White Abalone Research Plan

Kevin L. Stierhoff

12 August 2017

Contents

Executive Summary

TBD

Background and purpose

Population status

Threats

Recovery

National priorities for white abalone research

White Abalone Recovery Plan

In 2008, NOAA finalized the White Abalone Recovery Plan (hereafter, Recovery Plan; National Marine Fisheries Service, 2008)

Species in the Spotlight

NOAA's Species in the Spotlight initiative is part of a strategy to marshal resources on species listed under the Endangered Species Act of 1973 (ESA) for which immediate, targeted efforts are vital for stabilizing their populations and preventing their extinction. Eight species were identified by the National Marine Fisheries Service (NMFS) as among the most at-risk of extinction, including white abalone.

These species were identified as most at-risk of extinction based on three criteria (1) endangered listing, (2) declining populations, and (3) are considered a recovery priority #1[1] . We know the threats facing these species and understand the management actions we can take that will have a high probability of success. The 5-Year Action Plan actions builds upon existing recovery or conservation plans and details the focused efforts needed over the next 5 years to reduce threats and stabilize population declines. We will engage our partners in the public and private sectors in actions they can take to support this important effort. We will report on our progress through the Biennial Report to Congress and post updates on our website. This strategy will guide agency actions where we have the discretion to make critical investments to safeguard these most endangered species. The strategy will not divert resources away from the important and continued efforts to support all ESA-listed species under our authority. Many of our species have long-standing conservation programs supported by multiple partners. We remain committed to those programs. This action plan is designed to highlight the actions that can be taken by us, other federal and state resource agencies, environmental organizations, Native American Tribes and other partners to turn the trend around for this species from a declining trajectory to a trajectory towards recovery.

[1]Priority #1 is defined as a species whose extinction is almost certain in the immediate future because of a rapid population decline or habitat destruction, whose limiting factors and threats are well understood and the needed management actions are known and have a high probability of success, and is a species that is in conflict with construction or other developmental projects or other forms of economic activity. NMFS Endangered and Threatened Listing Recovery Guidelines (55 FR 24296, June 15, 1990).

Role of the Southwest Fisheries Science Center

Research themes

Research theme 1 - Remotely operated vehicle operations

The Recovery Plan identifies several critical actions to aid the recovery of this endangered species, two of which have been research foci since 2001: 1) assess and monitor wild subpopulations in cooperation with state, Federal, and international partners; 2) identify and characterize existing and potential white abalone habitat. White abalone have the deepest depth distribution of all abalone species in California (Leighton, 2000) **(Hobday, others)**, occurring at the highest density between 30 and 60 m. The deep distribution of white abalone habitat poses logistical challenges to sampling using traditional visual survey methods such as SCUBA, which is constrained by depth and bottom-time restrictions. For this reason, remote sensing technologies, primarily remotely operated vehicles (ROVs) and active acoustic sensors, have been developed and/or used by scientists at the SWFSC and their partners to conduct this research.

Research foci for Theme 1

Demography of deep-water populations in historically imporant areas

The SWFSC and its partners have used ROVs to survey white abalone at a number of historically important locations throughout the Southern California Bight (SCB) since 2000 (**Table: Survey site summary**). Monitoring effort has been greatest at Tanner Bank, San Clemente Island, Santa Catalina Island, and Cortes Banks and has produced estimates of population size, size distribution, and seabed habitat at those sites (Butler *et al.*, 2006; Stierhoff *et al.*, 2014a, 2012b, 2014b). Monitoring has focused primarily on the white abalone population Tanner Bank, which had the greatest density and largest estimated population size based on early surveys (Butler *et al.*, 2006), and at San Clemente Island where commercial landings were greatest (Hobday and Tegner, 2000; Hobday *et al.*, 2001).

Table: Survey site summary. A summary of remotely operated vehicle survey effort by site and year.

Survey site	Dives	Years
Tanner Bank	138	2000, 2002, 2004, 2006, 2008, 2010, 2014
San Clemente Island	119	2000, 2004, 2007, 2012, 2016
Santa Catalina Island	37	2000, 2005, 2008, 2016
Cortes Bank	33	2003, 2014
Palos Verdes	20	2015
Isla Natividad	17	2006
Punta San Jose	17	2006
Coronado Islands	6	2006
San Miguel Island	6	2005
San Nicolas Island	5	2001
Point Loma	4	2005
La Jolla Canyon	3	2005
Santa Cruz Island	1	2011

In 2002, bathymetric mapping was conducted at Tanner Bank, Cortes Bank, San Clemente Island, and Farnsworth Bank (off the coast of Santa Catalina Island) using a multibeam sonar to identify areas of rocky substrate and quantify the amount of potentially available white abalone habitat (**Figure: White Abalone Habitats**). Next, depth-stratified visual transect surveys were conducted using an ROV at each location to estimate white abalone density, abundance, and size structure. The results from surveys in 2002 and 2004 provided a "baseline" estimate of available habitat, abundance, and size structure of the populations in these areas. Subsequent visual surveys conducted at Tanner Bank in 2008 and 2010 indicated that the population at that site had declined by approximately 78% since 2002 despite protection under ESA (Stierhoff *et al.*,

2012a). Data from the most recent survey conducted at Tanner Bank and Cortes Bank in 2014 are still being analyzed, but preliminary results indicate the the population at those two sites remain severely depleted (K. Stierhoff, unpublished data). The majority of white abalone observed at Tanner Bank have been solitary (> 2 m nearest neighbor distance), large (> 9 cm), and the mean length in each survey has increased over time, which suggests an aging population of mostly isolated individuals with little or no indication of recent recruitment. A survey at San Clemente Island in 2012 suggested a small but stable remnant population (Stierhoff *et al.*, 2014a), but the extremely low density at that site resulted in population estimates with high uncertainty. Another survey at San Clemente Island in 2015 observed only two white abalone in 36 transects, and suggested a decrease in abundance at that site (K. Stierhoff, unpublished data), but the large error around the abundance estimates makes the interpretation of population trends difficult.

Exporatory surveys in other potentially viable deep-water habitats

In addition to the more intensive sampling conducted at the long-term monitoring sites, smaller-scale surveys have been conducted at some areas where white abalone have been observed or are thought to occur (**Table: Survey site summary**). In 2008, five visual transect surveys were conducted at Farnsworth Bank, but only one white abalone was observed. In 2015, 20 visual transect surveys were conducted at two sites near Palos Verdes, CA ("The Ridges" and "Horseshoe Kelp"). These two sites are relatively shallow (approximately 20-40 m), have been surveyed by numerous groups using SCUBA, and are known to be habitat for white and pinto abalone (*H. kamtschatkana*). During that survey, three white abalone were observed and 29 pinto abalone.

The delisting of white abalone under ESA requires consideration of the species' population status throughout its known geograpical range, which extends south to Punta Abreojos, Baja California, Mexico. Surveys were conducted, in cooperation with fishery managers and members of the local fishing coopertives (or cooperativos) off Punta San Jose (near Ensenada) and around Isla Natividad.

Following the First Binational Abalone Symposium hosted by CICESE in Ensenada, Baja California, renewed cooperation/enthusiasm...

In 2017, funding was received from the NMFS Office of Scientific and Technology International Research Program, the NMFS Office of Protected Resources, and the WCRO ($85K, total) to conduct new surveys in cooperation with local fishermen and fishery scientists in high-probability white abalone habitats to provide critical information on the status of white abalone populations in Mexico, and to help them develop methods and monitoring programs for white abalone.

Improving assessments using advanced technology

Design and development of visual survey tools In 1999, a ROV (*Phantom 2+2*, Deep Ocean Engineering) was purchased to conduct visual surveys of white abalone and generate baseline population estimates soon after the species was listed as endangered under the ESA. The earliest configuration of this ROV was rated to a water depth of 500 m and had a standard definition video camera (NTSC, 520 x 480 lines of resolution), halogen lights, and four thrusters (two horizontal, two vert-trans). There was no means of tracking the location of the ROV from the ship, and no tether management. Over time, the ROV hull was upgraded to a *Phantom DS4* (2001), which added two horizontal thrusters and increased the depth rating. Furthermore, additional cameras and sensors were added to improve the quality and quantity of data and imagery collected during surveys including: a high-resolution (3 megapixel) digital still camera (2003; Scorpio Plus, Insite Pacific) and strobes; calibrated, high-intensity lasers for estimating the size and range of targets observed near the seabed; a Doppler velocity log (2005; 1200 kHz Workhourse Navigator, Teledyne) for precise estimation of speed, distance, and altitude; a conductivity-temperature-depth (2006; Citadel CTD, RDI Teledyne) probe and oxygen optode (Model 3975, Aanderaa); an ultrashort baseline acoustic tracking system (2002; TrackPoint-IIplus, ORE Offshore); and a forward-looking scanning sonar (2005; MS1000, Kongsberg-Simrad). In 2010, a more precise and user-friendly USBL (TrackLink 1500HA, LinkQuest) was added.

In 2011, the engineers and biologists at the SWFSC finalized the design and construction of a new high-definition (HD), high-voltage, DC-powered ROV (HDHV-ROV) to improve the survey capabilities of the

ROV program. The HDHV-ROV incorporated many of the instruments from the *Phantom DS4* ROV, and added: an HD (1080i) color video camera (Mini Zeus, Insite Pacific); LED lighting (LED Multi-SeaLite, Deep Sea Power & Light); a fiber-optic umbilical to increase bandwith for video and data transmission; and brushless DC trusters, which greatly reduced noise and eliminated laborious maintenance required by the *Phantom* trusters. In 2016, a calibrated stereo camera pair was installed to improve the measurement of targets observed during the surveys, and a multibeam imaging sonar (M3, Kongsberg-Simrad) was added to aid navigation, provide high-resolution maps of the seabed, or both. We continue to explore ways in which the survey capabilities of the SWFSC ROV can be improved.

Improving visual survey methods

Accurate and precise measurements of transect length and width are critical to the estimation of abalone density and abundance. In 2016, a study was conducted to examine the accuracy and precision of distance estimates derived from different ROV instruments, and described a practical method to estimate transect width throughout surveys using standard survey equipment and analysital methods (Stierhoff *et al.*, 2016). That study found that transect distance measured using a Doppler velocity log were precise and accurate (**precision, accuracy**), and that transect area measured using the optical properties and orientation of the video camera were comparable to estimates derived using more laborious image analysis techniques. These methods significantly streamline and improve estimates of area searched during optical transect surveys, and will be employed during future surveys of abalone and other demersal fishes.

Improving assessments through habitat modeling

Initially, ROVs were used to survey white abalone populations in areas where historical landings were greatest (e.g., San Clemente Island, Tanner and Cortes Banks, and Santa Catalina Island). More recently, surveys have been conducted in areas where high-resolution multibeam bathymetric data exist and survey-based densities and abundances were greatest (i.e., Tanner Bank, and to a lesser extent San Clemente Island), and survey effort is typically focused on areas deemed potential white abalone habitat. Based on the results of Butler et al. (2006), potential habitat is broadly defined as rocky substrate between the depths of 30 to 60 m. However, other factors, including rugosity, slope, and geologic composition, likely determine whether some habitats are more optimal than others.

I will identify suitable habitat in the Southern California Bight to inform future outplanting efforts of White Abalone. Given that this population exists at such low numbers and data is limited to presence-only (lacking or unreliable absence data), maximum entropy (Maxent) models are strong candidates for modeling habitat suitability (Phillips et al 2006). Using White Abalone survey data (SWFSC ROV and SCUBA surveys, California Department of Fish and Wildlife (CDFW), citizen science, etc.) as well as potential environmental factors of suitable habitat, I will develop a Maxent model to inform White Abalone outplanting efforts. To the extent possible, I will evaluate the effects of climate change on the designated suitable habitats to predict long-term suitability.

Research theme 2 - SCUBA operations

To date, population assessment surveys have been limited to deep-water populations using ROVs. However, surveys of nearshore habitats by NOAA researchers and citizen scientist groups are identifying white abalone in areas where they were thought to be extirpated or at very low density. Heavy surge and dense kelp are often inaccessible or unsafe for using ROVs. Therefore, the SWFSC and its partners will increasingly use open-circuit SCUBA, closed-circuit rebreathers, or both to survey white abalone in shallow-nearshore areas where ROV surveys are impractical or impossible.

SCUBA surveys have several advantages over ROV surveys. First, measurements of shell length and nearest neighbor distances (which is important for estimating group size and for identifying reproductively isolated individuals) are more accurate than those from ROVs. Furthermore, SCUBA divers have the potential to collect biological samples for genetic analysis and disease monitoring (see Theme 3 below), which is not possible using ROVs.

Research foci for Theme 2

Demography of shallow-water populations

Brood stock collection

The collection of additional brood stock to enhance captive breeding efforts will be an essential part of a successful stock enhancement program. While collection of adult individuals is not possible using the ROV, it may be used to search for and identify white abalone in deep-water habitats where searching for abalone using SCUBA is impractical. Once individuals are identified with the ROV, directed SCUBA surveys (either open-circuit SCUBA or closed-circuit rebreathers) may be conducted to estimate nearest neighbor distances (a metric used to identify reproductively isolated individuals) and collect white abalone that are deemed to be singletons (see ***Theme X*** *below).*

Behavioral studies using acoustic telemetry

Funding sources

Discretionary NOAA funds

In 2000, soon after white abalone were listed as endangered under the ESA, the SWFSC received ~$200K to purchase an ROV (*Phantom*, Deep Ocean Engineering) for surveying deep-water white abalone populations throughout southern CA. Since then, the SWFSC has received between $15K-80K per year from West Coast Regional Office (WCRO, formerly the Southwest Regional Office) to support the costs of conducting field surveys, and improvements and repairs to the ROV system. These were typically discretionary funds and, therefore, the frequency and amount of funding were variable and unknown, and sometimes no funding was received. Nonetheless, the SWFSC was able to conduct meaningful surveys to monitor changes in white abalone populations at historically important locations every 2-4 years, an interval that is likely adequate to detect and track changes in population size. However, the level of funding received from the WCRO was not sufficient to survey all of the historically important sites, and the amount of survey effort (i.e., number of sea days) possible with the available funding was likely not optimal to minimize error in population estimates.

Interagency Agreements

Given the limited amount of funding generally available, and the need to focus survey efforts at Tanner Bank, few surveys had been conducted at other historically significant areas, including San Clemente Island (SCI). In 2012, the SWFSC and WCRO entered into an interagency agreement with the Navy to conduct the first population assessment surveys of white abalone along the western shore of SCI since it was originally surveyed in 2004 (**Table: MIPR Funds**). In 2015, a second agreement provided funding to provide updated population estimates, but also for various projects aimed at improving survey methods and gaining a better understand of the behavior of white abalone and other abalone species that occur in the U.S. Navy's operational areas around San Clemente Island and Point Loma near San Diego, CA. All interagency agreements aimed to support the Navy's Integrated Natural Resources Management Plan for SCI and the State of CA's Abalone Recovery and Management Plan (ARMP).

Table: MIPR Funds. Funding year, amount ($), and agreement number for agreements between the Navy and NOAA.

Year	Amount	Agreement.number
FY12	$76000	US NAVY SWR-F147
FY15-16	$251237	US NAVY WCR-F1404

US Navy/NOAA Memorandum of Agreement

IN 2016, the Navy and NOAA entered into a Memorandum of Agreement (MOA) where the Navy would provide financial support for the recovery of critically endangered white abalone populations that occur at Tanner and Cortes Banks in exchange for the ability to continue conducting at-sea testing and training within the Navy's irreplaceable and strategically significant Southern California (SOCAL) Range Complex that are compatible with the recovery of the species (also called the Seven-Year Plan). The MOA will provide a total of ~$2,175,000 over the course of the Seven-Year Plan in support of efforts to monitor demography; improve survey methodology; develop methods to monitor behavior, disease prevalence, genetic diversity, demography; and monitor habitats and assess outplant sites (**Table: Navy Funds**). Approximately $1,495,000 of funding is allocated to ROV operations to survey white abalone populations and their offshore habitats at San Clemente Island, Tanner Bank, and Cortes Bank, and to explore and characterize and monitor potential outplant sites in nearshore habitats. Approximately ~$200,000 is allocated to the development and refinement of advanced technology (e.g., acoustic telemetry and time-lapse videography) for studying the movement and behavior white abalone and other closely related surrogate species. Total funding in any one year ranges

from ~$118K-545K/year.

DON PROJECTS DIRECTLY BENEFITTING WHITE ABALONE RECOVERY ON TANNER AND CORTES BANKS								
Project Title (Navy Funding Command)	2016	2017	2018	2019	2020	2021	2022	Project Goals to Support White Abalone
NOLF SNI - White Abalone Surveys (NAVAIR) (From Navy - Row 5)								1) assess the current white abalone population at SNI.
NALF SCI - White Abalone Surveys and Management (CPF): Locations: San Clemente Island and Pt. Loma (From Navy - Row 10)	$117,876	$5,186	$125,394	$5,395	$130,460	$5,163	$5,714	1) Continue to monitor trends in key demographic variables of white abalone populations at San Clemente Island (e.g., abundance, density, size range); 2) reduce methodological biases associated with data collection by improving equipment and/or sampling design and comparing the detection rates of remotely operated vehicles and SCUBA; 3) assess the potential viability of wild abalone populations by monitoring movements of abalone aggregations and solitary animals; and 4) use the information collected to revise or amend existing recovery, restoration and management plans for abalone species.
Status assessment in Southern California (From Navy - Row 11)								
Tagging methods development to track long-term movements, behavior, growth		$50,000		$50,000		$50,000	$50,000	1) Apply acoustic, visual, and/or passive-integrated transponder (PIT) tags to the shells of wild white abalone or surrogates to track long-term movements and behavior
Withering Syndrome prevalence and susceptibility		$50,000	$50,000		$50,000			2) Characterize the health of wild abalone by determining the presence of the RLP that causes WS in wild abalone;
Genetic toolbox development		$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	3) Collect genetic material from wild abalone to examine diversity of the wild population; uncover markers for sex; higher fitness, and/or for tracking outplanted abalone
Monitor habitat and status of abalone at outplant sites		$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	4) Monitor outplant sites for veliger stage larvae and juveniles (habitat monitoring in FY16-17, abalone monitoring post-experimental outplanting using SCUBA, ROV and in situ camera methods in FY18-22
Tanner-Cortes Banks White Abalone Survey (From Navy - Row 12)		$0	$190,000	$0	$190,000	$0	$0	1) Proposed project would fund a minimum of two (2) surveys within the 6-year window between 2017-2022. Surveys would monitor for white abalone occurrence, density, and habitat type on Tanner-Cortes Banks. Preliminary thoughts would be to align field effort with SCI white abalone effort (indicated in blue highlight). Year of Tanner-Cortes Banks survey however open to negotiation with performer (NMFS) as to which years within the 6-year window would be optimal. Cost based on details from previous Navy/NMFS efforts factoring inflation costs and some nominal NAVFAC support.
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	
TOTAL	$117,876	$280,186	$540,394	$230,395	$545,460	$230,163	$230,714	
TOTAL FUTURE NAVY INVESTMENT WITH DIRECT BENEFIT TO WHITE ABALONE:								**$2,175,188**

Table: Navy Funds. Funding allocation by year and research theme for the US Navy/NOAA Memorandum of Agreement and Seven-Year Plan.

5-year Research Plan

Personnel

SWFSC Staff

Kevin Stierhoff, Ph.D. (Research Fisheries Biologist, ROV Team Lead), David Murfin (Electrical engineer), Scott Mau (Research Fisheries Biologist)

Partner institution staff

West Coast Regional Office

Melissa Neuman, Ph.D. (**Title**)

Restoration Center

David Witting, Ph.D. (**Title**)

Scripps Institution of Oceaongraphy

Brice Semmens, Ph.D. (Professor), Jordan Dinardo (Graduate student)

Others

Paua Research Group
William Hagy

Appendices

Literature cited

Butler, J., Neuman, M., Pinkard, D., Kvitek, R., and Cochrane, G. 2006. The use of multibeam sonar mapping techniques to refine population estimates of the endangered white abalone (*Haliotis sorenseni*). Fishery Bulletin, 104: 521–532.

Hobday, A., and Tegner, M. J. 2000. Status review of white abalone (*Haliotis sorenseni*) throughout its range in California and Mexico. U.S. Dep. Commer., NOAA Tech. Memo., NMFS-SWR-035: 101 pp.

Hobday, A., Tegner, M. J., and Haaker, P. L. 2001. Over-exploitation of a broadcast spawning marine invertebrate: Decline of the white abalone. Reviews in Fish Biology and Fisheries, 10: 493–514.

Leighton, D. 2000. The Biology and Culture of the California Abalones. Book. Dorrance Publishing Co., Inc., Pittsburgh, PA.

National Marine Fisheries Service. 2008. White abalone recovery plan (*Haliotis sorenseni*). Report. National Marine Fisheries Service.

Stierhoff, K. L., Murfin, D. W., Demer, D. A., Mau, S. A., and Pinkard-Meier, D. R. 2016. Improving the estimations of transect length and width for underwater visual surveys of targets on or near the seabed. ICES Journal of Marine Science, 73: 2729–2736.

Stierhoff, K., Cutter, G. R., Murfin, D., and Demer, D. A. 2012a. An overview of visual survey research and imaging technology development at the southwest fisheries science center. *In* Report of the national marine fisheries service automated image processing workshop, p. 48 pp. Ed. by K. Williams, C. Rooper, and J. Harms. U.S. Dep. Commer., NOAA Tech. Memo.

Stierhoff, K., Murfin, D., and Mau, S. 2014a. White abalone populations at Tanner Bank and Cortes Bank estimated from an optical survey: A report to NOAA's Southwest Fisheries Science Center. NOAA Fisheries Southwest Fisheries Science Center.

Stierhoff, K., Neuman, M., and Butler, J. 2012b. On the road to extinction: Population declines of the endangered white abalone, (*Haliotis sorenseni*). Biological Conservation, 152: 46–52.

Stierhoff, K., Neuman, M., Mau, S., and Murfin, D. 2014b. White abalone at San Clemente Island: Population estimates and management recommendations. U.S. Dep. Commer., NOAA Tech. Memo., NMFS-SWFSC-527: 25 pp.