming (Rogelj et al. 2010, UNEP 2010, 2011). As of July 2013, many governments were not implementing the policies needed to meet their inadequate 2020 emission reduction pledges, making it more difficult to keep global temperature rise to 2°C and likely leading to a temperature rise of at least 3.5 °C (USGCRP 2013). As noted in the NMFS Management Report, the U.S. has yet to issue regulations to limit greenhouse gas emissions in accordance with its pledge under the Copenhagen Accord (NMFS 2012).

B. Regulatory Mechanisms addressing other Threats to Pinto Abalone are inadequate

i. Poaching and Overharvest

The pinto abalone has reached its current precarious status due to the failure of fisheries regulations to protect the species from overharvest (Rogers-Bennett 2007). Successful fisheries management requires accurate predictions of sustainable harvest quotas, which is difficult for a species with periodic spawning events and varying dispersal and recruitment, and has often resulted in serious depletion through overharvest (Hobday et al. 2007). Overexploitation of broadcast spawning invertebrates such as the pinto abalone occurred in part because fisheries managers lacked sufficient information on life history characteristics and population dynamics of the species. Managers incorrectly assumed that a combination of high fecundity, broadcast spawning, and planktonic larvae would buffer pinto abalone from the effects of fishing (Rothaus et al. 2008). Pinto abalone are now too limited in numbers and density to have any realistic chance of breeding successfully in the wild and require active management and human intervention, both through captive breeding programs and management of ecological conditions.

Poaching continues to pose a serious threat to the pinto abalone, as discussed above in detail. Although regulatory mechanisms are in place and poachers have been apprehended and convicted, it is estimated the law enforcement agencies continue to miss up to 90% of poachers, with an even higher percentage possibly getting away completely undetected. The problem is rooted in the demand on the international Asian market, making enforcement via the laws and regulations of the United States even more difficult. A substantially increased anti-poaching effort would be necessary to reduce poaching impacts on pinto abalone. At this point, poachers are almost guaranteed to escape detection, while at the same time making substantial profit off their harvest. This is a serious and ongoing problem and one of the most pressing and immediate threats to continued existence of pinto abalone (Chadès et al. 2012).

ii. Commercial Abalone Farms

As wild abalone fisheries have declined throughout the world, farming of abalone is becoming increasingly widespread. In the United States and Mexico, abalone farming started in the 1970s, with commercial sales picking up in the 1980s. Most farms in the United States are land-based, with a few using ocean cages. Production is focused on red abalone (*H. rufescens*), which are fed wild-harvested kelp (*Macrocytis pyrifera*). Production in the United States is not expanding, due to permitting and cost issues, and to limited demand. In other areas of the world, including Australia, South Africa, Taiwan and China, abalone farming is a rapidly growing and profitable venture, with most facilities ocean-based (Campbell 2000). Abalone are highly prized in China, with farming efforts greatly expanding to the point that China is now an abalone exporter rather than importer. Unfortunately, commercial farming in Asia has done little to reduce the demand for poached wild abalone.

With the expansion of commercial abalone farming, aquaculture techniques have improved, promoting the survival of captive- reared populations. Maintaining genetic diversity is important for abalone which have suffered massive and rapid population declines worldwide and may suffer genetic bottlenecks (Timmins-Schiffman et al. 2013). Hatchery techniques perfected by the commercial industry are being used to restore abalone populations in some areas. There are serious concerns with using hatchery-raised abalone to supplement wild populations, with disease and parasite infestations a major problem, along with behavioral differences and reduced fitness of captive-raised stock when returned to the wild (Stevick 2010). While the hope would be that commercially farmed abalone would both increase genetic diversity to aid in outplanting to supplement wild stock and decrease demand for poached wild abalone, to date evidence does not indicate that this is happening. While regulatory mechanisms require abalone be certified disease-free prior to outplanting, abalone farms that are ocean-based pose risks of disease spread, and may result in genetic complications for wild abalone as well.

iii. Outplanting Hatchery Raised Abalone to Restore Wild Populations

Outplanting and seeding of hatchery-reared juveniles and larval abalone to enhance wild pinto abalone stocks has been actively pursued both the United States and Canada (Campbell 2000). Results have been highly varied, but evidence to date indicates that seeding is not an effective means to enhance natural abalone populations, even with implementation of predator control and use of ideal habitats for outplanting. Outplanting efforts to date have been largely unsuccessful, with poor long-term survival (Campbell 2000, Stevick 2010). Important considerations for hatchery-raised abalone such as increased disease risk, behavioral problems, shell deformation, and general reduced fitness are major issues (Straus and Friedman 2009). The creation of marine

reserves is considered one of the most effective means to protect and enhance abalone populations, while outplanting hatchery raised stock has minimal positive impacts on abalone stock based on efforts to date.

Captive breeding programs of pinto abalone report poor survival success, with fewer than 10% of captive-reared pinto abalone generally surviving one year post outplanting (Bouma et al. 2010, Stevick 2010). In an outplanting study in the San Juan Islands of Washington state, survival rates ranged from 0% for abalone captive abalone outplanted in 2009, to 1.3%- 10.9% for captive abalone outplanted in 2011 (Figure 9) (Hester et al. 2011). One-year survival at one site in Puget Sound ranged from 1.6- 24.9%, but longer term survival is unknown.

Figure 9: Biologist Josh Davis with a young farm-raised pinto abalone. Mr. Davis is part of a team working to restore Puget Sound's pinto abalone population. Source: (Welch 2012).

The poor survival of outplanted abalone may be due to reduced fitness of captive-reared animals. Hatchery-reared abalone may have poorer shell strength, with associated abnormalities that increase predation and mortality rates. Behavioral differences were also detected in hatchery raised red and green abalone, making them more susceptible to predation than their wild counterparts (Tegner 1989). Stevick (2010) found that rearing abalone in a habitat-enriched environment in an attempt to reduce behavioral differences between captive and wild abalone did not enhance survival of outplanted abalone in the San Juan Islands, Washington. Researchers recorded a one-year survival rate for these abalone of just 6.6% (Stevick 2010).

Location of release is also important, and consideration of a wide range of factors should be taken into account. Biogenic structure is important for the survival of native juvenile abalone, with adult sea urchin an important source of shelter (Campbell 2000). Juvenile abalone benefit from associations with sea urchins through protection from predators, enhanced food supply, and reduction in exposed feeding time. Release of hatchery-raised juvenile abalone into areas with the presence of sea urchins greatly enhanced the survival of juvenile red abalone (Campbell 2000). Recent research suggests that the survival rates of outplanted juvenile pinto abalone may be enhanced if abalone are released at lower densities into complex habitat substrate providing shelter from predators (Read et al. 2013). However, high cost, low survival rates, and behavioral issues, along with concerns about disease and genetic diversity, mean that outplanting is not considered the best or the only method to restore or protect pinto abalone populations.

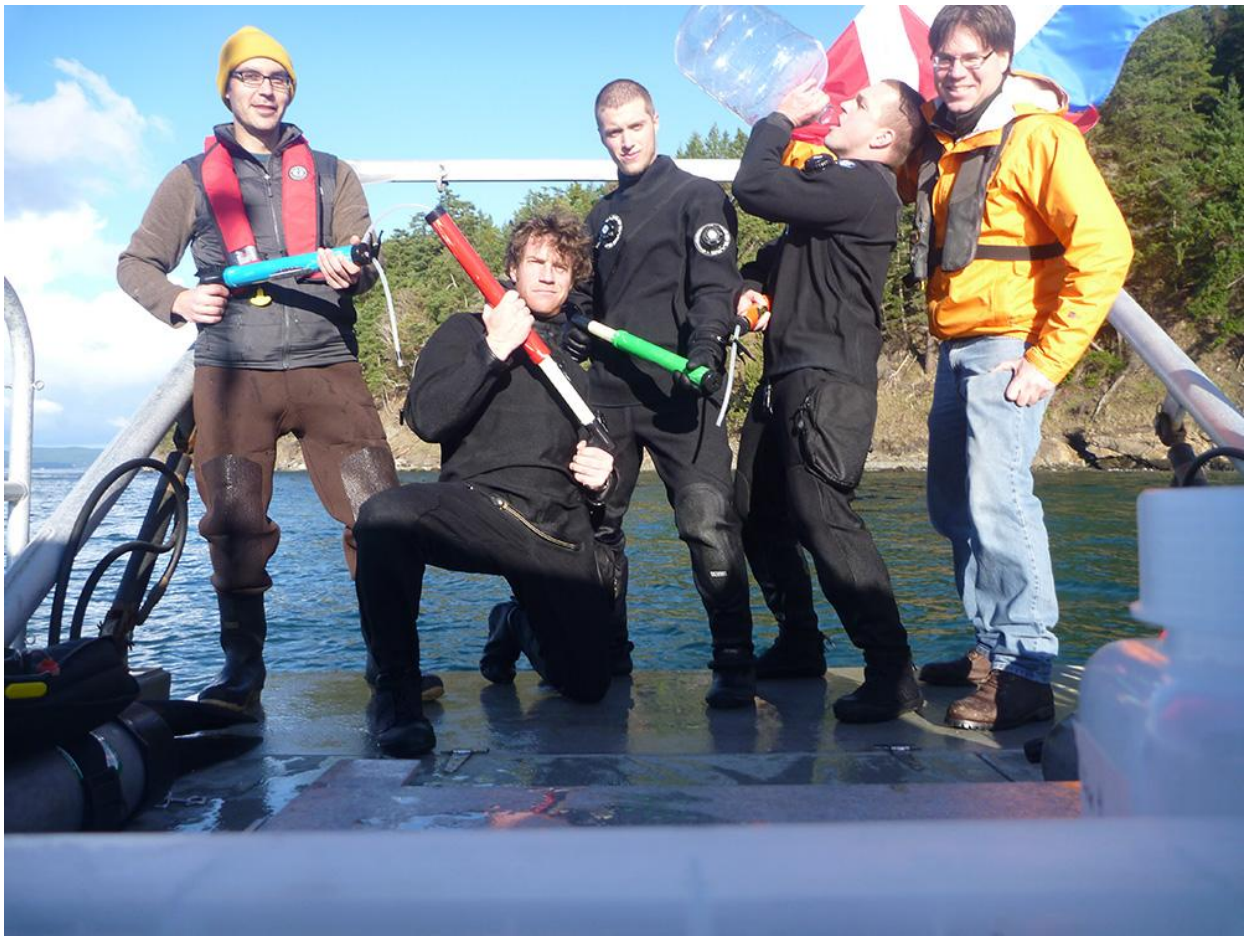

Figure 10: A dive team from the Puget Sound Restoration Fund poses with tools used for hand-seeding outplanted abalone. In 2011, the PSRF conducted the largest abalone release effort to date in the San Juan Islands, outplanting 1,200 abalone to carefully chosen sites. The team focused on genetically diverse animals which were disease-free. Source: http://www.restorationfund.org/projects/pintoabalone

Larval seeding, where hatchery raised abalone larvae are released into wild habitat, is another possible method to aid restoration of abalone populations, but research has found relatively low larval settlement rates of just 0.5- 10%, with unknown long-term survival (Stevick 2010). Research is complicated by difficulty in distinguishing wild from seeded abalone to determine long-term survival. While this method is less work-intensive and less costly, the payoff for raising captive abalone to a more viable size prior to outplanting appears to be worth the increased time and expense.

Another method is transplantation of wild "surf" abalone in poor habitat areas to more suitable habitat, in an effort to increase growth rates and encourage increased rates of recruitment. Emmett and Jamieson (1989) transplanted large (50-100 mm) surf abalone from exposed sites to sheltered sites with more productive abalone habitat. Survival rates were 39%- 72% nine months after transplant, with transplanted abalone showing enhanced growth (Emmet and Jamieson 1988). In a similar study, wild surf pinto abalone at more exposed sites grow at a slower rate that abalone in sheltered habitat (Campbell 2000). Thus, transplanting wild abalone to more productive sites may be a viable means of population restoration. However, there are few young adult pinto abalone populations in exposed habitat that would be suitable for such transplant today, due to a lack of recruitment and general aging of the population (Rothaus et al. 2008).

5. OTHER THREATS

A. DENSITY-DEPENDENT REPRODUCTIVE STRATEGIES LIMIT RECRUITMENT AND RECOVERY

Declining population size and density of the pinto abalone is devastating for the future of the species. As a broadcast spawner, the pinto abalone relies on high population density to ensure juvenile recruitment (Rothaus et al. 2008). Evidence of increasing average shell length in the pinto abalone confirms that juvenile recruitment is almost non-existent in many populations.

A population that is failing to regenerate through natural reproduction is extremely vulnerable to extinction. The combination of poaching, habitat loss, climate change, ocean acidification and predation may reduce the pinto abalone population to such low levels that Allee effects will hinder natural recovery (Allee et al. 1949). Reductions in food supply and loss or degredation of future habitat could further reduce growth and fecundity. NOAA Fisheries listing of the pinto abalone as a "Species of Concern" in 2004 has done little to reverse the negative trends facing the pinto abalone population, while Canadian efforts at restoration have also been largely unsuccessful (Fisheries and Oceans Canada 2012).

The viability of captive breeding of abalone is questionable, as after only one generation of breeding, populations suffer up to a 60% reduction in allelic richness and a 17-18% reduction in heterozygosity. This illustrates the difficulty in maintaining genetic diversity in populations that are artificially bred, which can limit the success of breeding programs (Lemay and Boulding 2009).

CRITICAL HABITAT DESIGNATION

The ESA mandates that, when NMFS lists a species as endangered or threatened, the agency must also concurrently designate critical habitat for that species. Section 4(a)(3)(A)(i) of the ESA states that, "to the maximum extent prudent and determinable," NMFS "shall, concurrently with making a determination . . . that a species is an endangered species or threatened species, designate any habitat of such species which is then considered to be critical habitat" 16 U.S.C. § 1533(a)(3)(A)(i); see also id. at § 1533(b)(6)(C). The ESA defines the term "critical habitat" to mean:

> i. the specific areas within the geographical area occupied by the species, at the time it is listed . . . on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and
>
> ii. specific areas outside the geographical area occupied by the species at the time it is listed . . . upon a determination by the Secretary that such areas are essential for the conservation of the species.

Id. at § 1532(5)(A).

The Center for Biological Diversity expects that NMFS will comply with this unambiguous mandate and designate critical habitat concurrently with the listing of pinto abalone. Critical habitat must include suitable habitat from Sitka, Alaska, to Point Conception, California, specifically rocky subtidal habitats with low to medium exposures, boulders, coralline cover and kelp canopies from 10 meters deep to subtidal areas (Rogers-Bennett et al. 2011). A combination of kelp canopies with associated corallines have proven to be the most suitable habitat for both adult and juvenile pinto abalone (Rogers-Bennett et al. 2011).

CONCLUSION

Several anthropogenic factors appear to have combined in complex ways to weaken pinto abalone populations, accelerate their mortality and cause subsequent declines. Based on the information presented above, it is clear that pinto abalone are in danger of extinction throughout their range, and therefore, are endangered within the meaning of the ESA, 16 U.S.C. § 1532(6). As demonstrated in this petition, pinto abalone face high-magnitude and growing threats to their continued existence. NMFS must promptly make a positive 90-day finding on this petition, initiate a status review, and expeditiously proceed toward listing and protecting this species. We look forward to the official response as required by the ESA.

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