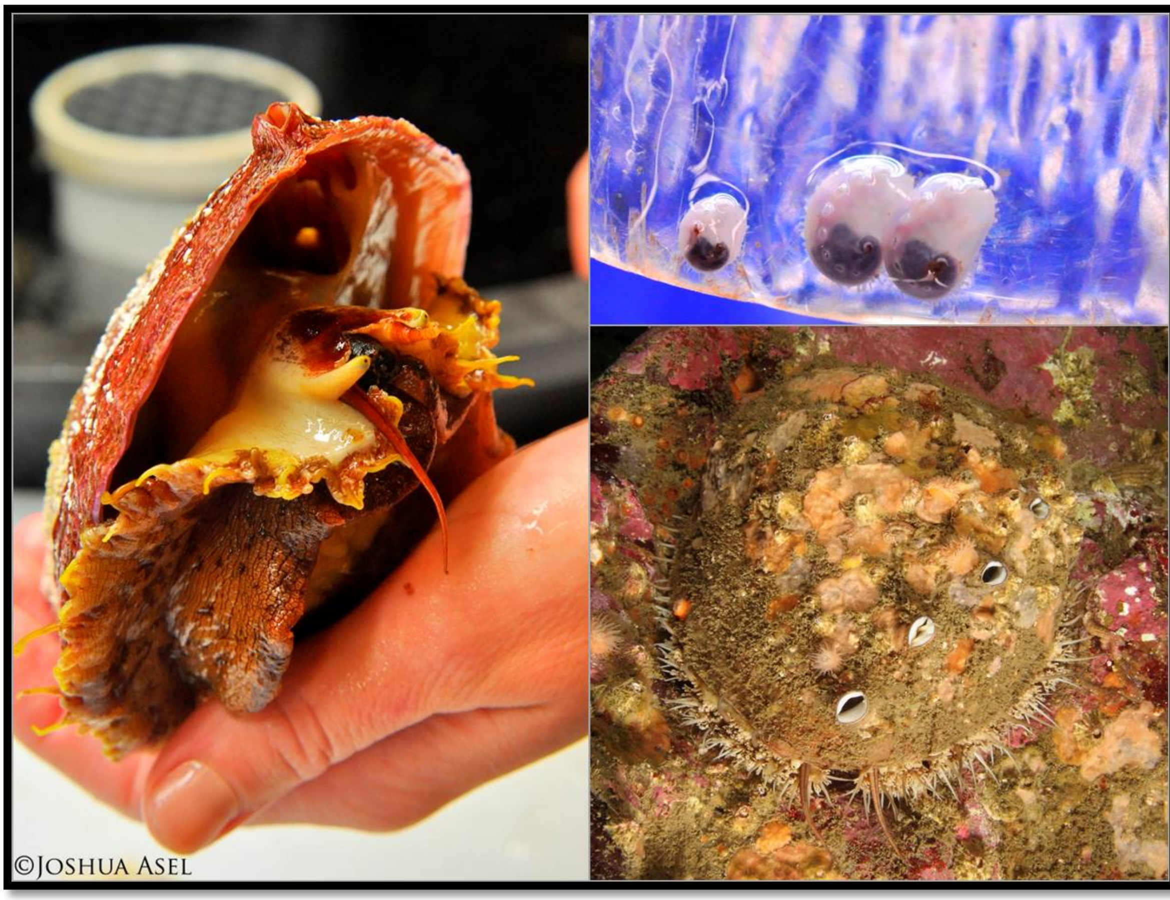
White Abalone
(Haliotis sorenseni)

Five-Year Status Review:
Summary and Evaluation



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National Marine Fisheries Service
West Coast Region
Long Beach, CA

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5-YEAR REVIEW
White Abalone (*Haliotis sorenseni*)

EXECUTIVE SUMMARY

The white abalone is a marine snail that occurs subtidally at depths of 5 to 60 meters (m) in waters off southern California and Baja California. They are broadcast spawners and relatively long-lived, with an estimated life span of 35 to 40 years. The species was listed as endangered under the Federal Endangered Species Act (ESA) in 2001. The primary threat to white abalone is the species' low densities caused by historical overharvest. The species' low densities have led to repeated recruitment failure and continued declines in abundance despite prohibitions on white abalone harvest in California since 1997 and in Mexico since 2003. In 2008, the National Marine Fisheries Service (NMFS) published the Final Recovery Plan for white abalone, to serve as a roadmap to guide recovery efforts. In 2016, NMFS published the Species in the Spotlight Five-Year Action Plan for white abalone, highlighting the priority recovery actions for 2016-2020.

This 5-year review update provides the following:

- A summary of progress to date on recovery implementation;
- An assessment of the best available information on the species' status to evaluate whether the recovery criteria related to the species' demographics and threats have been met;
- A summary of new information that has become available since 2008 regarding the species' biology, habitat, threats, and conservation/regulatory measures; and
- Recommendations on whether the ESA listing status should remain the same or change, and future actions.

Recovery efforts have focused on two key priorities: (1) Developing the captive propagation program to support future outplanting of white abalone; and (2) Monitoring wild populations to evaluate their status, recovery, and habitat use. Much progress has been made in producing large numbers of healthy white abalone for research and outplanting. Experimental studies are underway using other abalone species to develop and refine outplanting strategies and to inform and maximize the success of future white abalone outplanting. Increased monitoring efforts have also improved our understanding of the species' status and distribution in the wild. These steps toward recovery would not be possible without the strong partnerships among Federal, state, local, and international agencies; universities and other research institutions; public aquaria; local abalone farms; non-profit organizations; and citizen science groups. These partnerships and the funding that supports them are critical to continued recovery implementation and success. For example, the Navy and NOAA's Office of Aquaculture and Office of National Marine Sanctuaries have provided support in the form of funding, outreach, and field resources for monitoring and research studies in the lab and in the field.

Despite the progress made, white abalone in the wild remain at low densities and are far from meeting the abundance, density, size and spatial distribution, and population trends needed for downlisting and delisting. In addition, several threats remain to be addressed, such as illegal take and disease. Considering the status and continuing threats, we conclude that white abalone remain in danger of extinction. Therefore, the recommended ESA listing status for white abalone

is to remain the same: Endangered. Priority recommendations for future actions include expansion of the captive propagation program; development of an outplanting program; research to better understand the species-specific reproduction, growth, and survival needs of white abalone in the wild; monitoring of wild populations and their habitat; and development of a comprehensive outreach plan.

1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Regional or Headquarters Office: National Marine Fisheries Service (NMFS) West Coast Region (WCR) – Chris Yates, Assistant Regional Administrator for Protected Resources, 562-980-4007

Cooperating Science Center(s): NMFS Southwest Fisheries Science Center – Kristen Koch, Science and Research Director, 858-546-7081

1.2 Methodology used to complete the review

The NMFS West Coast Region (WCR) led the five-year review, with assistance and review by the NMFS Southwest Fisheries Science Center (SWFSC) and NMFS Office of Protected Resources (OPR). The Updated Information and Current Species Status (Section 3.6) was largely completed by Frances Glaser, a Cal Poly San Luis Obispo student who worked with the WCR and SWFSC in the summer of 2016 through the California State University COAST summer internship program. The primary sources of information and data in this review came from reports, publications, and information available from ongoing studies and reviews that have become available since the status review completed by Hobday and Tegner (2000) and the Final White Abalone Recovery Plan (NMFS 2008). We gathered information through: 1) literature searches on various search engines (e.g., Google Scholar, Research Gate, Web of Science); 2) publication of a Federal Register (FR) notice soliciting new information about white abalone; and 3) email and phone contact with abalone experts at universities and state and federal government agencies.

1.3 Background

1.3.1 FR Notice citation announcing initiation of this review:

81 FR 93902; 22 December 2016

1.3.2 Listing history

<u>Original Listing</u>
FR notice: 66 Federal Register 29046; 29 May 2001
Date listed: 29 May 2001
Entity listed: Species
Classification: Endangered

1.3.3 Associated rulemakings

NMFS determined that designation of critical habitat for white abalone was not prudent, because a designation would not provide significant benefits that outweigh the increased risk of poaching that may result from identifying the species' critical habitat (66 FR 29046, 29 May 2001).

1.3.4 Review History

This is the first, formal five-year review for white abalone. The original status review was completed in 2000 (Hobday and Tegner 2000). The Final Recovery Plan was completed in 2008 and provided updated information on the species' biology and status.

1.3.5 Species' Recovery Priority Number at start of five-year review

White abalone have a Recovery Priority Number of One, based on criteria in the Recovery Priority Guidelines (55 FR 24296, 15 June 1990)[1]. Priority One is given to species with a high risk of extinction, whose limiting factors and threats are well understood and whose needed management actions are known and have a high probability of success, but also may be in conflict with economic activities. White abalone have a high demographic risk as well as a high recovery potential. Past overfishing severely reduced white abalone populations in the wild to very low numbers and densities. The remaining individuals may not be close enough to successfully reproduce, or to reproduce at levels needed to rebuild and sustain populations. The major threat (low densities caused by overfishing) is known, as well as the major recovery needs (captive propagation, outplanting, and population monitoring) to address this threat. Over the past five years, the captive propagation program has demonstrated the ability to reliably produce healthy white abalone. At the same time, pilot studies are being conducted to evaluate different outplanting strategies and survey methods to maximize and monitor survival over time. Potential conflicts may arise if implementing regulatory actions for species recovery involves restrictions on activities, such as in-water construction or the opening of offshore areas to harvest of non-listed abalone species.

In 2015, NMFS launched the Species in the Spotlight program to highlight conservation actions to aid in the recovery of eight Priority One species. As part of this program, five-year action plans have been built off of the existing recovery plans for each species, to help guide Federal action agencies and provide a more detailed, near-term plan to engage partners to work toward recovery. White abalone are included in this program. The plan for white abalone can be found at this link: Five-Year Action Plan for white abalone (NMFS 2016).

1.3.6 Recovery Plan or Outline

Name of plan: Final White Abalone Recovery Plan
Date issued: October 2008
Dates of previous revisions, if applicable: Not applicable

[1] On 31 May 2017, NMFS published draft revised Listing and Recovery Priority guidelines (82 FR 24944). Applying the draft guidelines, white abalone would continue to have a Recovery Priority Number of one, based on the species' high demographic risk and high recovery potential.

2.0 RECOVERY IMPLEMENTATION

Efforts to protect and conserve white abalone have been ongoing since before the ESA-listing and publication of the Final Recovery Plan. NMFS has continued to work with other federal, state, and local partners to implement recovery actions and monitor the species' status. Over the past 10 years, conservation efforts have focused on two key recovery activities. First is the captive propagation program, which aims to increase production of captive-raised white abalone for outplanting (i.e., placing abalone into the ocean). The goal of outplanting is to enhance wild populations and boost their densities to support reproduction and eventually develop healthy, self-sustaining populations. Second is the monitoring of wild populations to evaluate their status, recovery, and habitat use throughout the Southern California Bight and Baja California, Mexico. Surveys using remotely operated vehicles (ROVs) and self-contained underwater breathing apparatus (SCUBA) have expanded from the offshore banks to sites along the mainland coast, with the goal of gaining a better understanding of the species-specific needs of white abalone and developing long-term monitoring programs. At the same time, NMFS continues to collaborate with partners to address threats, such as poaching and disease, and to raise awareness of conservation needs through public education and outreach.

The Species in the Spotlight Five-Year Action Plan for white abalone for 2016-2020 (NMFS 2016) summarizes the research and recovery actions that have been implemented since the ESA listing. This section briefly summarizes recovery implementation through agency actions and collaborative efforts over the last 10 years, since publication of the Final Recovery Plan in 2008.

2.2 Biological Opinions

Under Section 7 of the ESA, NMFS consults with Federal agencies to insure that their actions do not jeopardize the continued existence of white abalone. These consultations evaluate the effects of the actions on white abalone and their habitat, and are documented in biological opinions or letters of concurrence. Since the listing of white abalone in 2001, NMFS has consulted with Federal agencies on a few actions, including in-water construction and repair activities, wastewater discharge, and white abalone research and enhancement activities. In each case, we concluded that the proposed action was not likely to jeopardize the continued existence of white abalone and established measures to minimize adverse effects on the species. For the in-water construction and repair projects, monitoring was required to evaluate the presence of white abalone within the project area, and measures were established to collect and relocate any white abalone observed. For wastewater discharge activities, additional monitoring was required to better assess effects on white abalone. For research and enhancement activities (including collection of wild white abalone for captive propagation), specific criteria were established to limit collection to individual abalone that are most likely to be reproductively isolated, to minimize harm to wild populations. Overall, these consultations have minimized adverse effects on wild white abalone and supported key recovery activities (i.e., collection of wild broodstock for captive propagation).

2.3 Addressing Key Threats

Low density

The primary threat to the species is low densities in the wild due to past overfishing. Despite the closure of the abalone fishery in California since 1997, white abalone remain at low numbers and densities, such that the remaining individuals are likely too far apart to successfully reproduce (Hobday and Tegner 2000, Stierhoff et al. 2012). The Final Recovery Plan (NMFS 2008) identifies captive propagation and outplanting as the main recovery actions to enhance and establish healthy, self-sustaining populations in the wild. The captive propagation program began in 1999/2000 with the collection of wild broodstock for initial captive breeding efforts headed by the Channel Islands Marine Research Institute (CIMRI) and University of California, Santa Barbara (UCSB) (NMFS 2008). In 2008, the animals at CIMRI were transferred to the Bodega Marine Laboratory (BML) at the University of California Davis (UCD). BML took leadership of the captive propagation program, working with several partner facilities in Southern California. Since 2012, the production of captive white abalone has increased by orders of magnitude (NMFS 2016, Rogers-Bennett et al. 2016), with thousands of captive-bred juveniles in captivity as of 2018. For the first time, in 2015, juveniles from the 2014 cohort were distributed from BML to partner facilities in southern California, for grow-out and preparation for future outplanting. Overall, the captive propagation program has made significant progress in reliably producing large numbers of healthy white abalone. This is critical to support the next phase of recovery implementation – outplanting to increase densities of wild populations.

At the same time, NMFS has been collaborating with partners to evaluate the feasibility and effectiveness of different outplanting strategies to maximize survival. Experimental studies are being conducted using other abalone species, to work out factors such as the optimal size, density, or seasons at which to outplant animals, the effectiveness of different outplanting modules at increasing survival, and the best tagging techniques to identify outplanted vs wild-origin individuals. The results will inform future outplanting efforts for white abalone. In addition, survey efforts have also expanded in recent years. Since 2002, multiple ROV surveys have been conducted at the offshore banks (Behrens and Lafferty 2005, Butler et al. 2006, Stierhoff et al. 2012, Catton et al. 2016). Since 2010, multiple white abalone-focused SCUBA/ROV surveys have been conducted along the southern California mainland coast, following reports of white abalone in areas where they had not been observed for over 20 years, despite the presence of ongoing long-term monitoring (not focused on white abalone) (NMFS 2016). These surveys have identified multiple white abalone, providing valuable information on the species distribution, size structure, abundance, and habitat use, and informing future monitoring and research priorities for wild and outplanted populations.

Disease

Disease management is an important factor for the captive population. White abalone are susceptible to withering syndrome (WS), based on laboratory studies and observations of captive animals (NMFS 2008). WS poses a threat to the captive propagation program, because of the disease's ability to spread and cause mass mortalities in a relatively short period of time. For example, in 2002-2005, a large number of captive-bred white abalone at CIMRI died, showing symptoms of WS (NMFS 2008). In response to this mortality event and continuing water quality issues at CIMRI, the captive white abalone were moved to BML. Since then, protocols have been developed and implemented to minimize the introduction and spread of WS and other diseases among the captive white abalone population in California (see Final Recovery Plan, NMFS 2008). Protocols include quarantine of newly obtained animals prior to incorporation into the captive program, ultra-violet (UV) treatment of sea water to remove the WS pathogen, treatment of animals with oxytetracycline to remove the WS pathogen from infected individuals (Moore 2015), regular fecal testing to assess whether animals are infected with the WS pathogen (Moore and Marshman 2015b), and preservation and necropsy of mortalities to determine whether disease was the cause (Moore 2014, Moore and Marshman 2015a).

The effects of disease on white abalone in the wild are not clear. In lab trials, white abalone can suffer 100% mortality due to WS (Crosson et al. 2014). White abalone in the wild have not been observed exhibiting symptoms of WS, although recently collected wild animals were infected with the pathogen at varying levels (Moore and Marshman 2018, unpublished data). The potential effects of disease on the survival of outplanted animals are uncertain; however, studies are underway to determine how to prepare captive-bred abalone for life in the ocean, including exposure to diseases like WS. Continued research on disease dynamics and effects on abalone will inform management and conservation decisions.

2.4 Outreach Partners

Outreach and education is a critical component of the recovery program. NMFS continues to work with Federal, State, and local partners to develop and communicate a clear, unified, and consistent message about recovery goals, efforts, and needs, to build and expand public support for the recovery program and to combat poaching. To date, NMFS has developed a communication plan that includes an abalone conservation listserv and web stories to share the progress made by NMFS and recovery partners. NMFS is formalizing K-12 lesson plans on abalone conservation, to be shared via the NMFS website for use in local schools. NMFS is also working with its partners to develop an outreach and education plan, to incorporate and disseminate key messages through online tools and local aquaria and educational facilities. These partners include: Aquarium of the Pacific, BML, Cabrillo Marine Aquarium, California Department of Fish and Wildlife (CDFW), California Science Center, Center for Scientific Research and Higher Education at Ensenada (CICESE), Get Inspired, Instituto Nacional de la Pesca, Los Angeles Conservation Corps Sea Lab, Santa Barbara Museum of Natural History Sea Center, Stanford University, The Bay Foundation, and the University of California Santa Barbara.

2.5 Recovery Coordination

NMFS continues to coordinate with many partners on white abalone recovery, including other Federal, state, local, and international agencies; universities and other research institutions; public aquaria; local commercial abalone farms; non-profit organizations; and citizen science groups. NMFS hosts regular coordination calls among all captive propagation partners, and

CDFW hosts regular coordination calls among all outplanting partners, to share information, plan for upcoming activities, and discuss ideas. In early 2016, NMFS hosted an abalone workshop to bring together recovery partners throughout the coast to share project updates, discuss best practices, and identify future research needs for captive propagation and outplanting. In mid-2016, CICESE and NMFS hosted the first binational abalone workshop with researchers from California and Mexico to share about abalone research and conservation efforts and identify ways to continue and expand collaborations. Reports for both workshops are forthcoming.

3.0 REVIEW ANALYSIS

3.1 Application of the 1996 Distinct Population Segment (DPS) policy

Because white abalone is an invertebrate, under the ESA the whole species must be listed. Thus, the application of the DPS policy is not applicable.

3.2 Recovery Criteria

The Final White Abalone Recovery Plan was published in 2008 and contains objective, measurable criteria to evaluate the species' recovery. The recovery plan includes both demographic and threats-based criteria. The demographic recovery criteria represent the geographic and demographic characteristics of the species that we would expect when it has recovered from endangered to threatened status (downlisting) and to self-sustaining levels in the wild and no longer needs protection under the ESA (delisting). The threats-based recovery criteria represent the conditions that need to be met to reduce and/or mitigate the impacts of threats that have contributed to the species' extinction risk and to allow the species to sustain a recovered status. The threats-based recovery criteria address the five factors considered in listing a species under the ESA (see Section 3.3.2). Both the demographic and threats-based criteria reflect the best available and most up-to-date information on the species' biology and habitat.

Below, we list the demographic recovery criteria and the threats-based recovery criteria and discuss how each criterion has or has not been met.

3.2.1 Demographic Recovery Criteria for Downlisting

<u>Criterion 1: Density and Abundance</u>

A. Density of emergent animals (short-term) must be greater than 2,000 per ha for 75% of the geographic localities.
B. Maintain a total of 380,000 animals in the wild, distributed among all geographic localities in the USA and Mexico.

<u>Criterion 2: Size Frequency</u>

A. Proportion of size of emergent animals in 75% of geographic localities includes at least 85% intermediate-size animals (90 to 130 mm).
B. Proportion of size of emergent animals in 75% of geographic localities includes no more than 15% large animals (>130 mm).

Criterion 3: Trend

A. Achieve a stable or increasing estimate of geometric population growth ($\lambda \geq 1$) for >75% of the geographic localities over a ten-year period.

Criterion 4: Changes in distribution/reoccupation of historical range

A. Reoccupation of white abalone over a spatial scale that encompasses their historic range such that 75% of the geographic localities in the USA and Mexico are reoccupied and meet the aforementioned recovery criteria.

3.2.1.1 Have the demographic criteria for downlisting been met?

No, the demographic criteria for downlisting have not been met. Survey efforts have expanded throughout the southern California coast, but a monitoring program has yet to be implemented. As a result, information is not available to fully assess the downlisting criteria throughout the species' range. However, the best available population estimates indicate that white abalone abundance and density in the wild have declined significantly and remain critically low compared to estimated levels in the mid-1900s, prior to the modern commercial white abalone fishery. Based on the observation of new individuals that may have been produced in the last 10-15 years, limited recruitment is likely occurring, but not at the scale needed to support recovery. Available population growth data for an offshore bank[2] indicate declining trends, with a greater proportion of larger, older individuals. Overall, the density, abundance, size frequency, population growth rate, and distribution of white abalone in the wild are far below the levels required to meet the downlisting criteria. Below, we summarize the best available information for each criterion. Detailed information is provided in Section 3.6, Updated Information and Current Species Status.

Density and Abundance

Hobday and Tegner (2000) estimated a total abundance of less than 2,600 white abalone in California and Mexico, about 0.1% of the estimated abundance prior to the modern abalone fishery. More recent survey data indicate that the population is likely larger than previously estimated, based primarily on updated habitat data showing greater amounts of suitable habitat than previously thought. In 2002-2004, Butler et al. (2006) conducted ROV surveys off southern California at two offshore banks and one of the Channel Islands and found 258 individual white abalone, with the highest estimated density at one of the offshore banks in 2002 (approximately 0.002 abalone per m^2, or approximately 20 per ha). Abundance estimates for each area were: 12,819 abalone ±3,584 (SE – standard error) in 2002 and 5,883 ±3,324 (SE) in 2004 for one offshore bank; 7,366 ±5,340 (SE) in 2003 for a second offshore bank; and 1,938 ±1,598 (SE) in 2004 for one of the Channel Islands (Butler et al. 2006).

Additional ROV surveys have been conducted at one offshore bank since 2002 and show continued decline in white abalone abundance and density over the period from 2002-2014

[2] Due to poaching concerns, the locations of white abalone will only be referred to in general terms throughout this document.

(Stierhoff et al. 2012; Stierhoff et al. 2014 unpublished data, cited in Catton et al. 2016). The total number of white abalone observed declined from 194 in 2002 to 39 in 2010; the total estimated abundance at the location declined from 15,323 abalone ±5,362 (SEM – standard error of the mean) in 2002 to 3,375 ±1,396 (SEM) in 2010 (Stierhoff et al. 2012). Over the period from 2002-2014, the abundance of white abalone at the offshore bank is estimated to have declined by 76% (Catton et al. 2016). Although these abundance estimates contain a high degree of error, they generally indicate that abundance is greater than estimated by Hobday and Tegner (2000), but still well below the level required to meet the downlisting criteria.

In addition, depth-weighted mean density estimates are available for one offshore bank (2 abalone per ha for 2014) and one of the Channel Islands (0.62 abalone per ha for 2012) (Catton et al. 2016) and are orders of magnitude lower than the density needed to meet the downlisting criteria (2,000 abalone per ha).

Size Frequency

The size distribution of observed animals indicates that individuals are getting larger and older with little recruitment. At one offshore bank, approximately 50% of observed individuals were greater than 130 mm shell length (SL) in 2002 and 2004 (Butler et al. 2006). The average size of individuals increased from 132 ± 20 mm in 2002 to 144 ± 18 mm in 2010 (Stierhoff et al. 2012). Similarly, in 2004, about 50% of the observed individuals at another offshore bank (n=12) and about 60% of the observed individuals at one of the Channel Islands (n=5) were greater than 130 mm (Butler et al. 2006). All of the white abalone observed off the mainland southern California coast since 2010 were also greater than 130 mm SL (Neuman et al. 2016). The sizes of observed individuals indicate that recruitment has occurred in the past 10-15 years, but has been limited. Overall, white abalone populations in the wild consist primarily of larger individuals with a size frequency that does not meet the downlisting criterion.

Trend

We do not have sufficient data to assess population trends throughout the species' range. Information is available, however, for one offshore bank. ROV surveys for white abalone were conducted at the offshore bank in 2002, 2004, 2008, 2010, and 2014 (Stierhoff et al. 2012; Stierhoff et al. 2014 unpublished data, cited in Catton et al. 2016). Based on abundance estimates from these surveys, a population growth rate of 0.88 per year (lower and upper 95% confidence interval: 0.69, 1.12 per year) was estimated for the offshore bank, indicating an estimated annual decline of 12% (Catton et al. 2016). Catton et al. (2016) noted that a decline of 12% is approximately equivalent to the estimated adult natural mortality rate, indicating that adults are dying off with little to no recruitment to the population. At the same time, increased survey efforts along the mainland southern California coast since 2010 have resulted in observations of additional white abalone, at locations where they had not been observed for several years. These white abalone range in size from 136 to 190 mm SL, and may have recruited in the past 10-15 years, indicating a limited level of recruitment is occurring (Neuman et al. 2016). Regular long-term monitoring of these populations is needed to evaluate trends over time and to better ascertain the species' habitat requirements. The latter will aide in the selection of future outplanting sites. This information may be available for the next 5-year status review update.

Changes in distribution/reoccupation of historical range

At this time, information is not available to adequately assess the distribution of white abalone throughout their historical range. To date, targeted survey efforts have focused on a few key locations, whereas a comprehensive monitoring program has yet to be established. Monitoring efforts have increased since the ESA-listing in 2001. The SWFSC has conducted several ROV surveys since 2002 to evaluate white abalone presence, abundance, and density at the offshore banks (Butler et al. 2006, Stierhoff et al. 2012; Stierhoff et al. 2014, unpublished data cited in Catton et al. 2016). In 2016, NOAA led SCUBA surveys at two of the Channel Islands, but did not find any live white abalone (Obaza et al. 2017). Since 2010, increased survey efforts along the mainland southern California coast have led to the discovery of white abalone where they had not been observed for many years (NMFS 2016). Overall, the proportion of the historical range occupied by white abalone has increased since the listing, but much of the historical range remains to be surveyed for white abalone presence. In particular, little is known about white abalone populations off Baja California. A survey conducted in 2012 off Baja California identified both white and pinto abalone (*Haliotis kamtschatkana*), but was not able to distinguish between the two species due to similarities in habitat and physical characteristics (Boch et al. 2014). Comprehensive surveys are needed to evaluate the distribution of white abalone off Baja California.

3.2.2 Demographic Recovery Criteria for Delisting

<u>Criterion 1: Density and Abundance</u>

A. Density of emergent animals (detectable by human observation without substrate disturbance; short-term) must be greater than 3,000 per hectare (ha) for 75% of the geographic localities.
B. Maintain a total of 500,000 animals in the wild, distributed among all geographic localities in the USA and Mexico. Maintenance of 500,000 animals is based on crude estimates of abundance necessary to sustain a 90% probability of persistence in 100 years, per IUCN guidelines. The model assumes a conservative estimate of $\lambda = 0.90$ (i.e., 10% decline per year). The threshold value of 500,000 animals should be updated when empirical estimates of λ become available.

<u>Criterion 2: Size Frequency</u>

A. Proportion of size of emergent animals in each geographic locality includes at least 85% intermediate-size animals (90 to 130 mm).
B. Proportion of size of emergent animals in each geographic locality includes no more than 15% large animals (>130 mm).

<u>Criterion 3: Trend</u>

A. Achieve a stable or increasing estimate of geometric population growth ($\lambda \geq 1$) for >75% of the geographic localities over a ten year period.

<u>Criterion 4: Changes in distribution/reoccupation of historical range</u>

A. Reoccupation of white abalone over a spatial scale that encompasses their historic range such that 75% of the geographic localities in the USA and Mexico are reoccupied and meet the aforementioned recovery criteria.

3.2.2.1 Have the demographic criteria for delisting been met?

No, given that the downlisting criteria have not been met, the demographic criteria for delisting have also not been met.

3.2.3 Threats-based Recovery Criteria

The threats-based recovery criteria are the same for downlisting and delisting:

Listing Factor 1: Destruction, Modification, or Curtailment of Habitat or Range
The Final Recovery Plan did not identify criteria related to this listing factor because the destruction, modification, or curtailment of habitat or range was not identified as an important factor in the decline of white abalone historically and was not believed to limit the recovery of the population at the time the Final Recovery Plan was developed and finalized.

Listing Factor 2: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

A. In California, fishing for white abalone remains prohibited and regulations for other abalone species are designed to protect white abalone. In Mexico, no federal permits are issued that allow fishing for white abalone. These measures limit further reductions in density and genetic diversity. Enforcement of existing regulations and public outreach will help to minimize illegal harvest.
B. The CDFW Abalone Recovery and Management Plan (ARMP) remains in place and reflects updated information adequately to ensure that white abalone will be managed to maintain demographic numbers outlined in the recovery plan. There are assurances of adequate regulatory authority and funding for the state to implement the ARMP.

3.2.3.1 Have the Threats-based Recovery Criteria for Factor 2 been met?

Yes, the threats-based recovery criteria for Factor 2 have been met as described below.

2A. In California, harvest of white abalone and other abalone species remains prohibited south of San Francisco. North of San Francisco, recreational harvest of red abalone (*Haliotis rufescens*) is allowed and managed by CDFW, but this is outside of the geographic range of white abalone so there is no risk of white abalone being taken by mistake in the red abalone fishery. The Final Recovery Plan (NMFS 2008) stated that as of June 2003, Mexico does not issue permits to harvest white abalone. Currently, fishery regulations in Mexico prohibit recreational harvest of abalone and any harvest of intertidal abalone (pers. comm. with Miguel del Rio Portilla and Fabiola Lafarga de la Cruz, CICESE, 20 July 2017). Since at least 2012, catch quotas for white abalone, black abalone, and red abalone have not been authorized along the west coast of Baja California, Mexico (Carta Nacional Pesquera 2012).

2B. CDFW's ARMP was finalized in 2005 and reflects the demographic criteria outlined in the Final Recovery Plan. CDFW receives support to implement the ARMP through dedicated funds (e.g., recreational abalone fishery permit report card fees, fines for abalone violations, previously collected commercial landing taxes) and non-dedicated funds (e.g., general tax revenues, sport and commercial license fees). CDFW has also received funding for white abalone recovery and management through the ESA Section 6 Program and from the NMFS West Coast Region (WCR), allowing CDFW to expand their activities under the ARMP. CDFW continues to coordinate with NMFS and many partners to implement the ARMP. Activities under the ARMP include:

- Management of the recreational red abalone fishery north of San Francisco;
- Enforcing the abalone harvest moratorium under the Thompson bill (AB 663, passed in 1997), which prohibits the taking, possessing, or landing of abalone for commercial or recreational purposes south of San Francisco;
- Establishment of marine protected areas under the State Marine Life Protection Act (MLPA);
- Implementation of health monitoring and certification programs for captive abalone facilities and abalone farms to minimize the spread of diseases or parasites (https://www.wildlife.ca.gov/Conservation/Marine/ABMP/Aquaculture);
- Deployment and monitoring of juvenile abalone recruitment modules at sites along the Southern California coast to evaluate white abalone recruitment (Rogers-Bennett et al. 2016);
- Pilot abalone outplanting studies using red abalone, to inform future outplanting efforts for white abalone (Kawana et al. 2016, Rogers-Bennett et al. 2016); and
- Population modeling to evaluate the status of wild white abalone populations and the effectiveness of different outplanting scenarios (Li and Jiao 2015, Catton et al. 2016, Li and Rogers-Bennett 2017).

Listing Factor 3: Disease/predation

A. Routine monitoring results indicate no evidence of withering syndrome (WS)-infected animals in wild populations.
B. The impact of any emerging disease has been evaluated and conclusions drawn that it is unlikely to significantly affect white abalone populations.
C. A minimum of 50% of the white abalone geographic localities meeting the aforementioned demographic criteria fall outside the resident range of sea otters.

3.2.3.2 Have the Threats-based Recovery Criteria for Factor 3 been met?

No, the threats-based recovery criteria for Factor 3 have not been met. Progress has been made to evaluate the presence of the WS pathogen in wild white abalone, as well as to identify emerging diseases that could affect white abalone. However, further monitoring and research is needed to adequately address these Threats-based criteria for disease.

3A. WS has contributed to white abalone mortalities in captivity, but has not yet been observed in wild white abalone populations. Given the presence of the pathogen in waters throughout Southern California (Moore et al. 2002), wild white abalone are likely infected with the pathogen that causes WS; however, routine monitoring has not yet been established to evaluate the level of infection in wild populations. In 2016-2017, several wild white abalone were collected and brought into captivity to serve as broodstock for the captive propagation program. Prior to undergoing antibiotic treatment, fecal samples were collected to evaluate whether these individuals contained DNA of the pathogen that causes WS (a Rickettsiales-like organism called *Candidatus* Xenohaliotis californiensis or *Ca*.Xc), which is used as a proxy for the presence of the pathogen that causes WS. Of the 12 animals collected and tested, all but one were confirmed to be infected, with a wide range in pathogen levels (Moore and Marshman 2018, unpublished data). All the collected animals appeared healthy despite experiencing prolonged warm water events in 2015 and 2016. As population monitoring efforts expand throughout the coast, additional sampling may be conducted to evaluate infection rates in wild white abalone. For example, researchers have developed a swabbing technique to collect fecal samples without removing the abalone from the substrate (Ben-Horin and Witting 2013, unpublished data cited in Ben-Horin et al. 2016). A recent field sentinel study was conducted to assess the potential for infection by the pathogen and to better understand if molecular analysis (a quantitative PCR, or qPCR, assay) of seawater can be used to forecast the risk to abalone of becoming infected with the pathogen; analyses are underway (Fuller 2017; Crosson et al. unpublished data[3]).

3B. Other abalone diseases have emerged worldwide over the past several decades, including Herpes, ganglioneuritis, vibriosis, and sabellidosis (shell deformities). To date, Herpes and ganglioneuritis have not been observed in wild or captive abalone in California or Baja California. In 2016, an outbreak of vibriosis occurred at a red abalone farm in Baja California, killing 80% of the cultured abalone and broodstock (Cruz-Flores and Cáceres-Martínez 2016). Vibriosis has not yet been observed in California. Studies are needed to evaluate the susceptibility of California abalone, including white abalone, to these diseases and their potential effects on captive and wild populations. Monitoring is also needed to evaluate the presence of these diseases in captive and wild abalone populations, to assess the potential risk to white abalone populations.

A newly reported stippled *Rickettsiales*-like organism (ST-RLO) was observed in red abalone placed off southern California during a field sentinel study (Friedman 2017, unpublished data). These observations, combined with new data from Crosson and Friedman (in review) suggest that the ST-RLO may be evolving into a pathogen of red abalone. Whether or not this bacterium may cause disease in white abalone is unknown at present.

Sabellidosis has been observed in captive-raised abalone in California and Baja California and is caused by infestations of sabellid polychaete worms, such as

[3] Crosson et al. unpublished data: provided by Carolyn Friedman, Professor, University of Washington, School of Aquatic and Fishery Sciences, on 27 September 2017 via comments on draft white abalone five-year status review.

Terebrasabella heterouncinata (Kuris and Culver 1999) and *Boccardia proboscidae* (Cruz-Flores and Cáceres-Martínez 2016). In California, an eradication program and CDFW's sabellid-free certification program have essentially removed the worms from farms and prevented new infestations (Moore et al. 2007).

3C. As described above, white abalone populations have not yet met the demographic criteria for downlisting or delisting in any portion of their geographic range. In addition, the USFWS terminated the southern sea otter translocation program in 2012, allowing sea otters to expand their range into southern California waters (77 FR 75266; 19 December 2012). The 2016 census recorded 72 sea otters southeast of Point Conception, along the Santa Barbara County coast (Tinker and Hatfield 2016). The southern range limit has remained almost unchanged from 2012-2016 and sea otter numbers have also declined within the area (Tinker and Hatfield 2016). At this time, the overlap between the range of sea otters and white abalone is small. How the expansion of sea otters into southern California may affect white abalone recovery has yet to be evaluated.

Listing Factor 4: Inadequate regulatory mechanisms

A. An interagency (state/federal) task force is established to enforce regulations to protect established subpopulations and effectively alleviate illegal take of white abalone.
B. Implementation of bilateral agreements with Mexico are continued and adequately deter illegal international trade.
C. Future abalone harvest is monitored by the CDFW's ARMP such that the health of the species is maintained and populations remain self-sustaining.
D. Populations of white abalone in Mexico are adequately protected by regulatory mechanisms implemented by the Mexican authorities.

3.2.3.3 Have the Threats-based Recovery Criteria for Factor 4 been met?

No, the threats-based criteria for Factor 4 have not been met. Progress has been made to enforce regulations and protect white abalone from illegal harvest. Coordination between the U.S. and Mexico has improved regarding abalone conservation and illegal trade. However, further evaluation is needed to fully assess the effectiveness of enforcement measures and bilateral coordination in addressing illegal take and illegal trade of white abalone.

4A. A formal interagency task force consisting of NOAA's Office of Law Enforcement (OLE) and CDFW Enforcement has not yet been established. However, NOAA and CDFW continue to coordinate on abalone enforcement cases. Further assessment is needed to evaluate the threat of illegal take and the effectiveness of enforcement in protecting white abalone populations from this threat.

4B. Formal bilateral agreements with Mexico regarding illegal abalone trade have not yet been established and implemented. However, coordination between the two nations continues through participation in binational science and policy meetings where abalone management, protection, and conservation are discussed. In addition, coordination among researchers and resource managers has increased since the first binational abalone workshop hosted by CICESE and NMFS in 2016. Further work is needed to identify illegal trade issues and effective measures to deter illegal trade.

4C. At this time, harvest of white abalone in California remains prohibited. Researchers are developing monitoring methods to assess the status of wild populations and monitor outplanted populations. Should the species recover to levels that can sustain harvest, these programs can be applied to monitor and manage wild stocks.

4D. As stated above, regulatory protections for white abalone in Mexico include prohibitions on recreational and commercial harvest of white abalone along the west coast of Baja California. However, the effectiveness of these protections is difficult to evaluate at this time, given the limited information available on the status of wild white abalone populations in waters off Baja California. Monitoring data are needed to evaluate whether existing regulations adequately protect wild white abalone in Mexico.

<u>Listing Factor 5: Other factors affecting the species' continued existence</u>
A. Hybridization has been assessed and determined not to be a threat to the species.

3.2.3.4 Has the Threats-based Recovery Criterion for Factor 5 been met?

No, the threats-based criterion for Factor 5 has not been met. Though very uncommon in the wild, white abalone have the ability to hybridize (crossbreed) with all other abalone species along the California coast, with red abalone *(Haliotis rufescens)* being the most likely partner, and green abalone *(Haliotis fulgens)* being the least likely partner (Owen et al. 1971, cited in Hobday et al. 2001). Hobday et al. (2001) considered hybridization a minor threat to the species' persistence that was unlikely to have led to the species' decline. Since the ESA listing, the occurrence and frequency of white abalone hybrids has not been assessed in the field and would require further sampling and analysis to evaluate.

3.2.4 Long-term Monitoring Criteria for Downlisting

Criterion 1: A monitoring program is in place and underway to evaluate population abundance and structure for a minimum of 50 years after downlisting.

Criterion 2: A monitoring program is in place and underway to evaluate threats for a minimum of 50 years after downlisting/delisting.

Criterion 3: A quantitative, long-term forecasting analysis plan is under development to ensure that the probability of extinction in the wild is less than 10% within 100 years or 5 generations, whichever is longer.

3.2.4.1 Have the long-term monitoring criteria for downlisting been met?

No, the long-term monitoring criteria for downlisting have not been met. Over the past 10 years, significant progress has been made in developing monitoring programs and quantitative population models. However, more work is needed to establish population monitoring and threats monitoring programs and to refine extinction risk models.

1. Since the ESA listing, ROV and SCUBA surveys have been conducted to monitor wild white abalone population abundance and structure in the Southern California Bight. However, a comprehensive monitoring program is still being developed for use during recovery implementation and following downlisting of the species.

2. A long-term monitoring program to evaluate threats to the species after downlisting has yet to be developed. Developing such a program will require identifying the main threats of concern (e.g., low density, disease, sea otter predation, illegal harvest); appropriate monitoring criteria, metrics, and methods; responsible parties; time frames; and funding needs and sources.

3. Population models have been developed to evaluate the status of wild white abalone populations and their trajectory under different outplanting scenarios (Li and Jiao 2015, Catton et al. 2016, Li and Rogers-Bennett et al. 2017). As monitoring continues and outplanting efforts are initiated, these models can be updated and refined to evaluate the species' extinction risk over time.

3.2.5 Long-term Monitoring Criteria for Delisting

Criterion 1: A monitoring program is in place and underway to evaluate population abundance and structure for a minimum of 50 years after delisting.

Criterion 2: A monitoring program is in place and underway to evaluate threats for a minimum of 50 years after delisting.

Criterion 3: A quantitative, long-term forecasting analysis plan has been developed to ensure that the probability of extinction in the wild is less than 5% within 100 years or 5 generations, whichever is longer.

Criterion 4: If information collected during the long-term monitoring period suggests: (a) the decision to delist was in error, or (b) the species' status has changed substantially, a status review of the species should be conducted.

3.2.5.1 Have the long-term monitoring criteria for delisting been met?

No, given that the long-term monitoring criteria for downlisting have not been met, the long-term monitoring criteria for delisting have also not been met.

3.3 Updated Information and Current Species Status

3.3.1 Biology and Habitat

3.3.1.1 New information on the species' biology and life history:

White abalone have a maximum lifespan of 35-40 years, with most animals reaching sexual maturity in 4-6 years (between 88-134 mm) (Hobday et al. 2000, Andrews et al. 2013). As broadcast spawners, animals must be in close proximity to one another (likely within meters) in order for successful fertilization to occur (Babcock and Keesing 1999). Estimated fecundity (eggs released per year) of females ranged from 3.7- 6.5 million eggs per year (Tutschulte and Connell 1981); however, female white abalone in captivity have been observed to spawn 5 to 11 million eggs during one spawning event (pers. comm. with K. Aquilino, BML, 10 March 2016). The optimum temperature range for survival of white abalone eggs and larvae is 12-18°C, with increased mortality seen in abalone populations that have been exposed to temperatures greater than 18°C for over three months (Burton et al. 2008). On average, white abalone can grow between 10 and 29.2 mm/year, depending on size, with males tending to be larger than females (Behrens and Lafferty 2005). In general, juveniles experience very rapid growth, which gradually slows with age (Tutschulte and Connell 1981, Andrews et al. 2013).

Due to the sedentary nature of these animals, white abalone distribution has mainly been attributed to the dispersal of planktonic larvae. The larval duration of white abalone is relatively short, at an average of six days at 15°C (McCormick et al. 2008), which has led scientists to investigate the possibility of drift macroalgae as a dispersal mechanism. In a laboratory setting, over one third of juvenile white abalone present raised up in response to drifting macroalgae, with some individuals grasping onto and rafting on drifting macroalgae (McCormick et al. 2008). This dispersal mechanism may assist in increasing dispersal distance and decreasing dispersal time.

Increased survey efforts off the mainland southern California coast have led to observations of white abalone in relatively close proximity to pinto abalone *(Haliotis kamtschatkana)*, which may indicate shared habitat preferences (Neuman et al. 2016). Similar behavioral patterns have also been noted in white and pinto abalone, particularly when individuals of both species are in close proximity to one another (i.e., residing on the same rock) (Neuman et al. 2016). Further research will hopefully provide more insight into the relationship between white and pinto abalone. For example, time-lapse images collected since 2014 of white abalone located off southern California are being analyzed to determine how abiotic and biotic factors influence white abalone behavior.

3.3.1.2 Abundance, population trends, demographic features, or demographic trends

Rogers-Bennett et al. (2002) estimated a baseline (pre-modern abalone fishery) abundance of 360,476 individuals for white abalone in California, based on landings data from the peak of the fishery in 1969-1978. The current total population of white abalone in California is estimated to be in the thousands and declining by an estimated 12% annually (Catton et al. 2016). This section summarizes the best available data on abundance, population trends, demographic features, and demographic trends.

Trends at Offshore Banks and Channel Islands

In 1999, submersible surveys were conducted at two offshore banks and one Channel Island to determine the abundance and size distribution of white abalone (Behrens & Lafferty 2005). Out of 70 dives, 58 were determined to be within suitable white abalone habitat, with a total of 157 live white abalone observed. The mean shell length (SL) of white abalone across all three sites was 147.7 mm. The Channel Island had the largest individuals (mean SL: 163.1 mm), followed by the two offshore banks (133.8mm and 155.9 mm). White abalone were larger at more accessible sites (156.5 mm) than at remote sites (142.9 mm). White abalone were also larger in areas with crustose coralline algae (mean SL: 148.1 mm versus 134.8 mm in areas with no crustose coralline algae) and with red sea urchins (mean SL: 164.6 mm versus 143.5 mm in areas with no red sea urchins). No juveniles (<90 mm SL) were observed.

In 2004, surveys were conducted using a ROV and multibeam sonar mapping techniques to refine population estimates of white abalone at the two offshore banks and the Channel Island (Butler et al. 2006). A total of 258 individual white abalone were found at all three sites, with the highest counts at one of the offshore banks. Using this data, the total population of white abalone at the offshore bank was estimated to be about 5,883 individuals, and the total population of white abalone in California and Mexico was revised from the previous estimate of 3,000 individuals to 22,122 ± 10,520 individuals. Most of the animals observed at the offshore bank were large adults, with a mean shell size of 124 mm to 137 mm. Although white abalone are cryptic and accounts from former commercial divers suggest that juvenile white abalone were rarely observed even during the height of the fishery (Kushner 2001), no animals smaller than 90 mm long were observed, which may signal that little recruitment has occurred in the past decade. Furthermore, 89% of white abalone at all sites were observed as singletons (defined as individuals more than 2 m apart from other white abalone), with less than 25% of individual white abalone located within 5 m from another.

Similar ROV surveys were conducted at the offshore bank in 2008 and 2010, with a total of 71 white abalone observed in 2008 and 39 white abalone observed in 2010 (Stierhoff et al. 2012). The estimated abundance of white abalone at the location decreased by 78% between 2002 and 2010. The proportion of individuals in the largest size classes increased, while the proportion of individuals in the smallest size classes decreased, indicating that local populations are growing older and larger, with little or no recruitment occurring.

In 2012, scientists returned to the Channel Island to determine whether white abalone populations along the west shore were exhibiting signs of recovery or experiencing further declines (Stierhoff et al. 2014). Visual transect surveys were conducted using an ROV to evaluate the amount of available white abalone habitat, as well as to gain accurate counts of white abalone within three different depth strata (30-40 m, 40-50 m, and 50-60 m). The total number of white abalone observed (n=5) had not changed since the 2004 study, but the distribution of white abalone among depth strata varied between the two survey years. In 2004, all five white abalone were observed within the 40-50 m stratum, whereas in 2012, one white abalone was observed in the 30-40 m stratum, one white abalone was observed in the 40-50 m stratum, and three white abalone were observed within the 50-60 m stratum. Within the 50-60 m stratum, two of the three white abalone observed were considered to be a pair, as they were located ~0.5 m apart on the same boulder. Using these data, the total abundance of white abalone at the island was estimated to be 569 individuals in 2012, which was slightly higher than the abundance estimate for 2004 (330 individuals). A slight decrease in average group size was observed between 2004 and 2012 (1.44 and 1.19, respectively), as well as a slight increase in average shell length between 2004 and 2012 (172 mm and 177 mm, respectively).

In 2014, visual strip transect surveys were conducted using an ROV at the two offshore banks, to determine the number of white abalone within three different depth strata (30-40 m, 40-50 m, and 50-60 m) (Stierhoff et al. 2015, unpublished data). At one offshore bank, 16 transects were conducted with an average length of 547 m. No white abalone were observed and, thus, no population estimate could be calculated. At another offshore bank, 28 transect surveys were conducted with an average length of 551 m. A total of 19 white abalone were observed, all within the 40-50 m depth stratum, resulting in an abundance estimate of 3,745 white abalone. Shell lengths of white abalone ranged from 96 mm to 180 mm, with an average shell length of 150.2 mm, continuing the increasing trend in average shell length that has been observed since 2002. Only one pair of white abalone, consisting of two individuals about a meter apart, was observed in 2014. All other white abalone were observed as singletons.

Observations off Mainland Southern California

From 2010 to present, visual transect surveys have been conducted using SCUBA and ROV to monitor white abalone populations off the mainland southern California coast (Neuman et al. 2016). For each individual white abalone sighting, divers record individual location, depth, distance from nearest neighbor (m), and shell length (mm). About 10 white abalone were observed off Los Angeles County and about 20 white abalone were observed off San Diego County (Neuman et al. 2016). For white abalone surveyed off San Diego County, shell lengths ranged from 136-190 mm and nearest neighbor distances ranged from 5-62 m (Neuman et al. 2016). Some of these sightings may be repeat observations for the same individual.

Observations of Juveniles White Abalone

Although no juvenile white abalone have been found along the California coast in recent years, a total of three juvenile white abalone were observed off one of the Channel Islands, in 2000 and 2001 (Kushner et al. 2001). All three juveniles were found in artificial recruitment modules(wire mesh cages filled with substrates), with the two juveniles found in 2000 measuring 32 mm and 38 mm SL, and the juvenile found in 2001 measuring 29 mm SL (Kushner et al. 2001).

Observations off Baja California

In 2012, dive surveys were conducted to assess *Haliotis sp.* within a nearshore system off Baja California, Mexico, focusing specifically on white abalone *(H. sorenseni)* and pinto (threaded) abalone *(H. kamtschatkana assimilis)* (Boch et al. 2014). Due to difficulty in distinguishing white abalone and pinto abalone in the field, the two species were combined into one group and data were reported for this *H. assimilis/sorenseni* group. Divers surveyed and mapped 24 transects (each transect = 400 m²) over a total area of 9600 m². A total of 178 white/pinto abalone were found. The mean shell length across all sites was 175.2 mm (range: 40 to 240 mm SL). No white/pinto abalone were observed at depths shallower than 11 m or at depths greater than 25 m. Most individuals were observed at depths of 13-15 m and 19-21 m.

3.3.1.3 Genetics, genetic variation, or trends in genetic variation

Gruenthal and Burton's (2008) analysis of white abalone from one site indicated that wild populations still have significant genetic variation; however, this genetic diversity appears to be relatively low compared to other California abalone species (Hawk 2010). Using DNA extracted from shells, Hawk (2010) found no significant differences in genetic diversity among samples from 1940-1959 (pre-modern abalone fishery), 1960-1979 (during the peak of the abalone fishery), and 2000-2008 (after the declines caused by the fishery), indicating that the low genetic diversity is not associated with the most recent population decline caused by overfishing.

Genetic diversity has been a concern for the captive propagation program. From 1999 to 2004, 22 white abalone were collected from the wild and brought into captivity to serve as broodstock for the captive propagation program. Of these 22 wild broodstock, one male and three females spawned (in 2001 and 2003) and produced captive-bred animals that have survived and are currently used as broodstock in the program. At this time, only one of the original 22 wild broodstock remains alive in captivity; the other animals have died due to various causes (injuries due to collection, disease, accidents in captivity, unknown causes). Due to concerns regarding the genetic diversity of the captive-bred population and to increase the number of broodstock in the captive propagation program, an ESA Section 10(a)(1)(A) Scientific Research and Enhancement Permit was issued to BML in 2016 to collect additional white abalone from the wild to serve as broodstock. Under this Permit, 12 white abalone were collected from the wild in 2016 and 2017. Genetic samples collected from the wild broodstock and other white abalone observed during collection surveys will increase our understanding of the genetic diversity of wild populations.

3.3.1.4 Taxonomic classification or changes in nomenclature:

There were no relevant studies examining taxonomic classification since the last status review.

3.3.1.5 Spatial distribution, trends in spatial distribution, or historic range

Historically, white abalone populations could be found in coastal waters between 5-60 m deep from Point Conception, California to Punta Abreojos, Baja California, Mexico (Cox 1960, Stierhoff et al. 2012). Prior to the fishery collapse, major concentrations of white abalone occurred between 25-30 m deep (Stierhoff et al. 2012). Since the fishery collapse, the depth distribution of white abalone has shifted toward deeper depths, as most living individuals are those that were too deep to be fished during the 1960s and 1970s (Lafferty et al. 2004). In surveys conducted at an offshore bank from 2002 – 2010 between depths of 30 to 60 m, white abalone were most abundant and dense at depths of 40-50 m (Stierhoff et al. 2012).

Rising water temperatures caused by global climate change could cause further shifts in the distribution of white abalone. As mentioned in Section 3.6.1.1, the optimal temperature range for survival of white abalone eggs and larvae is 12-18°C, whereas the optimal temperature range for survival of juvenile and early adult white abalone is 12-15°C, with increased mortality observed when individuals were exposed to temperatures greater than 18°C for over three months (Burton et al. 2008). Rising water temperatures could increase larval survival as temperatures approach the optimum (12-18°C); however, juvenile and adult survival may decline at the same time. This could lead to an overall shift in the depth and spatial distribution of white abalone. At this time, such effects are uncertain; monitoring of wild populations is needed to detect shifts in the spatial distribution of wild populations.

3.3.1.6 Habitat or ecosystem conditions

Drift kelp is an important component of the white abalone diet and may also aid in dispersal (McCormick et al. 2008). White abalone use many different species of drift kelp (e.g., *Laminaria farlowii*, *Agarum fimbriatum*, etc.) (Hobday and Tegner 2000), but giant kelp (*Macrocystis pyrifera*) seems to be the most preferred as both a food source and dispersal agent (McCormick et al. 2008). During most years, California's cool, nutrient-dense waters provide ideal conditions for growth of giant kelp; however, during El Niño years, a lack of upwelling leads to warm, nutrient-poor waters and, in turn, reduced production of giant kelp (Vilchis et al. 2005). The increased frequency and intensity of these ocean warming events could cause reductions in the growth and production of giant kelp and subsequently reduce this important food source for white abalone. Monitoring is needed to evaluate how fluctuations in kelp canopy cover affect white abalone populations in the wild.

Previous estimates of white abalone habitat in southern California were low, at approximately 752 ha (Davis et al. 1998, Hobday et al. 2001). Since 2001, surveys using side-scan and multi-beam sonar have been conducted to refine estimates of potential white abalone habitat, to inform population estimates and future population restoration efforts (e.g., long-term monitoring and outplanting). These surveys have identified additional white abalone habitat in southern California. In 2002, approximately 60 ha of rocky habitat were identified off one of the Channel Islands within the depth range of 25-65 m (Cochrane et al. 2005). In 2002-2004, surveys conducted at two offshore banks and one Channel Island identified approximately 3,600 ha of rocky habitat between depths of 30 to 60 m (Butler et al. 2006). Additional surveys at the Channel Island in 2012 identified 14 patches of hard substrate between depths of 30 to 60 m, with the greatest proportion of habitat in the 30 to 40 m depth stratum (44%) and the smallest proportion in the 50 to 60 m depth stratum (25%) (Stierhoff et al. 2014).

Overall, the amount of potential white abalone habitat in southern California is greater than previously estimated, although what is available or suitable may need to be refined if white abalone prefer specific types of rocks or microhabitats. Observations in the field indicate that white abalone prefer the edges of reefs at the sand-rock interface (Cochrane et al. 2005) and associate with flat, moderate complexity habitats consisting of deformed (faulted or folded) rocks and sand and the presence of brown algae such as *Agarum fimbriatum* and *Laminaria* spp. (Butler et al. 2006).

3.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)

3.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range

The Recovery Plan states that habitat loss or modification is not likely to have contributed to the decline of white abalone. Loss or modification of habitat due to natural or anthropogenic factors has not been documented for white abalone and is largely unknown at this time. Long-term or short-term changes in ocean conditions could affect white abalone habitat through effects on water temperature and macroalgal growth. For example, the increased frequency and intensity of warm water events (e.g., El Niños) in recent years could elevate water temperatures above the optimum for larval and juvenile growth and survival, as well as increase the risk of disease (Vilchis et al. 2005). Warmer water temperatures could also reduce the production of giant kelp, an important food resource for abalone. To date, direct and indirect effects of changing ocean conditions on white abalone habitat have not been documented in the wild.

3.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes

The low population densities caused by historical overfishing continue to be the primary threat to white abalone in the wild. For example, white abalone populations in southern California continue to remain at low densities and are likely experiencing recruitment failure, despite closure of the commercial and recreational abalone fisheries since 1997 (Stierhoff et al. 2012, Catton et al. 2016, Rogers-Bennett et al. 2016). Poaching and illegal trade of white abalone continues to threaten remaining populations in southern California and Mexico. The rarity of white abalone could make them increasingly valuable on the market, fueling illegal harvest and trade (Courchamp et al. 2006). Attempts to transport frozen white abalone from the U.S. into Canada and from Mexico into the U.S. have been documented in recent years (pers. comm. with Art Demsky, Canada DFO, and Michelle Zetwo, NOAA Enforcement, cited in Stierhoff et al. 2012). The effects of poaching on the species' status and recovery have yet to be evaluated.

Scientific research and enhancement activities involving white abalone must be authorized under a permit issued by NMFS under Section 10(a)(1)(A) of the ESA, following a thorough analysis of the effects to ensure that such activities do not jeopardize the species. Since 2001, permits have been issued to authorize captive propagation of white abalone to support future outplanting efforts for recovery. In 2016, a permit was issued to BML allowing collection of up to 30 white abalone from the wild to serve as broodstock for the captive propagation program (12 white abalone were collected in 2016 – 2017). The permit contains several conditions to minimize effects on the wild population while maximizing benefits to the recovery program (i.e., increasing the number of spawners and enhancing the genetic diversity of the captive population). For example, specific criteria were established to limit the collection to individuals with a low probability of reproducing in the wild (e.g., individuals more than 10 m from another white abalone).

3.3.2.3 Disease or predation

Withering syndrome (WS) is a fatal disease known to affect all abalone species in California, including white abalone (Crosson et al. 2014). WS is a fecal-oral transmitted bacterial disease caused by a Rickettsiales-like prokaryote that infects the abalone gastrointestinal system and causes severe damage within the digestive gland, which can lead to symptoms such as starvation, absorption of pedal musculature, lethargy, and death (Friedman et al. 2000, Moore et al. 2002, Crosson et al. 2014). Juvenile abalone are also susceptible to WS (Moore et al. 2002). Recent studies have shown that white abalone, in particular, are very susceptible to WS. In a laboratory setting, less than 20% of green abalone exposed to WS died over a 26-week period, whereas 100% of white abalone exposed to WS died within 13 weeks (unpublished data by Friedman, cited in Crosson et al. 2014). Elevated water temperatures facilitate transmission of the pathogen and development of clinical symptoms of the disease (Moore et al. 2000, Braid et al. 2005, Vilchis et al. 2005).

The disease has affected white abalone held in captive facilities and is an important threat to the white abalone captive propagation program. The disease likely caused the die-off of a large number of captive-bred white abalone at CIMRI from 2002-2005 (NMFS 2011). Since then, the development and application of an antibiotic (oxytetracycline) treatment to remove the pathogen from infected animals (Moore 2015) and regular fecal monitoring to ensure animals remain infection-free (Moore and Marshman 2015) have been effective at managing and minimizing WS outbreaks among captive white abalone populations.

To date, no wild white abalone have been observed with clinical symptoms of WS, although individuals have been confirmed to be infected. Of the 12 wild white abalone collected in 2016 and 2017 to serve as broodstock, all but one tested positive for the pathogen; however, pathogen levels ranged widely among individuals and all appeared healthy despite prolonged warm water events in 2015 and 2016 (Moore and Marshman 2018, unpublished data).

The South African sabellid polychaete worm (*Terebrasabella heterouncinata*), which was introduced to California's abalone farms in the late 1980s, also poses risks to captive white abalone by causing severe shell defects that can potentially lead to breakage and decreased growth (Kuris and Culver 1999). CDFW's Sabellid Eradication Program, implemented in 1997, has essentially eliminated the worm from infested facilities and prevented new infestations (Moore et al. 2007). Facilities involved in the white abalone captive propagation program must be certified as sabellid-free by CDFW and undergo regular inspections. A recent emerging risk to the captive propagation program is an unknown species of fungus that causes shell lesions, which can lead to shell weakness and death of the animal (Cherr et al. 2013). Further studies are needed to identify this fungus.

Predation risk is an important factor to consider when conducting outplanting for white abalone recovery. Natural predators of white abalone include sea otters, sea stars, fishes, crustaceans, and octopuses (Hobday et al. 2000). In an experimental study conducted off southern California in 2016, octopus predation was likely a factor affecting the survival of outplanted red abalone (Hofmeister et al. in prep, cited in CDFW 2017). Additional experimental studies are ongoing to investigate octopus movements in relation to outplanting activities and the effectiveness of predator removals, to inform future white abalone outplanting strategies (CDFW 2017).

3.3.2.4 Inadequacy of existing regulatory mechanisms

As discussed in Section 3.6.2.2 of this document, illegal take/poaching and illegal trade of white abalone has been documented in recent years; however, the available information is limited regarding the extent of poaching and illegal trade and the effects on the viability of white abalone. Although regulations prohibiting harvest of white abalone have been implemented in California and in Mexico, increased enforcement effort may be needed to address the issue of poaching and illegal trade.

Introduction of pathogens or invasive species could pose a threat to both wild and captive white abalone. Several diseases have been found to have devastating effects on abalone in other parts of the world. Strict regulations are needed to ensure adequate monitoring whenever animals are moved (e.g., imports, transporting between facilities) for aquaculture, research, and/or food/hobby markets, to protect wild and captive populations from pathogens and invasive species. In California, state regulations require regular abalone health monitoring at aquaculture facilities, control import/export of abalone between facilities, and restrict outplanting abalone from facilities that have not met certification standards. Some improvements to existing regulations may be needed to further protect white abalone. For example, although a CDFW Import Permit is required to import non-native abalone species into California, a CDFW Import Permit is not needed to import native abalone species, even if the source of those abalone is outside of the U.S. This presents a potential risk because live abalone imported into the State could carry pathogens.

3.3.2.5 Other natural or manmade factors affecting its continued existence

Other factors that may affect white abalone include in-water construction or repair, ocean acidification, and exposure to contaminants and harmful algal blooms. The potential impacts of in-water construction or repair projects on individual white abalone and their habitat will depend on the location, scope, and specific activities involved and must be analyzed on a case-by-case basis. Since the listing, only a few projects have been identified that may affect white abalone, including a cable installation project at San Clemente Island (Tierra Data Inc. 2007), a project involving removal of remnant oil and gas pier structures (NMFS 2005), and discharge from wastewater treatment facilities (e.g., Hyperion, Point Loma Ocean Outfall) along the southern California coast. NMFS consults with the action agency to analyze the potential effects of these projects on white abalone and develop measures to avoid or minimize any negative effects.

Ocean acidification is an emerging threat that could affect white abalone growth and survival, as well as the growth and survival of crustose coralline algae, an important feature of juvenile settlement habitat (Crim et al. 2011, Morash and Alter 2015). Decreases in pH may not affect abalone shell length or surface area, but may lead to thinner and weaker shells, which may cause abalone to be more susceptible to predation (Gazeau et al. 2013). Abalone may also direct more energy towards maintaining acid-base equilibrium within their internal organs and body fluids, rather than towards other critical processes such as shell growth, immune function, protein synthesis, and reproduction (Gazeau et al. 2013). Early life-history stages may be the most vulnerable to changes in pH and experience reduced survival, shell length, and normal shell development when exposed to lower pH levels (Crim et al. 2011). Our understanding of the potential effects on white abalone is highly uncertain, due to variability in local conditions throughout the coast, natural variation in ocean pH, species adaptability, and uncertainty in projections of future pH levels. White abalone may be better able to adapt to the effects of ocean acidification compared to other calcareous species, because they experience natural fluctuations in pH levels in the California Current Ecosystem (Feely et al. 2004, Feely et al. 2008, Feely et al. 2009, Hauri et al. 2009). Further research on the effects of ocean acidification on abalone should be conducted to inform recovery of white abalone.

Other threats with uncertain impacts on white abalone include exposure to contaminants and to harmful algal blooms. White abalone may be exposed to contaminants discharged into marine waters intentionally (e.g., from wastewater discharges) or unintentionally (e.g., spills). Studies involving other abalone species indicate that exposure to contaminants at high concentrations and/or over a long period of time can result in negative effects on abalone health, including reduced growth, reproductive development, and survival. For example, Martin et al. (1977) found that exposure to high copper concentrations can kill black abalone and red abalone. Exposure to high levels of heavy metals such as copper and zinc can cause abnormal shell development in larvae (Conroy et al. 1996, Gorski and Nugegoda 2006), as well as reduced growth and survival in larvae, juveniles, and adults (Liao et al. 2002, Chen and Liao 2004, Tsai et al. 2004, Chen et al. 2011). Prolonged exposure to persistent pollutants at high enough concentrations has also been found to cause ovarian spermatogenesis (masculinization) and alter the timing of reproductive maturity in male and female abalone (Horiguchi et al. 1998, 2001, 2005). These studies indicate the potential for harmful effects on white abalone; however, the extent to which white abalone in the wild have been exposed to and affected by contaminants has not been adequately assessed. Further information is needed to identify the types of contaminants and the levels to which white abalone may be exposed, as well as the potential effects of this exposure on individuals and populations.

Exposure to harmful algal blooms could result in mortality of white abalone. Two recent events involving other abalone species have been documented along the California coast. In 2007, a bloom of the dinoflagellate *Cochlodinium* killed red abalone at the Monterey abalone farm by causing gill damage and reduced dissolved oxygen levels (Wilkins 2013, Howard et al. 2012). In 2011, a die-off of abalone and several other invertebrate species off Sonoma County (including abalone in the lab at BML) was linked to a bloom of a dinoflagellate in the *Gonyaulax spinifera* species complex that produced high levels of yessotoxin (Rogers-Bennett et al. 2012, De Wit et al. 2014). These events indicate the potential for harmful algal blooms to kill white abalone. To date, events involving white abalone have not been documented.

3.4 Synthesis

The white abalone was listed as endangered in 2001. In the years prior to the listing and in the years since, NMFS, CDFW, and other Federal, State, and local partners have been working together to implement recovery actions and monitor the species' status. In 2008, the Final Recovery Plan was issued and provides a roadmap to guide the species' recovery, including specific and measurable recovery actions, goals, and criteria. Over the past 10 years, recovery efforts have focused on two key recovery activities: (1) Developing the captive propagation program, to reliably produce large numbers of healthy, captive-raised white abalone and enhance wild populations through outplanting; and (2) Monitoring wild populations to evaluate their status, demographic trends, and progress toward recovery. Progress has been made on both fronts, but the species remains far from meeting the recovery goals and criteria. Recovering the species will take many years and strong partnerships, to develop and implement captive propagation, outplanting, and monitoring strategies, to fill important data gaps, and to assess the effectiveness of recovery actions at establishing healthy, self-sustaining populations in the wild.

Population Trends and Status

Low densities in the wild, due to past overfishing, remain the primary threat to the species due to the fact that abalone are broadcast spawners needing close proximity between the sexes to procreate. In the original status review, Hobday and Tegner (2000) estimated a total abundance of less than 2,600 white abalone in California and Mexico. Survey and habitat data generated since the listing indicate that the population is likely larger than previously estimated, though still well below the abundance required for downlisting (380,000 abalone) and delisting (500,000 abalone). The most recent depth-weighted density estimates for an offshore bank (2 abalone per ha for 2014) and one Channel Island (0.62 abalone per ha for 2012) (Catton et al. 2016) also indicate that densities in the wild are far below those required for downlisting (2,000 abalone per ha) and delisting (3,000 abalone per ha). The size distribution of observed animals is skewed toward larger sizes, indicating that individuals are getting larger and older, with little to no recruitment over the past 10 to 15 years.

Recovery Efforts

To address the threat of low densities, a major focus of recovery efforts to date has been to captively breed and outplant white abalone. Since the captive propagation program began in 1999, much progress has been made. The initial successful spawning events in 2001 and 2003 resulted in thousands of captive-bred animals. Due to disease and water quality issues, a large number of these captive-bred animals died and the program leadership shifted from CIMRI to BML in 2008. Since then, protocols and best practices have been implemented to effectively manage disease concerns. In recent years, the program has had increasing success at producing large numbers of healthy white abalone for outplanting. Efforts are now underway to collect additional broodstock from the wild, to increase the genetic diversity of the captive population. Studies have also been conducted or are ongoing to: (a) prepare captive-bred white abalone for outplanting; and (b) evaluate the feasibility and effectiveness of different outplanting strategies, using other abalone species as surrogates for white abalone, with the goal of applying these strategies in experimental studies and large-scale efforts involving white abalone.

Since the listing, much progress has also been made in monitoring wild populations along the coast and offshore banks, using ROVs and SCUBA. Data from ROV monitoring has been used to estimate white abalone population abundance, density, size distribution, and trends at offshore banks and islands. SCUBA monitoring has been used to estimate size distribution and nearest neighbor distances and observe behavior of white abalone in a small number of locations where they had not been observed for over 20 years along the mainland southern California coast (NMFS 2016). However, information to evaluate the species' status, distribution, and trends is still limited or lacking for most of the species' range. Development of a long-term monitoring program is needed not only to assess the species' status and progress toward recovery, but also to evaluate the success of outplanting efforts and to guide future efforts.

Progress has also been made on addressing other threats to white abalone. CDFW continues to implement measures under the ARMP for the recovery of white abalone and other California abalone species. Harvest prohibitions for white abalone have been established and remain in place in both California and Mexico, although further coordination and assessment is needed to evaluate the threat of illegal harvest and the effectiveness of enforcement measures to address illegal harvest and trade. Disease research has advanced significantly since the listing, but further monitoring and research is needed to evaluate the presence of the WS-pathogen in wild white abalone and the potential effects of WS and other emerging diseases on the wild population. Finally, the potential effects of sea otter predation and of hybridization with other abalone species also need further analysis.

Recovery efforts will require ongoing collaboration and strong partnerships among Federal, State, and local agencies and organizations. Inclusion on the NMFS Species in the Spotlight list is intended to raise public awareness of white abalone and promote conservation through agency actions and collaborative efforts. The Species in the Spotlight Five-Year Action Plan provides a more focused strategy to guide recovery activities over the next few years.

Summary and Conclusion

Overall, much progress has been made in monitoring and understanding the status of white abalone in the wild, developing effective methods to captively breed and produce healthy white abalone for outplanting, and addressing other threats to the species, such as disease and illegal harvest. However, wild populations remain at low densities with little to no recruitment and are far from meeting the demographic criteria describing a healthy, recovered population.

Considering the status and continuing threats, the white abalone remains in danger of extinction. Therefore, the recommended classification for white abalone is to remain the same: Endangered.

4.0 RESULTS

4.1 Recommended Classification

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist (*Indicate reasons for delisting per 50 CFR 424.11):*
  ____ *Extinction*
  ____ *Recovery*
  ____ *Original data for classification in error*
__X__ No change is needed

4.2 New Recovery Priority Number

Brief Rationale: No change to the Recovery Priority Number is recommended at this time for white abalone. A Recovery Priority Number of One remains appropriate for white abalone because the species has a high extinction risk, but also a high potential for recovery. Advances in captive propagation have led to increasing success in producing healthy white abalone for future outplanting. In addition, pilot studies using other abalone species are underway to evaluate outplanting strategies and will provide valuable information once outplanting of white abalone is ready to begin.

5.0 RECOMMENDATIONS FOR FUTURE ACTIONS

The Species in the Spotlight Five-Year Action Plan highlights priority actions to be conducted over the next five years. We summarize these priority actions below, as well as additional recommendations to address the Demographic and Threats-based Recovery Criteria.

<u>Species in the Spotlight Five-Year Action Plan priorities for 2016-2020</u>:

(1) *Expand the captive propagation program*: Captive propagation is the primary action to address the species' low densities in the wild. To date, the captive propagation program has already developed reliable methods and produced thousands of healthy white abalone for use in research and experimental outplanting. To meet the goal of large-scale outplanting over the next five to fifteen years, both the capacity and production of the captive propagation program must increase. The Five-Year Action Plan recommends expanding the captive propagation program through increasing the capacity at existing facilities and establishing partnerships with additional facilities, including commercial abalone culture facilities, where animals can be reared under conditions that mimic natural conditions to maximize the survival and fitness of the animals once introduced into the wild. This recommendation addresses Recovery Action 4: Continue, refine, and expand a captive propagation and enhancement program for white abalone in California with the goal of artificially enhancing populations in the wild.

(2) *Implement a successful outplanting program*: Experimental outplanting studies using other abalone species are underway, with the goal of determining the best size and density of animals to outplant and the optimal locations for white abalone outplanting efforts. The Five-Year Action Plan recommends continuing these experimental studies to refine methodologies and to inform future large-scale outplanting efforts, using other abalone species and captive-bred white abalone. White abalone experimental outplanting may occur within the next five years, depending on when appropriate permits are obtained and the availability of sufficient numbers of captive-bred animals. This recommendation addresses Recovery Action 4.6: Enhance wild populations by outplanting captive-bred white abalone in selected sites throughout the range of the species.

(3) *Monitor and enhance white abalone populations in the wild*: Monitoring using ROVs, SCUBA, in-situ time lapse cameras, and abalone recruitment modules have provided valuable information on the abundance, size and spatial distribution, recruitment, movements, and behavior of wild white abalone. The Five-Year Action Plan recommends continuing and expanding these efforts, to include more tools (e.g., tagging and tracking, genetic analyses for identification) and a greater spatial area, to inform our understanding of the species' status and the effectiveness of recovery efforts. These monitoring tools and methods will also be useful in the future, to evaluate the survival, growth, and contribution of outplanted white abalone to wild populations. This recommendation addresses Recovery Action 1: Assess and monitor white abalone subpopulations in the wild.

(4) *Identify, characterize, and prioritize existing and potential white abalone kelp forest habitat*: The Five-Year Action Plan recommends fine-scale characterization (on the order of meters) of habitats that currently or historically supported white abalone, through the use of ROVs, SCUBA surveys, acoustic mapping, time-lapse video, and local oceanographic data. This fine-scale characterization will inform prioritization of areas for conservation (e.g., recovery actions, marine protection areas) and/or regulatory efforts (e.g., ESA section 7 consultations, mitigation banking), by identifying areas most likely to promote survival of white abalone. This recommendation addresses Recovery Action 2: Identify and characterize existing and potential white abalone habitat.

(5) *Develop a comprehensive, multi-institution outreach plan*: The Five-Year Action Plan recommends developing consistent themes and unified messages to be used by all outreach and education partners, as well as highlighting the important role additional partners (e.g., researchers and fishery cooperatives in Mexico, enforcement agencies, citizen scientists) can play in outreach and education. This recommendation addresses Recovery Action 5: Plan and implement public outreach and education plan.

<u>Additional recommendations to address the Demographic and Threats-based Recovery Criteria</u>:

(1) *Develop formal interagency task force consisting of NOAA OLE and CDFW Enforcement*: At this time, a formal interagency task force has not yet been established to address illegal take. Coordination between NMFS and CDFW should continue and expand to evaluate the threat of illegal take, the effectiveness of enforcement efforts in protecting white abalone populations, and the need for additional enforcement efforts.

(2) *Develop and implement formal bilateral agreements with Mexico to protect white abalone*: Coordination between Mexico and the U.S. on white abalone protections should continue and expand to include efforts to identify, assess, and, if needed, improve measures to deter illegal trade of abalone. Data on illegal take of abalone should be collected, along with monitoring data on wild white abalone populations, to assess the status of the populations and the effects of illegal take.

(3) *Assess the health of wild white abalone and the infection rate with the WS-pathogen*: White abalone in captivity are known to be susceptible to WS, but the disease has not been observed in wild white abalone, although individuals have been confirmed to be infected with the pathogen. Monitoring should be conducted to evaluate the rate of infection of wild white abalone populations with the WS-pathogen. Development of new or refined techniques may be needed to assess animals for infection without removing them from the substrate.

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NATIONAL MARINE FISHERIES SERVICE
5-YEAR REVIEW
White Abalone (*Haliotis sorenseni*)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_X_ No change is needed

Review Conducted By: NMFS West Coast Region, Protected Resources Division

REGIONAL OFFICE APPROVAL:

Lead Regional Administrator, NMFS

Approve: ______________________ Date: June 6, 2018

HEADQUARTERS APPROVAL:

Assistant Administrator, NMFS

_✓_ Concur _____ Do Not Concur

Signature______________________ Date: 7/10/18