White Abalone Research Plan

SWSC - Advanced Survey Technologies Group

Kevin L. Stierhoff

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Executive Summary

TBD

Purpose

This research plan describes past, current, and future research activities involving researchers in the Advanced Survey Technologies (AST) Group at NOAA's Southwest Fisheries Science Center to facilitate the recovery of the critically endangered white abalone (*Haliotis sorenseni*) as defined in the White Abalone Recovery Plan (hereafter, Recovery Plan; National Marine Fisheries Service, 2008). Within NOAA, the AST Group has unique expertise and technological capabilities in the areas of underwater optics, active acoustics, and closed-circuit SCUBA (i.e., rebreathers) that were developed, in part, to survey and collect white abalone populations at depths beyond which traditional methods, for example open-circuit SCUBA, were ineffective, inefficient, or unsafe. The goal of this document it to prioritize research activities involving AST's equipment and staff over the next 5-10 years, toward the fulfillment of NOAA's mandate and stated objectives regarding the protection and rebuilding of white abalone. The recovery of white abalone will necessarily involve expertise and activities outside the scope of the SWFSC and AST. Therefore, it also aims to identify areas where the SWFSC and AST may collaborate with other research groups within and outside of NOAA to lend assistance, to seek advice, or both.

Background

Population status

White abalone were historically found between Point Conception, CA (USA) and Punta Abreojos, Baja California (Mexico). They are among the deepest occurring abalone species in California (5–50m depth), with major concentrations having occurred between 25 and 30 m (Tegner, 1989). White abalone are estimated to live up to 35 years (Tutschulte and Connell, 1988), and their longevity has been validated to be as great as 27 years using bomb radiocarbon dating (Andrews *et al.*, 2013). Like other abalone species, the recruitment of white abalone may be episodic (McShane and Naylor, 1996). White abalone once supported a brief commercial fishery in North America, but by the mid-1980s, landings fell to near zero and the commercial fishery was closed in 1997 (Hobday *et al.*, 2001). The white abalone fishery in Mexico appears to have collapsed in the 1960s (Shepherd *et al.*, 1998). Despite fishery closures, white abalone abundance continued to decline through the 1990s and as a result, white abalone became the first marine invertebrate to be listed as endangered throughout its range under the Endangered Species Act (ESA) in 2001 (National Marine Fisheries Service, 2001). A formal status review concluded that the species' abundance was greatly reduced due to overharvesting during the 1970s and that remnant populations showed no sign of recovery following the closure of the fishery (Hobday and Tegner, 2000). It is believed that no significant recruitment has occurred since the 1960s (Davis *et al.*, 1996; Hobday and Tegner, 2000) and that the substantial reduction in white abalone densities has contributed to this decrease in reproductive success through an Allee effect (Allee, 1931; Berec *et al.*, 2007). Limited information on movement patterns suggests that the more sedentary behavior of white abalone compared to green and pink abalone make it unlikely that recovery of locally extirpated or depleted populations could occur through immigration or aggregation, respectively (Hobday and Tegner, 2000; Tutschulte, 1976). Monitoring of wild white abalone has confirmed that, desipite protection under the ESA, populations continue to decline in some areas and that the wild population is at high risk of extinction (Butler *et al.*, 2006; Stierhoff *et al.*, 2014a, 2012). Given the continued decline of the species, recent efforts have focused on the development and expansion of captive breeding programs by NMFS and its partner institutions to hopefully restore wild white abalone densities to levels that are self-sustaining.

Threats and Recovery

The Recovery Plan aims to ensure the recovery of the white abalone population throughout its range (in both the US and Mexico), defined as the establishment of self-sustaining populations based on threshold densities, minimum population size, size frequency distributions, population trends, and spatial distribution (see details in National Marine Fisheries Service, 2008). It is important to note that this definition of white abalone recovery may not necessarily support a fishery. Loss and destruction of habitat, disease, predation, illegal harvest, and inadequate enforcement are all potential threats and impediments to white abalone recovery. However, the Recovery Plan states that the most significant threat to white abalone recovery relates to the residual effects low population density on their continued reproduction and survival.

Even if limited natural recruitment of white abalone is occurring, it is happening too slowly to give the species the foothold it needs to weather future threats and be viable over the long-term. Population trends based on ROV surveys in prime white abalone habitat indicated that the species was at high risk of extinction within 15 years, and should be considered as Critically Endangered as described by the IUCN Red List of Threatened Species (Catton *et al.*, 2016). The best way to safeguard white abalone against extinction is a captive breeding program aiming to produce young abalone. These captive-raised animals can enhance wild populations to the point that densities are boosted enough to sustain healthy and prolific populations. This enhancement may occur as a variety of approaches aimed at increasing abundance and reproductive success of white abalone in the wild by placement of these captive bred individuals (outplanting) in currently unoccupied areas or groups of wild abalone and captive bred abalone. Using results from ROV surveys, models have been developed to recommend stocking scenarios and densities that yield the greatest chance of success (Catton *et al.*, 2016). Captive breeding success has recently increased (Rogers-Bennett *et al.*, 2016) and provides encouragement that captive breeding will be able to produce sufficient juveniles to support the stocks enhancement efforts. ROV and SCUBA (both open- and closed-circuit) technology will facilitate the identification and collection of isolated individuals to increase captive brood stock. Continued monitoring of wild white abalone and their habitat must occur at the same time as captive breeding in order to identify habitats best-suited for future enhancement efforts and to track species' status over time. Given the difficulties of surveying shallow habitats using the ROV (due to surge, kelp entanglement, etc.), and the inability of SCUBA divers to safely and effectively survey white abalone and their habitats in deep water, both of these survey methods will be required to monitor recovery of wild and out-planted populations.

National and Regional priorities

Since being listed as endangered in 2001, white abalone research has been a priority for NOAA and the SWFSC, beginning with baseline habitat mapping population assessment surveys in 2002, the finalization of the Recovery Plan in 2008, and the selection of white abalone as a Species in the Spotlight in 2015.

White Abalone Recovery Plan

In 2008, NOAA finalized the Recovery Plan, which describes the status of the species, goals for recovery, and the recommended strategies to achieve recovery, including:

1. Assess and monitor subpopulations of white abalone in the wild in cooperation with the state of California, other federal agencies, private organizations and the Mexican government,
2. Identify and characterize existing and potential white abalone habitat through acoustic remote sensing technology,
3. Protect white abalone populations and their habitat in the wild,
4. Continue and expand a captive propagation and enhancement program for white abalone in California, and
5. Develop enforcement, public outreach and education plans. 6. Secure financial support for white abalone recovery.

Of those, the AST Group (and formerly the Benthic Resources Group) and its partners have been contributing primarily to Items 1 and 2 using visual and acoustic surveys. Recently, members of AST have contributed to Item 4 by using technical SCUBA diving equipment (closed-circuit rebreathers) to collect isolated white abalone in deep-water habitats to augment the brood stock used for captive breeding by the Genetics, Physiology, and Aquaculture Group at the SWFSC and its partner institutions throughout CA (principally Bodega Marine Laboratory at UC Davis, but also the Aquarium of the Pacific, the Cabrillo Aquarium, and UC Santa Barbara).

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.

Southwest Fisheries Science Center Priorities

The FY18 Strategic Plan outlined by the SWFSC places a high priority on research related to white abalone habitat and population assessment; captive breeding and stock enhancement; and overall recovery of this ESA-listed species in collaboration with various outside agencies including the US Navy, CICESE, and academic partners in the US and Mexico. This emphasis is in-part due to the selection of white abalone as one of eight Species in the Spotlight.

[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).

Research themes

OVERVIEW OF OF RESEARCH THEMES
* Use of ROVs and sonars to map habitats and count white abalone in deep water
* Modification and design/construction of ROV technology
* Using new multibeam sonars (e.g., M3)

Research theme 1 - Monitoring wild white abalone populations

Of the critical actions idenfitied in the Recovery Plan, two have been research foci at the SWFSC 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), with the highest observed densities presently between 30 and 60 m (Butler *et al.*, 2006; Stierhoff *et al.*, 2012). 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 multibeam sonars, have been 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 1**). 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, 2012, 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 historically greatest (Hobday and Tegner, 2000; Hobday *et al.*, 2001).

Table 1. A summary of remotely operated vehicle survey effort and white abalone observations by site and year.

Survey site	Dives	Counts	Years
Tanner Bank	138	361	2000, 2002, 2004, 2006, 2008, 2010, 2014
San Clemente Island	119	12	2000, 2004, 2007, 2012, 2016
Santa Catalina Island	37	2	2000, 2005, 2008, 2016
Cortes Bank	33	-	2003, 2014
Palos Verdes	20	3	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.*, 2012). 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 singletons (i.e., solitary, reproductively isolated individuals with > 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. A subsequent survey at San Clemente Island in 2015 observed only two white abalone in 36 transects (Neuman *et al.*, 2017). The low numbers of observations resulted in estimates of population size that are too imprecise for statistical comparisons to results from the 2004 or 2012 survey. If population trends are to be detected in extremely low-density areas like San Clemente Island, increased survey effort, improved survey design (perhaps through the development of predictive models that better identify potential white abalone habitat), or both will be necessary.

Support for these field studies has come primarily from discretionary internal funding sources; the timing and amount of those funds were often unpredictable and often only funded a small number of vessel days to conduct field surveys. More recently, the SWFSC and WCRO received additional funding from the US Navy to support, among other things, ROV surveys at San Clemente Island. In 2016, NOAA entered into a long-term Memorandum of Understanding with the US Navy to further support a variety of white abalone research activities at Tanner Bank, Cortes Bank, and San Clemente Island (see **Funding Sources** section below). These two additional sources of funding will provide substantially more funding for conducting field monitoring on a predictable schedule, which will hopefully reduce uncertainty in population estimates and increase the likelihood of detecting increases or further declines in wild white abalone populations at these priority areas.

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 1**). 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 of the US-Mexico Border to Punta Abreojos, Baja California, Mexico. In 2006, ROV surveys of supposed white abalone habitats were conducted in cooperation with fishery managers and members of the local fishing coopertives (or cooperativos) around the Coronado Islands (n = 6 transects), off Punta San Jose (near Ensenada; n = 17 transects)) and around Isla Natividad (n = 17 transects). Zero white abalone were observed during those transects and questions remain about whether scientists were actually directed to likely white abalone habitat. Following the First Binational Abalone Symposium hosted by CICESE in Ensenada, Baja California in 2016, renewed cooperation and enthusiasm emerged around common areas of interest and objectives toward white abalone recovery. To seize this opportunity, US (SWFSC and WCRO) and Mexican (CICESE, COBI) scientists and cooperativo fishermen sought funding to support additional studies of white abalone habitats along the mainland Baja California coast, Guadalupe Island, or both (to be determined following additional discussion with Mexican colleagues and fishermen). In 2017, funding was received from the NMFS Office of Scientific and Technology International Research Program and the NMFS Office of Protected Resources ($85K total) to conduct new surveys in high-probability white abalone habitats to provide critical information on the status of white abalone populations in Mexico. The goals of that research is to 1) better understand the current status of white abalone in Mexico; 2) identify habitat features that may promote white abalone growth and survival; 3) examine the genetic diversity of populations rangewide; and 4) build our capacity to share methods and data (e.g., ROV, SCUBA, multibeam sonar mapping, environmental sensor deployment, non-invasive tissue collection) with our Mexican colleagues.

Research Theme 2 - Improve survey methods using advanced technology

OVERVIEW OF RESEARCH THEME 2

Research foci for Theme 2

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 3 - 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 3

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 Funding

In 2000, soon after white abalone were listed as endangered under the ESA, the SWFSC received ~$200K to purchase an ROV (*Phantom* 2+2, Deep Ocean Engineering) for surveying deep-water white abalone populations throughout southern CA. Since then, the SWFSC has mostly relied upon the 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 discretionary funds and, therefore, the frequency and amount of funding were variable (between $15K-$80K per year) and unpredictable, and in some years no funding was received (**Table 2**). 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.

Table 2. Discretionary funding provided to the SWFSC by the WCRO in support of white abalone field monotoring.

Year	Amount
2004	0
2007	30000
2008	50000
2009	30000
2010	80000
2011	20000
2012	0
2013	50000
2014	50000
2015	0
2016	15000

Interagency Agreements

Given the limited amount of funding generally available from internal sources, and the need to focus survey efforts at Tanner Bank, few surveys had been conducted at other historically significant areas, particularly San Clemente Island (SCI). In 2012, the SWFSC and WCRO entered into a military interdepartmental purchase request (MIPR) 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 3**). 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 3. 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.

Competitive NOAA Funding

In 2017, the SWFSC, WCRO, and RC received funding from the Office of Science and Technology's International Science Program ($35K) to conduct a 10-d survey of white abalone and their habitats along the Pacific coast of Baja California, Mexico in collaboration with international colleagues from the Centro de Investigacion Científica y de Educación Superior de Ensenada (CICESE), the Comunidad and Biodiversidad (COBI), and local fishing cooperativos (to ensure industry support and participation). Additional funds ($50K) were provided by the NOAA's Office of Protected Resources to complete the work. Nearly half of the white abalone's historic range lies in Mexican waters. This project aims to use ROVs, multibeam acoustics, and SCUBA to collect critical information on the demography, spatial ecology, and genetics of white abalone populations in Mexico, which have gone largely unstudied since being ESA-listed in 2001.

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

Since most funding is received on a fiscal year (FY) schedule, planning is described on a FY calendar.

FY2018

FY2019

FY2020

FY2021

FY2022

Personnel

SWFSC Staff

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

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

Amanda Bird and Adam Obaza (Paua Research Group), William Hagy and Ronan Gray ()

Appendices

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