# A Decade of Scuba Effort Reevaluates Approach for Surveying White Abalone (Haliotis sorenseni Bartsch, 1940)

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Source: Journal of Shellfish Research, 42(1) : 105-112

Published By: National Shellfisheries Association

URL: https://doi.org/10.2983/035.042.0111

*Journal of Shellfish Research*, Vol. 42, No. 1, 105–112, 2023.

# A DECADE OF SCUBA EFFORT REEVALUATES APPROACH FOR SURVEYING WHITE ABALONE (*HALIOTIS SORENSENI* BARTSCH, 1940)

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***ABSTRACT*** Accurate distribution and density data of endangered marine species may be complicated by artifacts from exploitation, survey design, and general difficulty in accessing subtidal habitats. Occasional review of survey data may help restructure survey efforts to improve conservation outcomes. The white abalone (*Haliotis sorenseni*) is a marine gastropod listed under the Endangered Species Act thought to primarily inhabit depths beyond conventional scientific SCUBA limits (30–60 m) in the southern California Channel Islands. This study reviews surveys at four Channel Islands and four locations along the southern California mainland coast within SCUBA depth ranges and conducts a simulation comparison of the larger survey design used for this study with the standard transect approach presently common in the region. White abalone density was greater along the mainland, particularly in Point Loma and La Jolla, than the Channel Islands, where no live white abalone were recorded. The larger survey approach was found to be more effective at finding simulated white abalone, beyond the expected difference in areal coverage alone. These results show that surveys within SCUBA limits are an effective way to monitor *H. sorenseni* and that impacts from overfishing on the Channel Islands may make sections of the mainland coast one of the last refuges of white abalone. The greater efficiency of larger surveys can complement standard transect approaches to improve abalone monitoring at sites of interest. Both results can be applied to the immediate conservation of white abalone by improving site selection and monitoring approaches to active restoration efforts.

***KEY WORDS:*** Abalone, survey, SCUBA, habitat

## INTRODUCTION

Among the most important objectives in conservation of a depleted species is to identify locations of remaining individuals. These data provide myriad information and are often used in estimating population dynamics (Roberts et al. 2016, Kindsvater et al. 2018) and habitat utilization data, which are subsequently used to quantify the impact of continued stressors and craft appropriate management actions. Given the continued declines in many at-risk species populations worldwide (Ceballos et al. 2015), it is no surprise that the literature is replete with modeling exercises for data-poor species (Holmes 2001, Guisan et al. 2006). Yet, an underlying assumption in many of these survey models is a solid understanding of historic distribution to guide site selection. This assumption is often violated, particularly in marine organisms (Stirling et al. 2016). In these cases of insufficient baseline data, designing successful monitoring programs may be challenging (Harvey & Harvey 2009). Therefore, assumptions regarding habitat utilization and survey approach should be reevaluated as additional data are generated (Monsarrat et al. 2019).

White abalone (*Haliotis sorenseni* Bartsch, 1940) briefly supported a commercial fishery in the USA from 1969 to 1978, when 263 metric tons were landed in California. Prior to 1969, the species may have been harvested but landings data do not discriminate white from the presumably more abundant and heavily harvested pink abalone, *Haliotis corrugata*. By the mid-1980 s, landings declined to near zero and the commercial fishery was closed in 1997 (Hobday et al. 2001). The white abalone fishery in Mexico apparently collapsed in the 1960 s (Shepherd et al. 1998). A status review concluded that the population was reduced due to overharvesting during the 1970 s and that remnant populations showed no sign of recovery following the closure of the fishery (Hobday & Tegner 2000). As a result, in 2001, the National Marine Fisheries Service (NMFS) made white abalone the first marine invertebrate to be listed as endangered throughout its range under the Endangered Species Act (ESA; NMFS 2001).

In 2008, NMFS released a recovery plan that includes, among five other major actions, monitoring of remaining populations as a critical step to restore the species to self-sustaining levels (NMFS 2008). Most survey operations have taken place using submersibles or remotely operated vehicles (ROVs) in deeper waters (30–60 m) at offshore islands and seamounts (Davis et al. 1998, Butler et al. 2006; Table 1). Given that much of the present literature suggests white abalone are more frequently encountered in deeper waters (Hobday et al. 2001, Lafferty et al. 2004) and fishery-dependent data indicate offshore regions produced more catch (Hobday & Tegner 2000), targeting these areas makes sense. Although, historic literature shows that white abalone were found as shallow as 20 m (Cox 1960) and along the mainland coast (Rogers-Bennett et al. 2002). Therefore, it is possible a large swath of white abalone habitat within conventional scientific diving limits (depths ≤30 m) along the mainland coast is not being adequately surveyed.

Along with survey location, it is possible that commonly implemented ("standard") survey designs are ill-suited to record rare species (Smith 2006, Chapman & Underwood 2008). Fishery-independent surveys of invertebrates are often accomplished with SCUBA or ROV, each of which are resource-intensive and designed to assess broad trends across many species [Yoklavich 2005, California Ocean Science Trust and California Department of Fish and Wildlife (CDFW) 2013].

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DOI: 10.2983/035.042.0111

TABLE 1.

**White abalone surveys, including the present study, conducted along mainland California, the Channel Islands and offshore banks listed by year surveys were undertaken including literature reference, total area surveyed, density of white abalone observed, and survey method [remotely operated vehicle (ROV) or SCUBA].**

| Year | Study | Region | Survey area ($m^2$) | Density (white abalone/$m^2$) | Method |
|---|---|---|---|---|---|
| 1996 | Davis et al. (1996) | Channel Islands | 30,600 | 0.000098 | SCUBA |
| 1998 | Davis et al. (1998) | Channel Islands | 77,050 | 0.000117 | ROV |
| 1999 | Hobday et al. (2001) | Anacapa Island | 127,000 | 0.000089 | ROV |
| 1999 | Hobday et al. (2001) | Catalina Island | 863,000 | 0.000081 | ROV |
| 1999 | Hobday et al. (2001) | San Clemente Island | 250,400 | 0.000094 | ROV |
| 1999 | Hobday et al. (2001) | Santa Cruz Island | 337,000 | 0.000050 | ROV |
| 1999 | Hobday et al. (2001) | Tanner Bank | 154,100 | 0.000081 | ROV |
| 2002 | Butler et al. (2006) | Tanner Bank | 108,000 | 0.001300 | ROV |
| 2003 | Butler et al. (2006) | Cortes Bank | 48,000 | 0.000800 | ROV |
| 2004 | Butler et al. (2006) | San Clemente Island | 39,000 | 0.000150 | ROV |
| 2004 | Butler et al. (2006) | Tanner Bank | 65,000 | 0.000610 | ROV |
| 2008 | Stierhoff et al. (2012) | Tanner Bank | 71,700 | 0.000990 | ROV |
| 2010 | Stierhoff et al. (2012) | Tanner Bank | 77,500 | 0.000503 | ROV |
| 2012 | Stierhoff et al. (2014) | San Clemente Island | 59,000 | 0.000085 | ROV |
| 2010–2015 | Present study | La Jolla | 15,232 | 0.000853 | SCUBA |
| 2010–2015 | Present study | Palos Verdes | 40,800 | 0.000074 | SCUBA |
| 2010–2015 | Present study | Point Loma | 13,092 | 0.000382 | SCUBA |

Rare marine species, such as white abalone, may have unique habitat preferences not yet discerned that might be frequently missed with low spatial coverage inherent to standard marine surveys (Pante et al. 2006, McGarvey et al. 2010). The combination of limited survey area and possibility of unique habitat preferences may lead to undersampling white abalone. Comparison of standard with alternate survey approaches, which cover larger areas, would quantify differences among approaches in the likelihood of encountering white abalone. Although evaluation of differences in survey approaches would not change the resource intensiveness of monitoring in marine habitats, it would better quantify differences across approaches that may inform conservation planning.

First, multiple years of SCUBA surveys along the mainland coast of California and several Channel Islands were evaluated to examine the distribution of remnant wild white abalone in the Southern California Bight. Second, these survey data were used to determine whether an alternate approach to surveys, focused on increased spatial coverage, may add value for white abalone conservation. This assessment was made by simulating differences among one of the most common invertebrate survey methods used in the region with the large-scale approach implemented for select SCUBA surveys in this study. If practicable, a SCUBA-driven approach would reduce the resource burden for surveys and the data would complement those from less accessible offshore regions and depths. Beyond increasing the understanding of population dynamics, locating remnant white abalone in more accessible areas would enhance opportunities for collection of wild adult abalone for the established captive breeding program. In addition, it would identify habitat characteristics where white abalone are present that may be useful in selecting locations for outplanting captive-bred juveniles, as is considered necessary for recovery (NMFS 2008).

## MATERIALS AND METHODS

### *Study Locations and Survey Protocols*

Surveys for white abalone were conducted over the course of a decade, from 2010 to 2020, in the Southern California Bight, including five regions along the mainland from Santa Barbara to San Diego County and four Channel Islands (Fig. 1). This area encompasses a large portion of the historic range of white abalone along the west coast of the United States. Since white abalone are rare, regions were typically not selected at random but targeted potentially suitable white abalone habitat; regions were identified *a priori* using a combination of historic white abalone fisheries landings data (Fig. 2), appropriate depth range for conducting conventional SCUBA surveys (≤30 m) and, in some cases, available data on suitable habitat characteristics and presence of other abalone species that occupy similar habitat (e.g., *Haliotis kamtschatkana*, *rufescens,* and *corrugata*). Once within a survey region, final sites were selected based on surface and bottom conditions, confirmation of appropriate depth range and habitat features (e.g., low-relief rocky reef and presence of canopy and/or understory macroalgae), and in some cases, an adaptive process incorporating information from prior exploratory dives. Coordinates were collected from the bow of the vessel using a handheld GPS, with as little slack in anchor line as possible, for increased positional accuracy and so that sites (and individual white abalone) could be easily relocated.

Surveys were conducted by several different groups, including both experts in the field of abalone ecology as well as citizen scientists with extensive experience in abalone identification and data collection in southern California subtidal habitats. Survey protocols were developed collaboratively and with guidance from NOAA NMFS and are thus, similar among all groups. Two variations of a standard band transect survey were used,

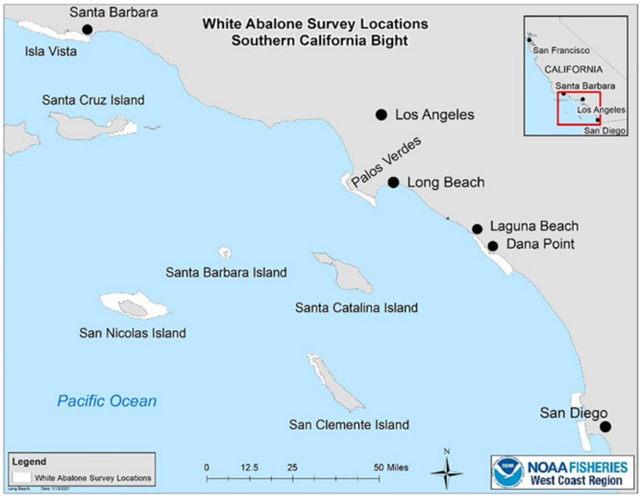


**Figure 1. Spatial depiction of survey areas targeted for this study.**

depending on the number of divers. Both methods involved first deploying a single baseline transect tape from the anchor of a vessel and following a predetermined heading, depth stratum, or suitable habitat features (e.g., reef ledge system). Second, methodical searches were conducted by (1) one-to-two dive teams searching a swath of area to either side of the baseline transect (using a "standard" single-transect approach), or (2) if several dive teams were present, by deploying additional transects perpendicular to the baseline at regular intervals and searching to either side (an "alternate" approach used to increase survey coverage at a site). Divers enumerated all abalone species and measured the size (maximum shell length in millimeters along the longest axis of the shell) of each abalone found on a transect. Smaller abalone (<100-mm shell length) are often cryptic, so divers used lights to search in crevices, moved aside understory macroalgae, and also gently lifted larger rocks when possible. If a white abalone was encountered, its location in the transect area was recorded to the nearest 0.1 m using $x$ and $y$ coordinates and, when practicable, a Pelican buoy was deployed from depth immediately adjacent to the animal so that accurate GPS coordinates could be taken

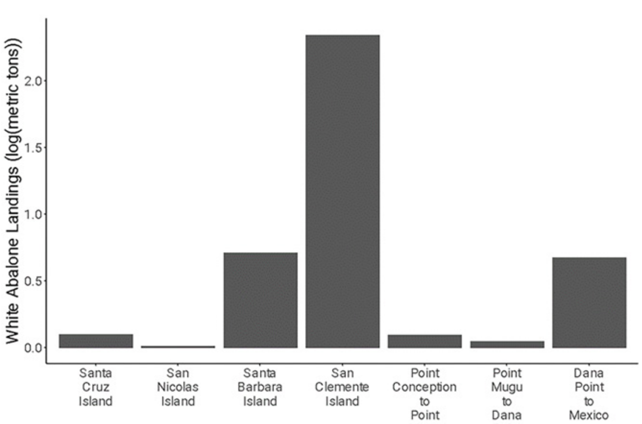


**Figure 2. Cumulative historic white abalone landings by region. Not all regions targeted for white abalone are included in this plot. Data adapted from CDFW (2005).**

from the surface using a handheld GPS. In some cases, the shell was marked with chalk to prevent double counting on adjacent transects. For surveys in the Channel Islands and a subset of those in Point Loma, shells found were collected and brought to the surface for identification, size measurement, and photo documentation. Dive teams also qualitatively evaluated habitat characteristics encountered on transects, though a review of those data are beyond the scope of the present study.

White abalone were also opportunistically recorded during collection for a captive breeding program under the NOAA Invertebrate Enhancement Permit 14344–2R [authority Section 10(a)(1)(A) of the ESA of 1973 (ESA; 16 U.S.C. 1531 et.seq.)]. Because of the rigorous protocol required to select and remove an individual, no collections were made the same day an abalone was identified. Animals collected were either recorded during a previous survey or from tips provided by partner institutions or citizen divers and, therefore, not used in density calculations in the present study. The depth and size of collected abalone were recorded but surveys in the vicinity of this animal during collection were not included as part of this study.

### *Data Analysis*

Live white abalone density (abalone $m^{-2}$) was estimated for each transect surveyed by dividing the number of novel abalone observed by the transect area. The same process was used to calculate density (shells $m^{-2}$) for white abalone shells found on transect. Total area surveyed at each site and for all sites within a region was calculated as the sum of dive team transect areas surveyed. Mean white abalone densities and respective variances were calculated for all sites within a region (e.g., Santa Cruz Island or Point Loma) using individual transects as samples. Mean shell length was calculated for all novel individuals across all sites and regions. If depth was recorded, the total number of white abalone observed was grouped into 10-m depth bins to examine depth distribution for the range of depths surveyed. If a site was surveyed more than once during this study, only data for observations of novel white abalone were included in analysis; in some cases, a novel abalone was distinguished by differences in size and distinct shell fouling community using photographs. Genetic samples were also collected from each animal using the methods from Hamm & Burton (2000) to augment the morphological differences among individuals, though those results are beyond the scope of this study. In the event a repeat individual was located, survey area for the same individual was not included in cumulative survey area. Two sites in Point Loma and one in Palos Verdes were surveyed repeatedly throughout this study and allowed investigators an opportunity to document the cumulative number of novel white abalone encountered and area surveyed for each site over time to determine the amount of effort expended to identify one new individual. All analyses were conducted using R (R Core Team 2018).

Comparisons between the "alternate" survey protocol outlined in this study and standard 2-m band transect surveys (hereafter referred to as *study* and *standard* approaches) commonly implemented in the region were conducted by simulating the position of three abalone in a hypothetical $20 \times 50$-m plot. The likelihood of encountering a simulated abalone on a survey was based on two parameters: (1) area of the site surveyed and

(2) detectability of an abalone. First, the study approach covers the entire site in a single survey with subsequent surveys overlapping the same area, whereas the standard approach includes two band transects, each 2-m wide and 25-m long. That is, each iteration of the study approach covers 1,000 $m^2$ and each iteration of the standard approach 100 $m^2$. Simulated transects for the standard approach started on one side of the site and expanded to the other with additional survey iterations, though transect placement should be irrelevant to this exercise given random positioning of abalone. Second, detectability is defined as the likelihood an animal is encountered if it is present in a surveyed area. For the purpose of this exercise, detectability was estimated based on 11 surveys of a single site in Palos Verdes that recorded three white abalone over the same area. If it is assumed that only three abalone were present on the site, and the final one was recorded on the $10^{th}$ survey, then detectability is 0.3 for a single white abalone and 0.099 for all three. A total of 1,000 simulations of abalone position were conducted and the average encounter for each of the three animals with increasing effort for each survey method was determined. The chance of encountering each abalone was averaged for each effort level over all simulations. The probability of encountering any one of the three abalone was the sum of probabilities of encountering any single abalone and the probability of encountering all three the product of those probabilities. In the event the probability of encountering any single abalone exceeded one, it was assumed that animal would be recorded in all subsequent surveys as specific location data is typically collected for all live white abalone. This exercise assumes no immigration or emigration of white abalone and no movement among surveys, the most commonly observed behavior in large wild adult white abalone.

## RESULTS

Live white abalone density was greatest in the mainland regions of La Jolla and Point Loma, followed by Palos Verdes (Figure 3). Densities (± *SD*) in La Jolla (0.0006 ± 0.0001 white abalone $m^{-2}$) and in Point Loma (0.0005 ± 0.001 white abalone $m^{-2}$; Table 2), translate to one individual every 1,667 $m^2$ in La Jolla and 2,000 $m^2$ in Point Loma. No white abalone were identified during survey efforts at the Channel Islands, despite containing the largest areas assessed for any region. In contrast

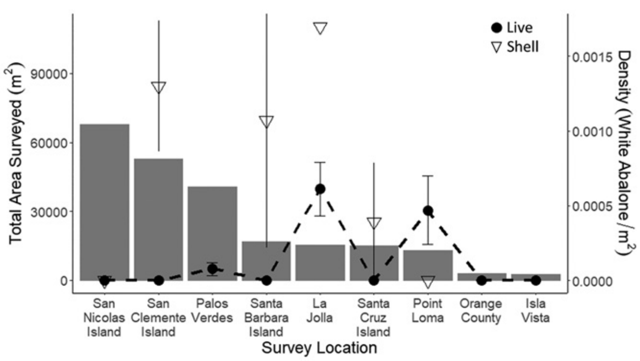


**Figure 3. Survey area (bar), white abalone density for (A) live animals (line and black point) and (B) shells (triangle) for each region included in this study. Error bars are standard error.**

with the live animal results, white abalone shell densities at San Clemente Island, Santa Barbara Island, and Santa Cruz Island were relatively high, particularly when compared with the lack of any live animals recorded during those surveys. Although survey effort across novel habitat did not appear to affect number of animals encountered, repeated surveys of the same site indicate overlapping effort over time may yield records of additional individuals (Fig. 4).

Forty-two white abalone were recorded in this study and that includes individuals collected for broodstock that were reported on nonsurvey dives. Of those recorded, length and depth data were taken for 30 individuals as positioning on reef structure made measurement impossible for some. Length ranged from 136 to 190 mm (mean 164 ± 13.7 mm). Survey depth range was 6.9–31.8 m and mean depth of recorded white abalone was 19.2 ± 5.15 m (Fig. 5). Of particular note was an individual found in 7 m of water on the interior side of the Port of Long Beach breakwater, a highly urbanized waterbody.

The study method was more effective at finding white abalone than the standard method during the simulation exercise (Fig. 6). A maximum of 20 survey iterations were completed in this simulation, representing two and 20 surveys of the entire site for study and standard methods, respectively. One abalone was found within two surveys using the study method, whereas 20 iterations of the standard method never reach a probability greater than one of finding a single abalone. Because a single-recorded abalone is assumed relocated in all subsequent surveys, the study method rapidly approaches a probability of one in finding all abalone (within six surveys), whereas the standard method has a perpetual low probability of locating all three.

## DISCUSSION

White abalone densities within conventional scientific SCUBA limits (≤30 m) recorded in this study are low, particularly when compared with an estimated density required for population viability (Babcock & Keesing 1999), as well as pinto (Bird 2018), green, and pink species also found in southern California (Taniguchi et al. 2013). These results are not surprising, given that they are consistent with the science that led to listing *Haliotis sorenseni* under the federal ESA (NMFS 2001). Of greater interest is comparison among recent surveys, where white abalone densities from standard scientific SCUBA depths in La Jolla from this study were similar to ROV surveys (30–50 m) at Tanner and Cortes Bank (Butler et al. 2006, Stierhoff et al. 2012). Densities recorded in Point Loma, although lower than La Jolla, are comparable with ROV surveys conducted in the Channel Islands (Davis et al. 1996, Butler et al. 2006). No shells were recovered from Point Loma, though this survey area was a minor subset of the overall effort in the region. Surveys at the Channel Islands as part of this study returned zero live white abalone. Yet, the shell data suggest that live white abalone once existed in the region, if not in the immediate vicinity of surveys. Shells, therefore, provide further evidence that white abalone were prevalent within SCUBA depth limits in these formerly prominent regions. When combined with the location-specific data on broodstock collection, the surveys performed for this study show that white abalone densities within standard scientific diving depth range along several mainland regions are comparable with those from deeper, more remote locations.

**TABLE 2.**

**Survey locations and dates surveyed for the present study, including region within the Southern California Bight, total area surveyed, number of live white abalone recorded, and depth range observed among all transects at a site.**

| Survey location | Region | Total area surveyed ($m^2$) | Survey dates | White abalone recorded | Depth range (m) |
|---|---|---|---|---|---|
| Isla Vista | Mainland | 2,625 | 8/19/15 | 0 | 13.5–18.3 |
| La Jolla | Mainland | 15,232 | 9/19/2010–6/14/2017 | 12 | 8.1–29.1 |
| Orange County | Mainland | 3,000 | 10/16/17 | 0 | 16.5 |
| Palos Verdes | Mainland | 40,800 | 2/6/2018–8/28/2019 | 3 | 16.2–24.0 |
| Point Loma | Mainland | 13,092 | 11/14/2010–2/2/2020 | 5 | 15.3–28.5 |
| San Clemente Island | Channel Islands | 52,800 | 10/24/2018–10/28/2018 | 0 | 12.0–30.9 |
| San Nicolas Island | Channel Islands | 67,800 | 10/3/2016–11/3/2016 | 0 | 8.40–27.0 |
| Santa Barbara Island | Channel Islands | 16,644 | 10/3/2018–10/4/2018 | 0 | 15.6–25.5 |
| Santa Cruz Island | Channel Islands | 15,015 | 10/28/2014–11/4/2016 | 0 | 22.5–25.8 |

The implications of this conclusion are substantial. Marine species are often data-poor, and those outside of conventional dive depths require considerable investment to collect data across limited spatial and temporal scales. Accurate and frequent data drive recovery actions for ESA-listed species and awareness that white abalone may be found within diving depths and close to the mainland will greatly enhance conservation efforts. For example, at the time of manuscript preparation, recovery efforts involving outplanting of captive-bred juvenile white abalone, in accordance with the recovery plan, are underway in Palos Verdes and Point Loma. If not for the surveys in this study, outplant activities may have been focused on remote regions, limiting the frequency and magnitude of outplant events and monitoring. Since recovery efforts may need to reach industrial levels of captive production and outplanting to recover the species, conducting effective outplants along the mainland should reduce overall recovery time and cost. The goal of this study is not to label surveys in remote regions or with a ROV beyond dive limits ineffective. On the contrary, surveys along the mainland complement those from less accessible areas that will ultimately better inform recovery actions.

A comparison of historic fishery landings to densities of live white abalone and shells reported in fishery-independent surveys conducted because closure of the fishery in 1997, including the current study, reinforces the conclusions that led to listing under the ESA; densities of remnant individuals are not sufficient to support natural reproduction and there is little evidence of successful recruitment in the wild (NMFS 2008). San Clemente Island received most of the fishing pressure and, despite decades of a fishing ban, white abalone were absent in this study and well below recovery goals of 0.2 emergent individuals/$m^2$ in others (Butler et al. 2006, Stierhoff et al. 2014). Santa Barbara Island exhibits a similar trend and has not recovered from historic fishing pressure. Point Loma and La Jolla, however, fall in a region of similar fishing pressure to Santa Barbara Island, but exhibited the greatest white abalone densities in this study. This disparity may be a result of greater subtidal area in the mainland region as compared with Santa

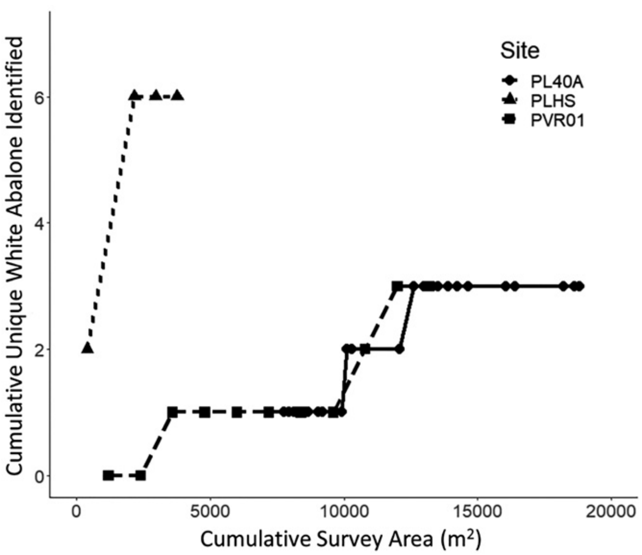


**Figure 4. Cumulative number of white abalone recorded over time on sites visited multiple times. Solid line with circular points represents one site in Point Loma, the shorter dashed line with triangle points a second site in Point Loma, and the longer dashed line with square points a site off Palos Verdes.**

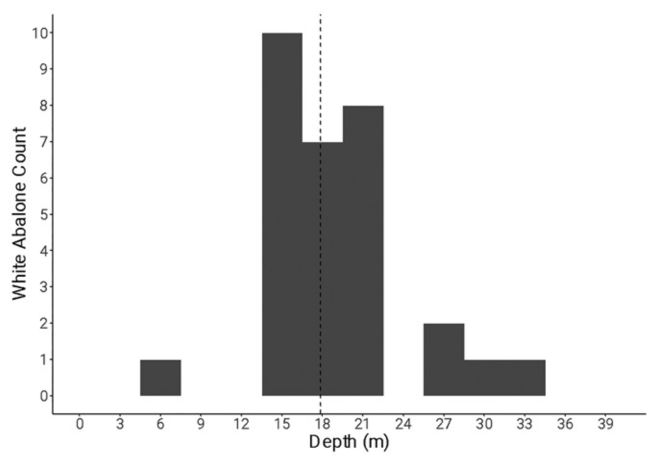


**Figure 5. Histogram of recorded depth (feet) for 27 white abalone recorded during surveys or collected for broodstock. Dashed line is median recorded depth in meters.**

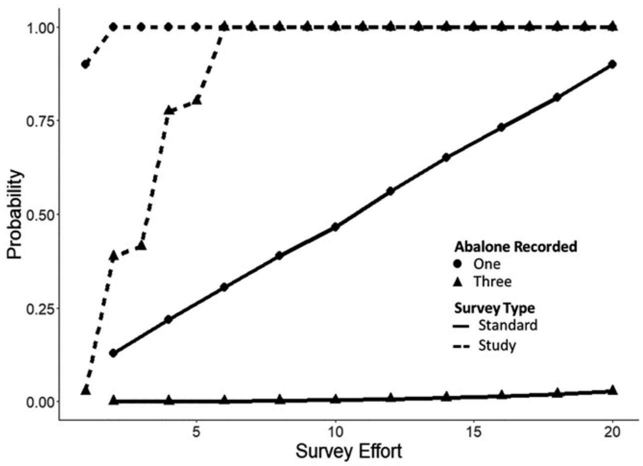


**Figure 6. Plot of probability in detecting one or three white abalone in a simulated 20 × 50-m survey area using two different survey methodologies.**

Barbara Island, or some other factor that is more difficult to discern, such as differences in abalone density prior to fishing or habitat. Most importantly, white abalone densities have still not recovered from fishing pressure, despite many years of a moratorium. Additional strategies are then required, in this case outplanting, to recover the species.

The additional white abalone recorded during repeat surveys suggest two nonmutually exclusive explanations. White abalone may be more active and immigrate onto a plot over time and white abalone are cryptic, creating the possibility they are occasionally overlooked during surveys. There is acoustic tracking evidence that a subset of wild adult pink (Coates et al. 2013) and pinto abalone are mobile (Neuman et al. 2019), and a mark-recapture study showing red abalone may move >100 m in a month (Ault & DeMartini 1987). In addition to immigration, it is plausible that white abalone may also move throughout a survey site, leading to greater cumulative counts with repeated surveys. The only infallible approach to avoid this issue is to collect genetic samples from each individual to confirm uniqueness. Absent those resources, comparison of size and images of shell fouling community may limit the chances of double counting. Unlike animal movement, which may lead to inflation of counts, overlooking individuals would lower them. White abalone are often positioned on top of rocks (Lafferty et al. 2004) and mean length of remaining populations is approximately 130–140 mm (Stierhoff et al. 2012) or even greater (mean of 164 mm in this study), suggesting that they should be readily visible. Although, abalone of that length are likely to be older (Andrews et al. 2013) and their shells more likely to bear heavy shell fouling causing them to blend in to surrounding reef. Regardless of the cause, the data from this study favor repeated surveys at sites considered likely to contain white abalone, either through recording other individuals, promising habitat features, or both, to better record remaining populations (Refsnider et al. 2011).

If white abalone may be assumed to not readily immigrate and emigrate from a site, this study has shown that large-scale surveys are far more effective. The concept that a greater search area will lead to more effective surveys is not novel, but the addition of detectability and relocation of recorded abalone illustrate the nonlinear benefit of the survey design presented in this study. At two complete surveys of a simulated site, a single white abalone is not expected to be recorded via the standard approach, whereas at least one is expected over two iterations of the study approach. These results have tangible impacts on data from subtidal surveys in the region, as many monitoring groups use 2-m band transects to survey for invertebrates (Gillett et al. 2011, Kushner et al. 2013). This simulation exercise is not intended to discredit these approaches as their goal is to monitor trends in all documented species and not track rare species. This study shows that the survey methods may even be complementary; the study approach can more appropriately survey areas where the standard approach initially identified a white abalone. Data from standard surveys should be viewed as a starting point for documenting white abalone presence, and large-scale efforts the highest standard for collecting data on white abalone.

Greater than expected densities of white abalone located in mainland coastal regions should not be interpreted as a statement on habitat suitability. The story of abalone in Southern California in the past century has been driven by overexploitation (Hobday et al. 2001) and disease (Friedman et al. 2007). Although the surveys reported in this study found no white abalone on San Clemente Island and those conducted with ROVs document dwindling populations (Stierhoff et al. 2014), 80% of the 263 tons of white abalone landed during its fishery was from that region (Hobday & Tegner 2000). Therefore, regions that are presently devoid of white abalone must be considered in context with their history. This study shows that white abalone may be found in regions and depths previously thought unlikely and may be absent from expectedly suitable areas. Resource managers and scientists working on exploited species should approach recovery with soft eyes adept at identifying unexpected distributions to improve conservation outcomes.

## ACKNOWLEDGMENTS

The authors wish to thank the many divers and institutions that participated in white abalone surveys, especially the NOAA Southwest Fishery Science Center, Channel Islands National Marine Sanctuary, Channel Islands National Park, California Department of Fish and Wildlife, The Bay Foundation, Vantuna Research Group, Marissa Charters, Truth Aquatics, Channel Islands Adventures, Scripps Institute of Oceanography, Aquarium of the Pacific, Jim Melrod, Bill Monteleone, Kyle Monteleone, Jeremy Roth, Ian Taniguchi, Jenny Hofmeister, Arjay Rafferty, Shelby Kawana, Athena Maguire, Julia Coates, Cleridy Lennert, Ben Walker, Katie Sowul, Heather Burdick, Tom Ford, Rilee Sanders, Ben Grime, Scott Mau, John Hyde, Ed Parnell, Jonathan Williams, Julie Bursek, Dave Kushner, Daniel Muñoz, Ashley Kidd, Constance Gramlich, Lia Protopapadakis, Steve Murvine, Chris Schmuckal, Bob Cranston, Russ Vetter, Sara Briley, Kurt Schaefer, Chris Waterston, Mark James, Dimitri Deheyn, Ronan Gray, Dennis Darnell, Dave Rudie, and many others. Dave Leighton and Paul Dayton helped advice BH during the early stages of his exploration for white abalone in San Diego, and connected him with Bob Shea, who provided an oral history on the abalone fishery and excellent guidance on areas to survey. Thank you to Rick Morse for creating the map in Figure 1. This manuscript is dedicated to the memory of Barbara Koerschner Hagey, who patiently supported the work conducted for this manuscript.

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