



Black Abalone Monitoring at Channel Islands National Park 2008-2010

Channel Islands National Park report to National Marine Fisheries Service, October 2010

Natural Resource Report NPS/CHIS/NRDS—2012/542



ON THE COVER

Tagged black abalone from Willows Anchorage, Santa Cruz Island
Photograph by: Dan Richards

Black Abalone Monitoring at Channel Islands National Park 2008-2010

*Channel Islands National Park report to National Marine
Fisheries Service, October 2010*

Natural Resource Report NPS/CHIS/NRDS—2012/542

Daniel V. Richards and Stephen G. Whitaker
National Park Service
1901 Spinnaker Drive
Ventura, CA 93001

.

June 2012

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is also available from the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>) or the Mediterranean Coast Network (<http://science.nature.nps.gov/im/units/medn/>) on the Internet.

Please cite this publication as:

Richards, D. V. and S. G. Whitaker. 2012. Black abalone monitoring at Channel Islands National Park 2008-2010: Channel Islands National Park report to National Marine Fisheries, October 2010. Natural Resource Report NPS/CHIS/NRDS—2012/542. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	v
Tables.....	vii
Executive Summary	ix
Acknowledgments.....	xi
List of Acronyms	xii
Introduction.....	1
Methods.....	3
Study Area	3
Monitoring	5
Tagging	6
Results and Discussion	9
2008 Monitoring	14
2009 Monitoring	20
2010 Monitoring	25
Conclusions.....	27
Literature Cited	35
Appendix A Tagged Abalone Records	39

Figures

	Page
Figure 1. Rocky intertidal community monitoring site locations in Channel Islands National Park.	4
Figure 2. a) Temperature logger housing at Willows Anchorage. b) Temperature logger in habitat. Arrow indicates location of housing beneath the boulder in photo.	6
Figure 3. Tagged abalone at Willows Anchorage. Passive Integrated Transponder (PIT) tag embedded in marine epoxy.....	7
Figure 4. Otter Harbor reef with large and small crevice habitat	8
Figure 5. Willows Anchorage intertidal zone. <i>Endocladia muricata</i> is the common red algae. This is the eastern portion of the site with boulders and various crevice and rock-crack micro-habitats	8
Figure 6. a)Temperature profiles for Otter Harbor sunny exposed area of black abalone habitat; b) Temperature profile for Otter Harbor under overhang in abalone crevice habitat..	12
Figure 7. Nearest neighbor distances for black abalone at Otter Harbor and Willows Anchorage, February and June 2010.	14
Figure 8. Nearest neighbor distances for all abalone measured between 2007 and 2010 at Otter harbor and Willows Anchorage.	14
Figure 9. <i>Haliotis cracherodii</i> size distributions in spring 2008. All sites were combined, but not all sites were sampled.	16
Figure 10. <i>Haliotis cracherodii</i> size distributions in summer 2008. All sites were combined, but not all sites were sampled.	17
Figure 11. <i>Haliotis cracherodii</i> size distributions in fall 2008. All sites were combined, but not all sites were sampled.	17
Figure 12. <i>Haliotis cracherodii</i> density and counts for all years at each island.....	23
Figure 13. <i>Haliotis cracherodii</i> size distribution in spring 2009, all sites combined	24
Figure 14. <i>Haliotis cracherodii</i> size distribution in fall 2009, all sites combined.....	24
Figure 15. <i>Haliotis cracherodii</i> size distributions at Santa Cruz Island, February 2010.....	28
Figure 16. <i>Haliotis cracherodii</i> size distributions at Anacapa Island, spring 2010.....	30

Figures (continued)

	Page
Figure 17. <i>Haliotis cracherodii</i> size distributions at Santa Cruz Island, spring 2010	30
Figure 18. <i>Haliotis cracherodii</i> size distributions at San Miguel Island, spring 2010	30
Figure 19. <i>Haliotis cracherodii</i> size distributions at Anacapa Island, fall 2010	31
Figure 20. <i>Haliotis cracherodii</i> size distributions at Santa Cruz Island, fall 2010.....	31
Figure 21. <i>Haliotis cracherodii</i> size distributions at San Miguel Island, fall 2010.....	31
Figure 22. Black abalone double tagged with vinyl number tag and PIT tag.....	32
Figure 23. Juvenile black abalone at Willows Anchorage.....	32
Figure 24. Juvenile red abalone at Willows Anchorage, one of 11 found in June 2010	32
Figure 25. Measuring black abalone at Otter Harbor site. Otter Harbor has abundant crevices providing protection for abalone.....	33
Figure 26. A withered black abalone at Otter Harbor site..	33

Tables

	Page
Table 1. Size distribution of <i>Haliotis cracherodii</i> at Otter Harbor, San Miguel Island.	10
Table 2. Size distribution of <i>Haliotis cracherodii</i> at Willows Anchorage, Santa Cruz Island.....	13
Table 3. <i>Haliotis cracherodii</i> counts from 2008 sampling. Data from sites are combined by island.	16
Table 4. Sea star and <i>Haliotis cracherodii</i> searches in spring 2008.....	18
Table 5. Sea star and <i>Haliotis cracherodii</i> searches in fall 2008.....	19
Table 6. <i>Haliotis cracherodii</i> counts from 2009 sampling.	21
Table 7. Sea star and <i>Haliotis cracherodii</i> searches in spring 2009.....	21
Table 8. Sea star and <i>Haliotis cracherodii</i> searches in fall 2009.....	22
Table 9. <i>Haliotis cracherodii</i> counts from 2010 sampling.	28
Table 10. Sea star and <i>Haliotis cracherodii</i> searches in spring 2010.....	29
Table 11. <i>Haliotis cracherodii</i> searches in fall 2010.....	29

Executive Summary

The black abalone, *Haliotis cracherodii*, is a large herbivorous gastropod that primarily inhabits crevices and undersides of ledges and boulders in the intertidal and shallow subtidal zones of the California Channel Islands and mainland. Once one of the most spatially-dominant organisms in the mid-intertidal zone at the northern islands in Channel Islands National Park (CINP) in the early 1980s, current populations have been depressed to less than one percent of historic black abalone populations. During the late 1980s and 1990s, the southern California black abalone population collapsed due to Withering Syndrome (WS), a disease caused by a Rickettsiales-like bacterium, *Candidatus Xenohaliotis californiensis* that attacks digestive epithelial cells. As a result of the widespread decline in populations, the National Marine Fisheries Service (NMFS) listed black abalone as a federally Endangered Species in February, 2009.

Monitoring data from CINP were used in documenting the population decline of black abalone and have proven useful in determining long-term abundance trends following collapse. CINP monitors twenty-one rocky intertidal sites distributed across the five northern islands off the coast of southern California. The specific monitoring objective for *H. cracherodii* involves determining population dynamics through the use of fixed plots and timed searches and measuring size frequencies. The movements of tagged black abalone have also been studied since 2006. This report summarizes CINP black abalone monitoring and research data between 2008 and 2010.

Black abalone monitoring is conducted using fixed plots and timed searches at 21 monitoring sites at the five Channel Islands by CINP. Relative abundance and size structure data of black abalone are collected at each site one or more times each year. Nearest neighbor distances were gathered as an indication of spawning capability and aggregation propensity. In addition, we have tagged abalone at Willows Anchorage on Santa Cruz Island and Otter Harbor on San Miguel Island with Passive Integrated Transponder (PIT) tags embedded in epoxy on the shell of abalone. The aim of tagging individuals is to gain understanding of growth, survival, and movement.

Results from 2008-fall 2010 are presented in this report. Since 2007, 101 PIT tags were placed at Otter Harbor. Four abalone were double tagged due to tag failures. Tags have been read on 11 occasions at Otter Harbor, including three consecutive days in February 2007. Two tagged abalone were found dead at Otter Harbor during 38 months of monitoring. Since 2006, 103 PIT tags were placed on black abalone at Willows Anchorage. Five abalone were double tagged due to failure of the first PIT tag. Tags were read during 12 monitoring events including one two-day sequence in March, 2007 and a three-day sequence in June, 2010. Three tagged abalone from Willows Anchorage were known to have died.

Nearest neighbor distance measurements indicate that the majority of black abalone occur within 10 cm of another supporting the hypothesis that they aggregate.

We mapped and labeled crevices in 2010 so that we can accurately describe locations of individual and aggregated abalone, allowing tracking of abalone locations. Temperature loggers were installed in 2009 to record the annual variation of temperatures that intertidal abalone are exposed to.

Since 2005 we have documented increasing numbers of juvenile black abalone (from zero to hundreds) at Willows Anchorage, Valley Anchorage, and Orizaba Cove on Santa Cruz Island and Middle Anacapa Island. Additional surveys in 2010 found juvenile black abalone present on other reefs along both north and south sides of Santa Cruz Island. Moderate populations of black abalone were found at San Miguel Island, however the populations at those sites have not been increasing and juvenile black abalone are rare. Black abalone populations at Santa Rosa Island are still below one percent of historic levels and juvenile abalone are rare there as well.

Acknowledgments

In 2009 and 2010, Channel Islands National Park (CINP) received funding from the National Marine Fisheries Service Endangered Species Program to support black abalone studies (NOAA-NMFS-2008-SWR-097, and NOAA-NMFS-2008-SWR-F128). Jacob Elliott worked as a Student Conservation Association (SCA) intern from November 2008 to August 2008 for the intertidal monitoring program, and was rehired as a biological technician from February 2009 to August 2009.

Channel Islands National Marine Sanctuary (CINMS) provided boat time and staff assistance with the intertidal monitoring. We were granted the use of the R/V Shearwater for five days each spring and fall to access sites at both Anacapa and east Santa Cruz Islands. The use of this vessel greatly facilitated scheduling with tides and overall safety at these sites.

Work at Santa Cruz Island was performed in part at the University of California Natural Reserve System, Santa Cruz Island Reserve on property owned and managed by The Nature Conservancy. Thanks to Dr. Lyndal Laughrin and staff at the University of California reserve field station for their assistance. Thanks also to Carol Blanchette and others from the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) Marine Science Institute, University of California, Santa Barbara (UCSB) for their collaboration and assistance.

We are grateful to the many people that assisted with the monitoring. During the 2008 sampling seasons, field assistants included: Jessie Altstatt Santa Barbara Channelkeepers, Tal Ben-Horin UCSB, Carol Blanchette PISCO-UCSB, Jacob Elliott SCA intern, Clair Fackler CINMS, Laura Francis CINMS, Steve Francis CINMS, Christy Hand CINP, Laura Harvey CINP, Luis Hurtado Texas A&M University, Connie Jenkins VIP, Lianne Koczur SCA intern CINP, Kristen Kusic-Heady UCSC, Charlie Lara CINMS, Danielle Lipski CINMS, Haven Livingston UCSC PISCO, Kelly Moore CINP, Mike Moss CINP, Benjamin Pister Cabrillo National Monument, Natalie Senyk CINMS, Terrence Shinn CINMS, Josh Sprague CINP, and Kyle Walters UCSC PISCO.

During the 2009 sampling seasons, field assistants included: Jessie Altstatt, SB Channelkeepers, Kevin Barnes CINP, Carol Blanchette PISCO-UCSB, Cynthia Button NMFS, Rachel Clausing UCLA, Lisa Drake CINP, Jacob Elliott SCA intern, Laura Francis CINMS, Reg Greenwood CINMS, Nick Griesse CINP, Christy Hand CINP, Melissa Hayashida SCA intern, Connie Jenkins volunteer, Charlie Lara CINMS, Danielle Lipski CINMS, Ken Niessen volunteer, Benjamin Pister Cabrillo National Monument, and Terrence Shinn CINMS.

During the 2010 sampling seasons, field assistants included: Jessie Altstatt volunteer, Jacob Elliott CINP, Connie Jenkins volunteer, David Kushner CINP, Charlie Lara CINMS, Danielle Lipski CINMS, Kelly Moore NPS, Mathew Nelson volunteer, Terrence Shinn CINMS, Ann Vileisis volunteer, and Susan Wang NMFS.

List of Acronyms

Acronym	Description
ANI	Anacapa Island
CDFG	California Department of Fish and Game
CINP	Channel Islands National Park
CINMS	Channel Islands National Marine Sanctuary
ENSO	El Niño Southern Oscillation
MARINe	Multi-Agency Rocky Intertidal Network
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
PISCO	Partnership for Interdisciplinary Studies of Coastal Oceans
PIT	Passive Integrated Transponder
SCA	Student Conservation Association
SBI	Santa Barbara Island
SCI	Santa Cruz Island
SMCA	State Marine Conservation Area
SMI	San Miguel Island
SMR	State Marine Reserve
SRI	Santa Rosa Island
TNC	The Nature Conservancy
UCLA	University of California Los Angeles
UCSB	University of California Santa Barbara
UCSC	University of California Santa Cruz
WS	Withering Syndrome

Introduction

The black abalone, *Haliotis cracherodii*, is one of seven species of abalone found along the California coastline. It primarily inhabits crevices and undersides of ledges and boulders in the intertidal and shallow subtidal zones. *H. cracherodii* is capable of growing to approximately 200 mm (measured as maximum shell length), but is typically 100-140 mm. All species of abalone are broadcast spawners and undergo a pelagic larval phase. Larvae are generally thought to spend a relatively short time in the plankton and drift card (Chambers 2005) and molecular studies (Hamm and Burton 2000 and Chambers et al. 2006) indicate low dispersal. Two to four years following settlement, mature black abalone emerge from the undersides of boulders and utilize open crevices to feed on drift kelp and other seaweeds (VanBlaricom et al. 2009). Long-lived and slow growing, black abalone are capable of occupying extensive area and constituting a large portion of the consumer biomass in the rocky intertidal zone.

Black abalone were one of the most spatially-dominant organisms in the mid-intertidal zone at the northern islands in Channel Islands National Park (CINP) in the early 1980s (Richards and Davis 1993). Currently in southern California, less than one percent of historic black abalone populations remain (VanBlaricom et al. 2009). During the late 1980s and 1990s, the southern California black abalone population collapsed due to Withering Syndrome (WS), a disease caused by a Rickettsiales-like bacterium, *Candidatus Xenohaliotis californiensis* that attacks digestive epithelial cells (Gardner et al. 1995; Friedman et al. 1997; Friedman et al. 2000; Friedman et al. 2002, VanBlaricom et al. 2009). Mortality commonly occurs as abalone fail to absorb nutrients, undergo pedal atrophy and consequently lose the ability to adhere to rocky substrata (Haaker et al. 1992).

In response to the population collapse, the State of California prohibited harvest of black abalone in 1993. In 1999, the National Marine Fisheries Service (NMFS) added *H. cracherodii* to the list of Candidate Species (NMFS; 64 FR 33466) to be considered for protection under the Federal Endangered Species Act (VanBlaricom et al. 2009). Black abalone officially became listed as a federally Endangered Species in February, 2009 following the formal status review determination that extinction in the next 30 years is likely (VanBlaricom et al. 2009).

Monitoring data from CINP were used in documenting the population decline of black abalone and have proven useful in determining long-term abundance trends following collapse. CINP monitors twenty-one rocky intertidal sites distributed across the five northern islands off the coast of southern California. The specific monitoring objective for *H. cracherodii* is to determine population size structure and abundance through the use of fixed plots and timed searches and measuring size frequencies. The movements of tagged black abalone have also been studied since 2006. The purpose of this report is to summarize CINP black abalone monitoring and research data between 2008 and 2010.

Monitoring data from the Mediterranean Coast Network (MEDN), Inventory and Monitoring Program's (I&M) rocky intertidal program at CINP were used in documenting the population decline of black abalone and have proven useful in determining long-term abundance trends following collapse. Through the MEDN, we monitor twenty-one rocky intertidal sites distributed across the five northern islands off the coast of southern California. The specific monitoring objective for *H. cracherodii* is to determine population size structure and abundance through the

use of fixed plots and timed searches and measuring size frequencies. The movements of tagged black abalone have also been studied since 2006. The purpose of this report is to summarize CINP black abalone monitoring and research data collected between 2008 and 2010.

Methods

Study Area

The five park islands encompass approximately 323 kilometers (176 miles) of coastline, the majority (approximately 80%) of which is rocky shore (Figure 1). Rock types vary from hard, weathered volcanic-basalt or breccias to easily eroded Monterey shale and sandstone. Rocky intertidal monitoring sites (21 total) were originally established to include the various exposures and rock types of each of the islands, though broad rocky benches were targeted (Richards and Davis 1988).

The park islands span the transition zone between cooler waters of the Oregonian biogeographic province and the warmer Californian waters from the south. Mean annual air temperature along the mainland in this area is 15°C. Mean rainfall is about 38 cm per year (Daily et al. 1993). There is a climatic gradient across the island chain with San Miguel Island having the most precipitation, cloud cover and wind. Santa Barbara Island to the southeast is the warmest and driest. The mean monthly sea temperatures range from 13°C in April at San Miguel Island to nearly 20°C at Santa Barbara Island in August and September (Engle and Richards 2001). Swell varies throughout the year with winter storms bringing high northwest wind and waves during the winter and spring, and distant southern hemisphere storms sending large swells to the south-facing shores in summer.

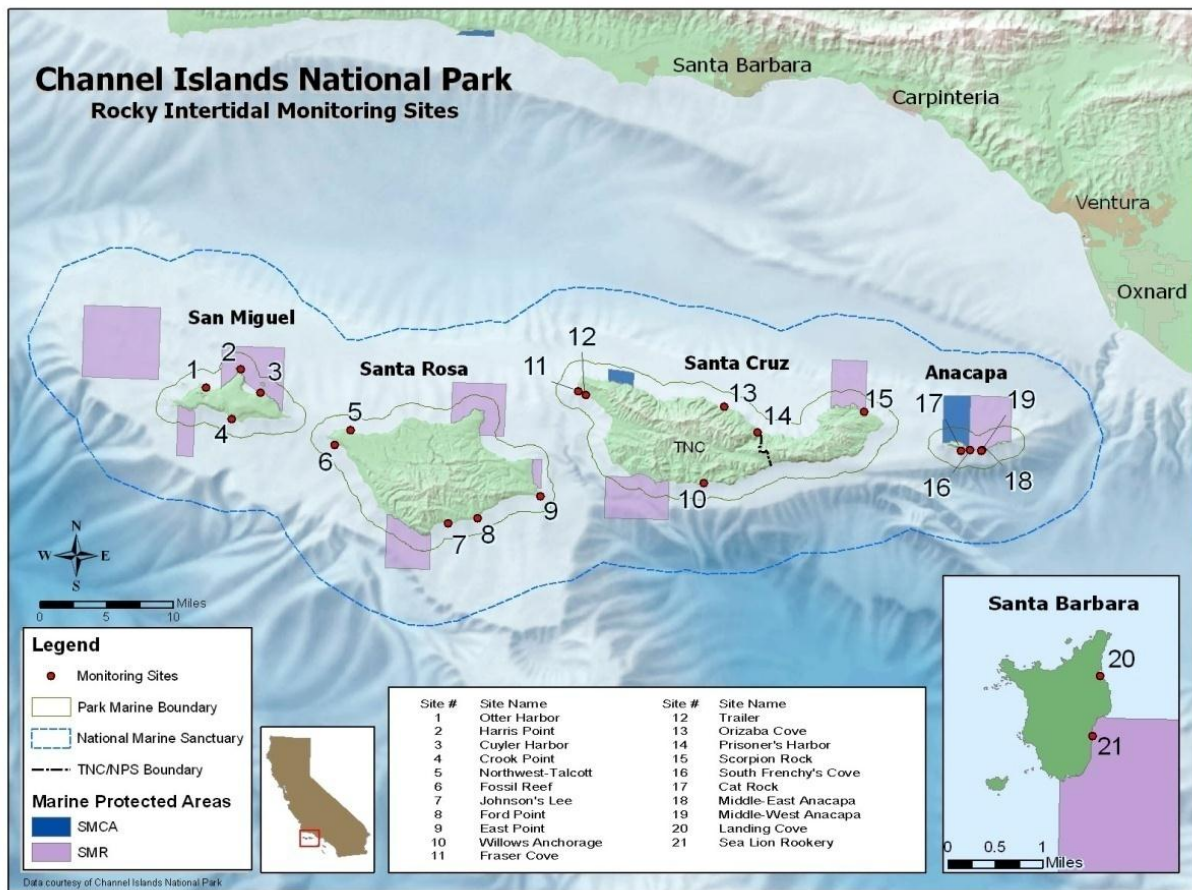


Figure 1. Rocky intertidal community monitoring site locations in Channel Islands National Park. Note: TNC= The Nature Conservancy, SMCA= State Marine Conservation Area, SMR= State Marine Reserve, Sites 18 and 19 are on adjacent reefs.

Monitoring

The CINP Rocky Intertidal Monitoring Program began in 1982. Abalone monitoring was added to the protocol when the program was expanded beyond Anacapa Island in 1985. Twenty-one sites were established on the five Park islands between 1982 and 1994 (Figure 1). Monitoring at each site generally consists of an array of 15-35 fixed photoplots to monitor sessile invertebrates (e.g. mussels, and barnacles) and dominant algae (e.g. rockweed and *Endocladia*); 1-5 irregular plots to monitor *H. cracherodii* and 3-5 circular plots for giant owl limpet, *Lottia gigantea*, densities; and timed counts for seastars and black abalone. Sampling is usually conducted twice each year; once in spring (March-June) and fall (September-January). Occasional abalone samples are taken in summer (late June-August) or winter (February). Monitoring protocols detailed in Richards and Davis (1988) and Engle *et al.* (1998) have been followed. Updated protocol summaries can be found in Richards and Lerma (2000) and Richards *et al.* (2010). All sites may not be visited each season due to unsafe conditions, logistical difficulties, or the presence of nesting seabirds or breeding pinnipeds. Field work is conducted during daytime low tides, generally with minus tides (below mean low water).

CINP is a member of the Multi-Agency Rocky Intertidal Network (MARINe) (www.marine.gov); a consortium of governmental and non-governmental organizations that monitor rocky intertidal sites throughout California with a standardized protocol and a shared database (Engle 2008). Data are maintained in Microsoft Access databases and Excel files in the Channel Islands National Park network and the MARINe central database. Annual reports are available on the internet at <http://science.nature.nps.gov/im/units/medn/>.

Relative abundance and size structure data are collected for black abalone at each site by searching a defined area of the reef or by utilizing a timed-interval search. Sites are of variable sizes and the areas are defined by natural breaks in the reef allowing repeated searches of similar area. Timed-searches are typically 30-minutes long. More time is often devoted to searches at sites that have the greatest numbers of abalone (e.g. Otter Harbor, San Miguel Island and Willows Anchorage, Santa Cruz Island). These protocols were implemented in response to abalone population levels declining. Prior to the effects of WS, black abalone were counted and measured in fixed-irregular plots (5 plots per site) at 11 sites. Fixed plots were used when abalone were abundant, often too numerous to count and measure over the whole reef. However, the fixed-plots became inadequate for sampling by the early 1990s as abalone disappeared. Fixed-plots are still checked for comparison to early samples but abalone are rarely encountered in the plots.

During the timed or defined-area searches, typically one observer searches for abalone by carefully inspecting crevices and cavities among boulders, and checking under kelp or other canopy-forming seaweeds. Abalone are identified to species, shell lengths are measured with vernier calipers or estimated if an accurate measurement is not possible, and the nearest neighbor distance is recorded using five spatially-descriptive categories (touching, < 10 cm, 10-100 cm, 1-5 m, >5 m). Aggregation sizes (number of abalone within one meter of another) are generally noted as well. Shell size serves as a proxy for age giving us a picture of the population structure. Nearest neighbor distance and aggregation size give us insight to the theory that abalone aggregate naturally and we hope it serves as an indication of spawning potential, since, as

broadcast spawners, their reproductive options increase with proximity to other abalone. There may be other Allee Effects from aggregation such as an increased ability to capture drift kelp.

To record the daily temperature regime experienced by black abalone, temperature loggers (TidbiTs ® Onset Computer Corporation) were placed in PVC (Polyvinyl Chloride) pipe housings epoxied to rocks (Figure 2a) near the mean low-tide line in black abalone habitat at eight sites (Middle Anacapa West, Willows Anchorage, East Point, Johnson's Lee, Fossil Reef, Northwest Talcott, Crook Point, and Otter Harbor) in 2009. The housings allow limited water exchange that we think will act similar to the abalone's body mass in tempering the extremes of total submersion and exposure to sun and cold nights during low tide. The housings are exposed to air during low tides and are fully submerged during high tide. To approximate the exposure of abalone, housings are placed in shaded crevices (Figure 2b). Loggers record ambient temperatures every 30 minutes and are downloaded every six to 12 months in the field to an Optic Shuttle device and processed with Onset's Boxcar software (Onset Computer Corporation website).

At East Point, the housing and logger became dislodged and have not yet been replaced. At Otter Harbor, two recording stations were established to compare a sun-exposed, open wall and a protected crevice with overhanging rock. The open wall was one of the original abalone fixed plots and the shaded crevice is still well-populated with black abalone. This information may provide insight into abalone habitat preferences.

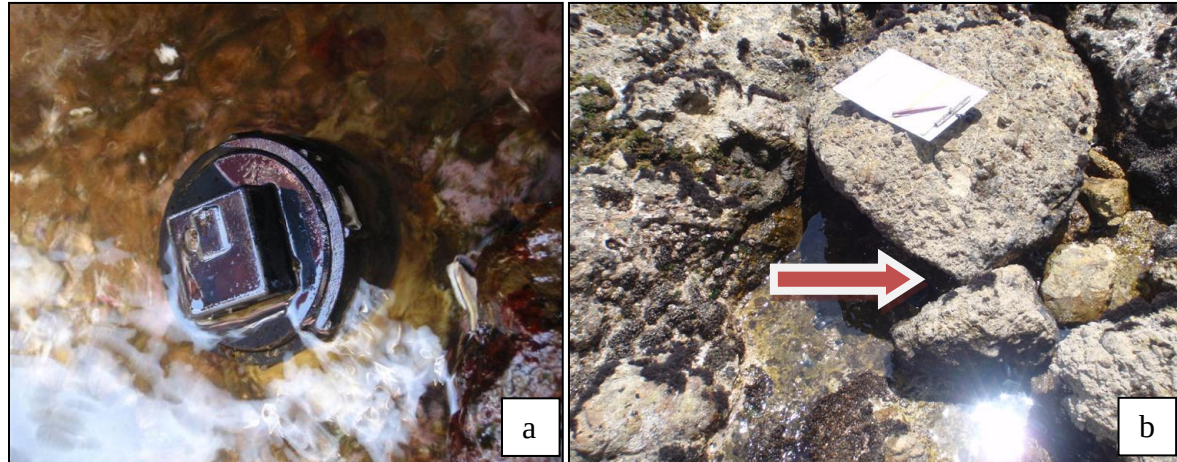


Figure 2. a) Temperature logger housing at Willows Anchorage. b) Temperature logger in habitat. Arrow indicates location of housing beneath the boulder in photo.

Tagging

Tagging is conducted at two sites where black abalone are relatively common. Passive Integrated Transponder (PIT) tags (Biomark TX1400SST) are attached to abalone shells with marine epoxy (Z-Spar Splash Zone Compound, A-788) (Figure 3). When necessary, shells were cleaned briefly with a nylon brush to remove diatom film then rinsed with seawater. Abalone were not removed

from the rock. A small amount of epoxy with the PIT tag embedded was then pressed onto the back of each shell, usually near the whorl. Recently we began applying an additional small piece of epoxy adjacent to the PIT tag with a numbered vinyl fish tag to provide a visual reference for malfunctioning PIT tags. PIT tags are read with a Biomark Pocket Reader waved over the tagged shell, activating the unique numbers associated with the tags.



Figure 3. Tagged abalone at Willows Anchorage. Passive Integrated Transponder (PIT) tag embedded in marine epoxy.

Shell lengths are measured as accurately as possible with vernier calipers while abalone remain attached to the substratum. This method minimizes disturbance to abalone, but often results in reduced accuracy of measurements since individuals located in narrow crevices or against hard surfaces may not provide adequate space to correctly use calipers. Increased confidence in measurements is afforded through multiple estimates of size for individuals that are difficult to access.

Reef areas and crevices were mapped in 2010 with a Trimble Nomad Pro XR GPS. Crevice maps will allow us to identify the specific location of each tagged abalone. General movement patterns between crevices can be determined without the time involved to measure the location of each animal.

Two sites are of particular interest for monitoring *H. cracherodii*. One is Otter Harbor, on the northwest side of San Miguel Island, has consistently had 150-200 *H. cracherodii* observed within the site-area during the last several years, much more than other monitoring sites at the islands. The population of adult abalone at Otter Harbor appears to be relatively stable. Individuals are consistently found in the same crevices. The crevices vary in size and shape from large surge channels to narrow, shallow cracks along the rocky reef (Figure 4). At Otter Harbor, the entire northwest-facing reef is wide (nearly 50 m from water to the low bluff and coastal

terrace) and long and has a shallow-angled slope. A small beach flanks the site on the east and continuous reef exists to the west.

The other site of interest, Willows Anchorage on Santa Cruz Island, only recently received increased numbers of juvenile abalone recruiting to the area. The south-facing reef is a fairly narrow and steep rocky bench flanked by areas of boulders at either end (Figure 5). A sandy beach lies adjacent to the east side of the site and a steep rocky point is located to the west.



Figure 4. Otter Harbor reef with large and small crevice habitat.



Figure 5. Willows Anchorage intertidal zone. *Endocladia muricata* is the common red algae. This is the eastern portion of the site with boulders and various crevice and rock-crack micro-habitats.

Results and Discussion

Since the population decline of black abalone in the late 1980s and early 1990s numbers of abalone have been less than one percent of historic levels at all sites throughout CINP. The number of abalone found on any one reef is typically less than 10, and rarely over 100. Two exceptions have been Otter Harbor, San Miguel Island, and more recently, Willows Anchorage, Santa Cruz Island.

Monitoring black abalone aggregations in fixed plots is no longer practical due to the low densities following the mortalities caused by Withering Syndrome. Fixed plots had been established around abalone aggregations in areas that were accessible. As populations declined, many of these proved to be less desirable habitat than deeper crevices. Reef-wide searches were generally adopted in 1998 for all sites as a means to see a relative picture of the population dynamics with sizes and general abundance. Reef-wide searches are harder to conduct and are difficult to do consistently. Variations in tide level and sea conditions can affect one's ability to search lower intertidal zones and under boulders for instance. Adding the time factor allows us to track the effort somewhat.

At Otter Harbor, thousands of black abalone were present during the mid-1980s, but eventually numbers declined, particularly during El Niño periods in 1992 and 1997 (Richards 1998). With the exception of the occasional lone individual, black abalone disappeared from the fixed plots after 1992. However within the greater area of the site, Otter Harbor has consistently had the largest and most stable population of black abalone during the last 20 years compared to other sites. Between 2007 and 2010, only a very few juvenile abalone (<45 mm) were found. Except for some recruitment in 1999 and 2005, juveniles comprised less than five percent of the population since 1997. Mean sizes varied little (94-107 mm) and over 80% of the abalone were between 45 and 127 mm. (Table 1).

Table 1. Size distribution of *Haliotis cracherodii* at Otter Harbor, San Miguel Island.

Year	Season	Total Count	Count Sized	Mean Size	StDev	Min Size	Max Size	%<45mm	%45-126mm	%127-145mm	%>145mm
1985	spring	529	529	112.63	27.67	15	151	2.84%	58.60%	36.86%	1.70%
1985	fall	544	544	102.92	33.66	15	168	8.82%	62.13%	27.76%	1.29%
1986	spring	459	459	113.48	27.92	25	148	2.83%	53.59%	42.70%	0.87%
1986	fall	493	493	109.09	27.73	14	145	1.42%	63.69%	34.89%	-
1987	spring	461	461	112.36	25.70	42	146	0.22%	60.30%	38.83%	0.65%
1987	fall	490	490	108.99	26.38	25	147	1.22%	67.14%	30.61%	1.02%
1988	spring	427	427	109.52	26.30	30	146	1.17%	63.70%	34.66%	0.47%
1988	fall	458	458	107.08	29.82	11	155	4.15%	63.76%	31.22%	0.87%
1989	spring	416	416	111.94	25.50	23	148	1.68%	61.30%	36.78%	0.24%
1989	fall	426	426	108.70	27.94	20	150	3.52%	62.91%	33.33%	0.23%
1990	spring	418	418	106.59	28.93	23	157	3.59%	65.07%	30.62%	0.72%
1990	fall	366	366	107.72	26.52	25	145	1.91%	68.85%	29.23%	-
1991	spring	239	239	105.07	26.99	31	145	1.67%	74.06%	24.27%	-
1991	fall	123	123	104.87	24.51	35	145	1.63%	81.30%	17.07%	-
1992	spring	83	83	96.92	28.21	24	141	6.02%	81.93%	12.05%	-
1992	fall	45	45	83.73	35.35	15	136	17.78%	75.56%	6.67%	-
1993	spring	17	17	86.47	33.81	39	129	11.76%	70.59%	17.65%	-
1993	fall	14	14	82.29	30.78	40	122	7.14%	92.86%	-	-
1994	spring	13	13	58.77	38.90	20	123	53.85%	46.15%	-	-
1994	fall	48	48	60.42	29.35	19	131	35.42%	60.42%	4.17%	-
1995	spring	27	27	74.00	25.57	25	122	14.81%	85.19%	-	-
1995	fall	22	22	72.73	31.68	30	127	27.27%	68.18%	4.55%	-
1996	spring	2	2	116.00	.00	116	116	-	100.00%	-	-
1997	spring	206	206	88.68	31.58	28	161	5.83%	79.61%	10.68%	3.88%
1997	fall	6	6	72.83	19.70	60	110	-	100.00%	-	-
1998	spring	3	3	78.67	18.72	65	100	-	100.00%	-	-
1998	fall	59	59	75.37	14.63	50	108	-	100.00%	-	-
1999	spring	50	50	73.44	23.02	29	112	16.00%	84.00%	-	-
1999	fall	58	58	79.21	21.25	47	124	-	100.00%	-	-
2000	spring	105	105	80.31	22.85	39	153	2.86%	95.24%	0.95%	0.95%
2000	fall	36	36	90.06	24.65	45	142	-	94.44%	5.56%	-
2001	spring	49	49	84.47	24.99	39	127	4.08%	93.88%	2.04%	-
2001	fall	84	84	89.86	22.21	40	148	1.19%	94.05%	3.57%	1.19%
2002	spring	67	67	91.24	20.42	40	139	1.49%	97.01%	1.49%	-
2002	fall	32	32	103.34	21.83	48	150	-	93.75%	3.13%	3.13%
2003	spring	not sampled	0					-	-	-	-
2003	fall	87	87	97.38	22.77	50	156	-	89.66%	9.20%	1.15%
2004	spring	48	48	102.42	20.17	50	143	-	91.67%	8.33%	-
2005	spring	75	75	91.24	34.72	26	154	18.67%	69.33%	10.67%	1.33%
2005	fall	79	80	83.24	32.55	34	147	8.75%	80.00%	10.00%	1.25%

Table 1 (continued). Size distribution of *Haliotis cracherodii* at Otter Harbor, San Miguel Island.

Year	Season	Total Count	Count Sized	Mean Size	StDev	Min Size	Max Size	%<45mm	%45-126mm	%127-145mm	%>145mm
2006	fall	63	1	60.00		60	60	-	100.00%	-	-
2007	spring	112	112	94.07	26.71	48	188	-	90.18%	7.14%	2.68%
2007	fall	119	120	100.50	23.99	40	162	1.67%	84.17%	8.33%	5.83%
2008	spring	160	160	99.38	23.65	30	162	1.25%	86.88%	6.88%	5.00%
2008	fall	192	192	100.54	24.59	49	163	-	88.02%	7.81%	4.17%
2008	winter	57	57	107.98	21.20	65	150	-	82.46%	14.04%	3.51%
2009	spring	138	138	102.72	24.00	45	185	-	85.51%	10.87%	3.62%
2009	fall	180	41	96.73	28.51	40	151	2.44%	82.93%	9.76%	4.88%
2010	winter	174	174	100.86	25.72	30	162	1.15%	83.33%	11.49%	4.02%
2010	spring	125	81	107.49	27.10	45	163	-	74.07%	14.81%	11.11%
2010	fall	159	159	105.79	25.98	30	165	0.63%	75.47%	16.98%	6.92%

Since 2007, 101 PIT tags have been placed at Otter Harbor (Appendix A). Four abalone were double tagged due to tag failures. Tags were read on 11 occasions at Otter Harbor, including three consecutive days in February 2007. Only two empty tagged shells were found at the site (both abalone had been tagged over a year before the shell was discovered).

We mapped and labeled crevices in 2010 (CINP GIS database). In past surveys we relied on qualitative descriptions of the crevices making it difficult to consistently label the location of each abalone. The new maps will help us accurately describe locations of individual and aggregated abalone. They will also allow better identification of gross movement (from one crevice to another) of tagged abalone.

Temperature loggers were installed at Otter Harbor in 2009. The protected crevice logger was placed just under an overhang and recorded temperatures between 51°F and 69°F, while the fully exposed logger recorded temperatures from 48°F to 67°F between December, 2009 and March, 2010 (Figure 6). Average temperature for the protected logger during this period was 56.8°F and nearly the same for the exposed logger at 56.6°F.

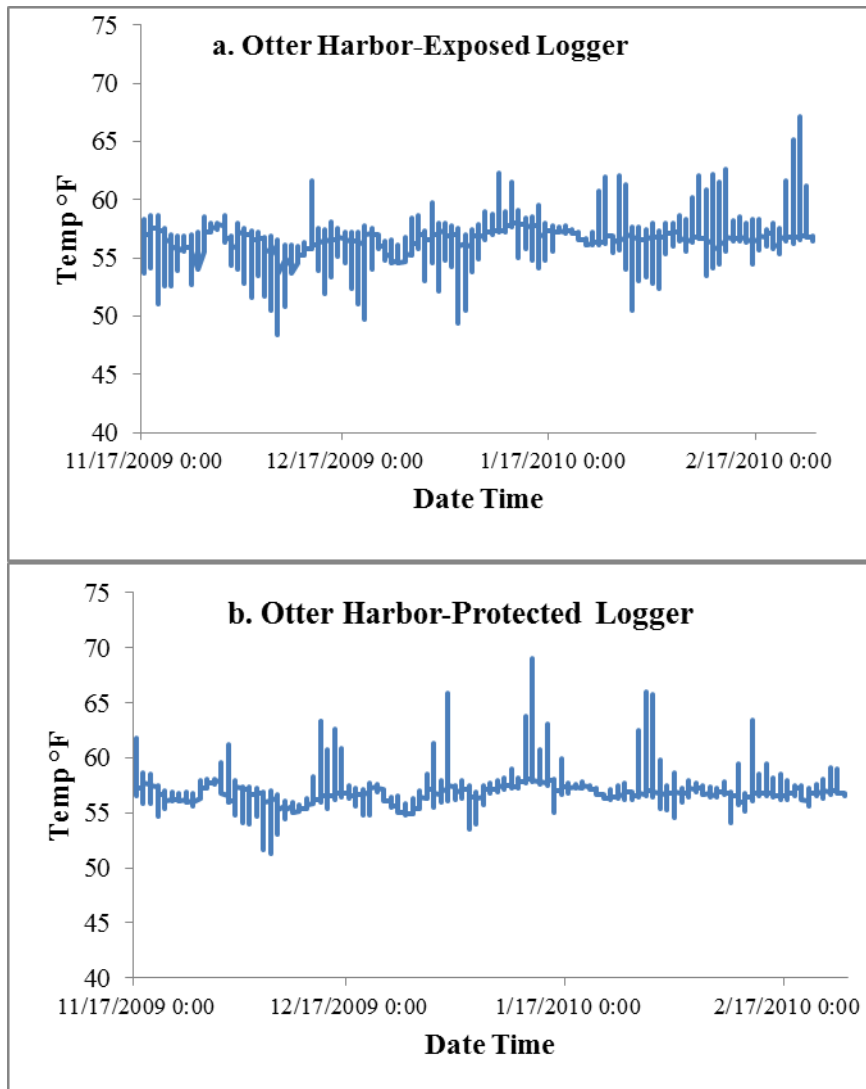


Figure 6. a) Temperature profiles for Otter Harbor sunny exposed area of black abalone habitat; b) Temperature profile for Otter Harbor under overhang in abalone crevice habitat..

Long-term rocky intertidal monitoring began at Willows Anchorage in 1994 following the collapse of the black abalone population in southern California and timed counts were always done there. Until 2005, no young *H. cracherodii* recruits were observed at the site and abalone densities were consistently low at Willows Anchorage. Only nine black abalone were located at the site in 2005. During the last five years, the black abalone population at Willows Anchorage has grown immensely and mean sizes of *H. cracherodii* have decreased markedly due to higher percentages of juveniles than before (Table 2). Increased numbers of juvenile abalone were also seen at other locations on Santa Cruz Island (Valley Anchorage, Scorpion Rock and Orizaba Cove) and Middle West Anacapa Island during the same time period. Significant recruitment was not seen at the other islands.

Table 2. Size distribution of *Haliotis cracherodii* at Willows Anchorage, Santa Cruz Island.

Year	Season	Count	Count Sized	Mean Size	StDev	Min Size	Max Size	%<45mm	%45-126mm	%127-145mm	%>145mm
1999	spring	2	2	91.00	1.41	90	92	-	100.00%	-	-
2000	spring	2	2	76.00	35.36	51	101	-	100.00%	-	-
2000	fall	1	1	66.00		66	66	-	100.00%	-	-
2001	spring	1	1	80.00		80	80	-	100.00%	-	-
2001	fall	1	1	100.00		100	100	-	100.00%	-	-
2002	fall	5	5	75.40	12.84	56	92	-	100.00%	-	-
2003	spring	0	0					-	-	-	-
2003	fall	1	1	90.00		90	90	-	100.00%	-	-
2004	spring	5	5	71.00	22.37	50	105	-	100.00%	-	-
2005	fall	9	9	49.78	16.60	28	82	44.44%	55.56%	-	-
2006	fall	26	26	75.69	20.56	45	112	-	100.00%	-	-
2007	spring	47	47	62.45	16.71	32	101	12.77%	87.23%	-	-
2008	spring	56	56	62.09	20.32	28	120	23.21%	76.79%	-	-
2008	summer	56	46	69.63	18.81	40	111	6.52%	93.48%	-	-
2008	fall	183	182	59.32	20.24	25	116	26.37%	73.63%	-	-
2009	spring	177	177	56.86	19.66	24	140	31.64%	67.23%	1.13%	-
2009	fall	143	58	63.47	21.53	30	134	18.97%	79.31%	1.72%	-
2010	spring	172	172	63.40	17.80	23	163	11.63%	87.79%	-	0.58%
2010	summer	435	435	56.21	23.45	14	163	31.95%	67.82%	-	0.23%
2010	fall	359	289	60.64	20.79	25	127	26.64%	73.01%	0.35%	-

Since 2006, 103 PIT tags were placed on black abalone at Willows Anchorage (Appendix A). Five abalone were double tagged due to failure of the first PIT tag. Tags were read during 12 monitoring events including one two-day sequence in March, 2007 and a three-day sequence in June, 2010. Three tagged, empty shells were found (one shell had a non-functional tag and the individual could not be identified, one was found alive nine months post-tagging and one was found dead two months post-tagging), and at least one (non-tagged) abalone was observed in the clutches of a *Pisaster ochraceus*.

A temperature logger placed at Willows Anchorage revealed a range of 49° to 65°F between November 2009 and June 2010. This logger housing was in a shaded location under the cover of a boulder (Figure 2) Crevices were mapped in 2010 to aid in determining distribution and movement.

Data reflecting the distance-to-nearest neighbor for each observed black abalone indicate that most individuals are located relatively close ($\leq 10\text{cm}$) to each other (Figure 7), and very few were found greater than one-meter away from other abalone which supports the hypothesis that abalone aggregate for spawning or other purposes. Figure 7 shows data from 2010 while Figure 8 displays information from all nearest-neighbor-distance data at each site between 2007 and 2010. Similar distributions exist regardless of location or duration of time sampled. Aggregation size

information has not yet been fully analyzed. Future effort will be spent investigating the relationship between the nearest-neighbor distance and aggregation size data.

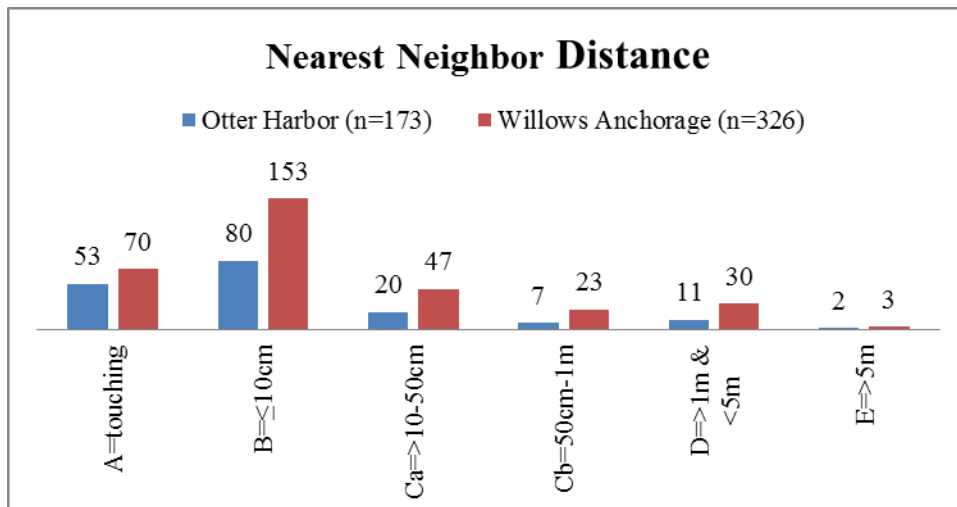


Figure 7. Nearest neighbor distances for black abalone at Otter Harbor and Willows Anchorage, February and June 2010.

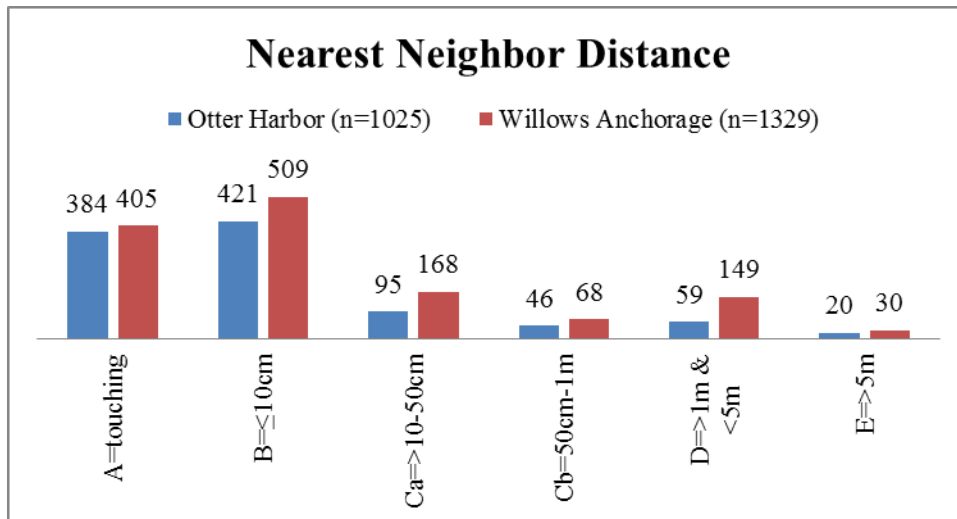


Figure 8. Nearest neighbor distances for all abalone measured between 2007 and 2010 at Otter harbor and Willows Anchorage.

2008 Monitoring

Haliotis cracherodii were found in fixed monitoring plots at Crook Point and Harris Point, San Miguel Island in spring 2008 (Table 3). In fall, two *H. cracherodii* were seen in plots at Crook Point and Ford Point and one individual was in a plot at Harris Point. Abalone were not found

inside any other fixed plots during spring or fall. Less than half the study sites had greater than 10 *H. cracherodii* found during 30-minute searches. No abalone were found at Cuyler Harbor, Northwest-Talcott, Prisoner's Harbor, South Frenchy's Cove, and Sea Lion Rookery during one or both monitoring seasons.

Small *H. cracherodii* (<50 mm) were uncommon at most sites and mean sizes were greater than 80 mm at all islands except Anacapa and Santa Cruz indicating low recruitment overall (Table 3). Size distribution data from all sites combined are presented in Figures 9-11. Note that most of the juveniles were found at Willows Anchorage and Middle Anacapa. The bimodal size distribution of all the abalone measured in spring represents two normally-distributed size classes with modes at 80 mm and 120 mm perhaps indicative of multiple recruitment pulses (Figure 9). Further evidence of heterogeneous recruitment may be the multimodal distribution of *H. cracherodii* measured in summer (Santa Cruz Island only) which had two equivalent modes at 70 mm and 90 mm and a reduced peak at 140 mm (Figure 10). The distribution of abalone measured in fall was slightly skewed towards larger individuals (mode=70 mm) (Figure 11). The largest individual (183 mm) was measured at Johnson's Lee in spring (Figure 9).

The greatest number of *H. cracherodii* was found at Otter Harbor. We counted 175 and 194 individuals in spring and fall, respectively during extended searches of the entire site (Tables 4-5). Willow's Anchorage had the second greatest number of abalone with 184 counted in fall during an extended (3 hr.) count (Table 5). The spring count (n=56) was only for 30 minutes and we only covered the eastern portion of the site (Table 4). In 2008, almost as many black abalone were observed at Willow's as were counted at Otter Harbor. (Note that different levels of effort may be applied at different sites or seasons depending on conditions).

No abalone were found exhibiting symptoms of Withering Syndrome symptoms in 2008.

Table 3. *Haliotis cracherodii* counts from 2008 sampling. Data from sites are combined by island.

Island Code	Year	Season	Count Random	Count InPlots	Count Sized	Mean Size	StDev	Min Size	Max Size
AN	2008	spring	28	0	18	70.22	25.46	37	131
AN	2008	fall	74	0	74	63.19	24.51	22	170
SB	2008	fall	1	0	1	83.00		83	83
SC	2008	spring	84	0	82	71.16	29.59	28	158
SC	2008	summer	122	0	112	74.24	61.28	40	165
SC	2008	fall	272	0	272	54.21	44.59	19	130
SM	2008	spring	215	2	217	101.83	23.07	30	162
SM	2008	fall	215	3	218	99.35	30.71	49	163
SM	2008	winter	57	0	57	107.98	21.20	65	150
SR	2008	spring	23	0	23	126.57	32.94	55	183
SR	2008	fall	38	2	39	111.03	41.20	25	176

CountRandom is the number of abalone from timed searches, CountInPlot is the number of abalone found in fixed plots (not all sites were monitored each season, thus area size is different). Count Sized is the number of abalone actually measured; some abalone under boulders for example may not be measured. AN=Anacapa, SB=Santa Barbara, SC=Santa Cruz, SM=San Miguel, SR=Santa Rosa. Summer SC includes Trailer, Valley Anchorage and Willows Anchorage only. Fall SC includes Valley anchorage and Winter SM includes Otter Harbor only.

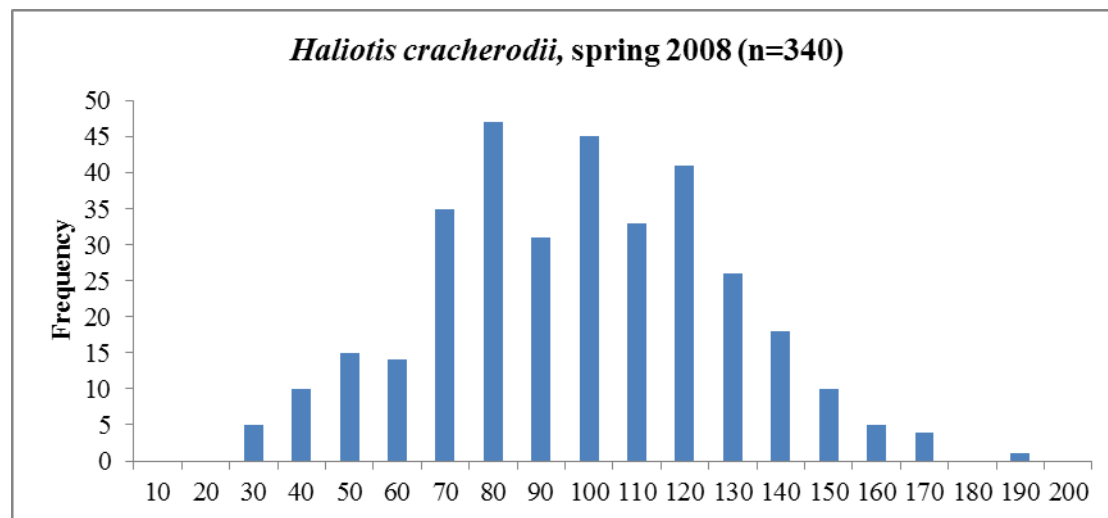


Figure 9. *Haliotis cracherodii* size distributions in spring 2008. All sites were combined, but not all sites were sampled.

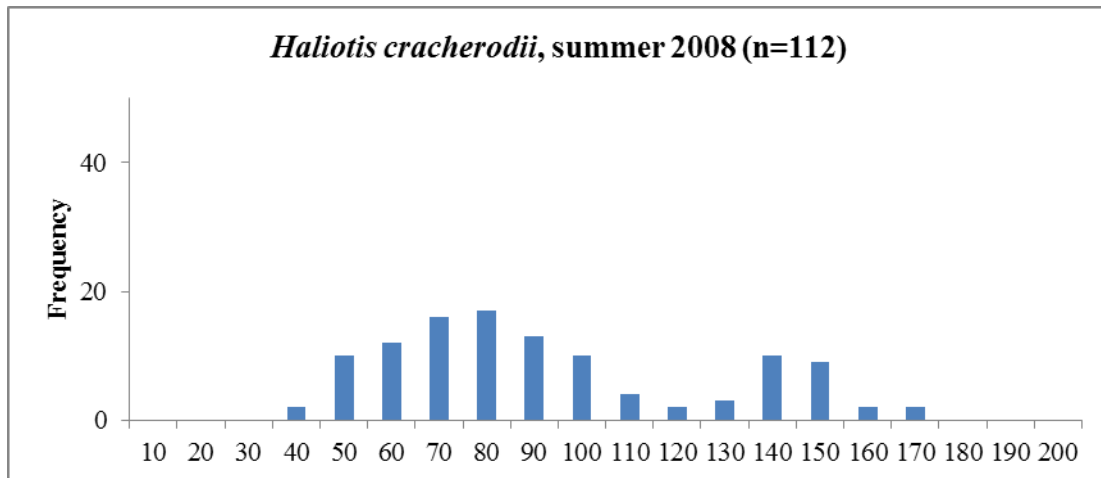


Figure 10. *Haliotis cracherodii* size distributions in summer 2008. All sites were combined, but not all sites were sampled.

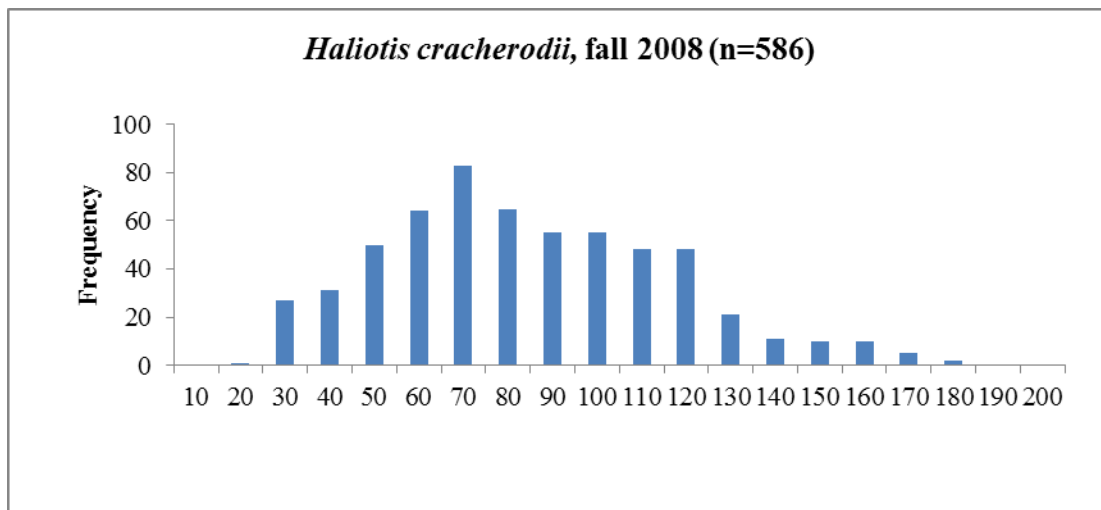


Figure 11. *Haliotis cracherodii* size distributions in fall 2008. All sites were combined, but not all sites were sampled.

Table 4. Sea star and *Haliotis cracherodii* searches in spring 2008.

Site	Sampling Date	Seastars in 30 min	Abalone in plots	Abalone search*
Cuyler Harbor, SMI	5/7/08	190 P.o	x	0
Crook Point, SMI	5/9/08	83 P.o.	1	43
Otter Harbor, SMI	5/10/08	76 P.o., 10 P.g., 2 P.m	0	175
Harris Point, SMI	5/8/08	13 P.o., 3 P.m.	1	13
Fossil Reef, SRI	4/13/08	242 P.o., 2 P.g.	0	4 black, 2 red
Johnson's Lee, SRI	4/9/08	189 P.o.	0	4
Ford Point, SRI	4/12/08	299 P.o.	0	10
Northwest-Talcott, SRI	4/11/08	0 P.o., 8 P.g., 2 P.m	0	1
East Point, SRI	4/10/08	357 P.o., 1 P.b.	x	4
Fraser Cove, SCI	3/20/08	66	x	0
Trailer, SCI	3/19/08	134	x	16
Willows Anchorage, SCI	3/18/08	360	x	56
Scorpion Rock, SCI	3/6/08	207 P.o., 1 P.g., 3 P.m	x	0
Prisoner's Harbor, SCI	3/17/08	154 P.o.	x	2
Orizaba Cove, SCI	3/7/08	nc	x	10
Cat Rock, ANI	3/5/08	15 P.o.	0	3
South Frenchy's Cove, ANI	3/3/08	5 P.o.	x	0
Middle Anacapa-West	3/4/08	616 P.o.	0	25 ₁

*30-minute timed search except at Otter harbor (see text). (x indicates no plot or transect, nc indicates no count performed, P.o.= *Pisaster ochraceus*, P.g.=*P. giganteus*, P.b.= *Pisaster brevispinous*, P.m.= *Patiria miniata*). ₁= Middle Anacapa-West combined with Harbor Seal Arch.

Table 5. Sea star and *Haliotis cracherodii* searches in fall 2008.

Site	Sampling date	Sea stars in 30 min	Abalone in plots	Abalone search*
Cuyler Harbor, SMI	1/20/09	162 P.o.	x	0
Crook Point, SMI	1/21/09	47 P.o.	2	9
Otter Harbor, SMI	1/22/09	344 P.o., 18 P.g., 1 P.m.	0	194
Harris Point, SMI	1/23/09	25 P.o., 1 P.g., 3 P.m. 1 P.h.	1	17black, 1 red
Fossil Reef, SRI	1/9/09	312 P.o., 3 P.m., 3 P.h.	0	8
Johnson's Lee, SRI	1/11/09	417P.o.	0	1
Ford Point, SRI	1/10/09	512 P.o.	2	18
Northwest-Talcott, SRI	1/8/09	2 P.o., 6 P.g., 3 P.m.	0	0
East Point, SRI	1/7/09	840 P.o.	x	6 ¹
Fraser Cove, SCI	12/11/08	371 P.o.	x	1
Trailer, SCI	12/11/08	195 P.o., 1 P.m.	x	13
Willows Anchorage, SCI	12/10/09	434 P.o.	x	184
Scorpion Rock, SCI	11/25/08	169 P.o., 1 P.g., 1 P.m.	x	1
Prisoner's Harbor, SCI	12/9/09	94 P.o.	x	0
Orizaba Cove, SCI	11/26/08	541 P.o.	x	8
Cat Rock, ANI	11/11/08	5	0	4
South Frenchy's Cove, ANI	11/11/08	33	x	0
Middle Anacapa-West	11/12/08	733	0	33 HSA, 37 MW
Sea Lion Rookery, SBI	10/16/08	758	0	0
Landing Cove, SBI	10/18/08	224	x	1

*30-minute timed search except at Otter harbor and Willows Anchorage (see text). (x indicates no plot or transect, nc indicates no count performed, P.o.= *Pisaster ochraceus*, P.g.=*P. giganteus*, P.m.= *Patiria miniata*). Middle Anacapa-West (MW) site includes Harbor Seal Arch (HSA) but area is reported separately. 1 =12 abalone found in extended 1 hour search at East Point.

2009 Monitoring

Table 6 presents the counts and size distribution of *H. cracherodii* found in 2009 at each island (all sites combined by island). Especially in areas with numerous abalone, measurements were made after the timed count was completed, since measuring may slow the search effort. Note that all abalone counted may not have been measured due to inaccessibility or limited time. It is also possible that additional abalone were found while making measurements beyond those observed during the 30-minute search. Mean sizes were lowest at Anacapa and Santa Cruz Islands where continued recruitment was observed.

Tables 7 and 8 present the numbers of abalone and seastars counted at each site. The numbers of seastars at some sites is concerning since they may prey on juvenile abalone. At Willows Anchorage, 175 *H. cracherodii* were found during a three-hour search in spring, 2009, and 143 *H. cracherodii* were observed during a reduced search effort (90 minutes) in fall. At Otter Harbor we spent three hours searching in spring (n=143) and 90 minutes in the fall (n=180).

H. cracherodii were observed in fixed plots at Harris Point, Ford Point and East Point during 2009 (Tables 7 and 8). Timed searches yielded comparable counts of *H. cracherodii* (Tables 7 and 8) in recent years. At Trailer we found 14 *H. cracherodii* in spring and an additional 27 individuals during an extended search (30 minutes) on adjacent reefs. At Santa Cruz Island, primarily Willow's Anchorage, abalone numbers increased markedly during the last several years (Figure 12). Figure 12 is included here to show the changes we have been seeing at each of the islands. Prior to the early 1990s abalone were only counted in fixed plots. Site-wide surveys or timed counts began different years. The NPS began monitoring abalone at Santa Cruz Island in 1998. No abalone were found at Cuyler Harbor, Northwest-Talcott, South Frenchy's Cove, Sea Lion Rookery or Landing Cove. Note that part of the Harbor Seal Arch portion of Anacapa Middle West site was not sampled in 2009 due to time restrictions and sea conditions.

The normal size distribution of *H. cracherodii* measured at all sites in spring 2009 (Figure 13) is indicative of a small but presumably healthy population comprised of multiple-age classes. Fall data (Figure 14) show a more pronounced bimodal distribution typical of multiple age-classes. We found large (>180mm) adult abalone at all of the islands except Santa Barbara in 2009. At least one juvenile abalone (<45mm) was found at each of the northern islands. Further signs of recruitment are the relatively small (e.g. <30 mm) individuals found at several sites as these are believed to be only 1-2 years old (Haaker et al. 1995). Yet, black abalone population levels at the islands still remain less than one percent of 1985 population levels (Richards 1988, Richards and Davis 1993). One dead abalone was found at Harris Point, San Miguel Island with the appearance of symptoms related to Withering Syndrome.

Table 6. *Haliotis cracherodii* counts from 2009 sampling.

Island Code	Year	Season	Count Random	Count InPlots	Count Sized	Mean Size	StDev	Min Size	Max Size
AN	2009	spring	17	0	17	61.82	27.94	30	138
SC	2009	spring	208	0	200	61.10	24.82	24	186
SM	2009	spring	175	1	176	103.44	23.79	45	185
SR	2009	spring	35	3	38	110.76	39.75	30	185
AN	2009	fall	13	0	13	91.23	44.52	21	180
SB	2009	fall	0	0	0				
SC	2009	fall	175	0	80	71.78	26.17	30	135
SR	2009	fall	25	1	26	127.42	34.66	60	186
SM	2009	fall	239	1	101	106.32	26.91	40	151

Data from sites are combined by island. CountRandom is the number of abalones from timed searches, CountInPlot is the number of abalones found in fixed plots (not all sites were monitored each season, thus area size is different). Count Sized is the number of abalone actually measured; some abalone under boulders for example may not be measured.

Table 7. Sea star and *Haliotis cracherodii* searches in spring 2009.

Site	Sampling Date	Seastars in 30 min	Abalone in plots	Abalone search*
Cuyler Harbor, SMI	4/6	102 P.o.	x	0
Crook Point, SMI	4/5	66 P.o., L.h. present	0	24
Otter Harbor, SMI	4/4	118 P.o., 3P.g., 6 P.m.	0	143
Harris Point, SMI	4/3	7 P.o. 2 P.m.	1	19
Fossil Reef, SRI	5/30	327 P.o., 2 P.h., 2 P.g., 2 P.m.	0	6
Johnson's Lee, SRI	5/26	586 P.o., 1 P.g.	0	3
Ford Point, SRI	5/27	529 P.o.	2	18
Northwest-Talcott, SRI	5/29	0 P.o., 1 P.g., 1 P.m.	0	0
East Point, SRI	5/28	983 P.o.	1	10
Fraser Cove, SCI	4/28	329 P.o.	x	2
Trailer, SCI	4/27	289 P.o.	x	14
Willows Anchorage, SCI	4/29	631 P.o., 2 P.m., L.h. present	x	175
Scorpion Rock, SCI	x	nc	x	nc
Prisoner's Harbor, SCI	4/30	110 P.o., 1 P.g.	x	1
Orizaba Cove, SCI	3/7	738 P.o., 6 P.g. 4 P.m.	x	13
Cat Rock, ANI	x	nc	nc	nc
South Frenchy's Cove, ANI	3/9	26 P.o.	x	0
Middle Anacapa-West	3/8	556 P.o.	nc	17 ¹

*30-minute timed search except at Otter harbor and Willows Anchorage (see text). (x indicates no plot or transect, nc indicates no count performed, P.o.= *Pisaster ochraceus*, P.g.=*P. giganteus*, P.b.= *Pisaster brevispinus*, P.h.=*Pycnopodia helianthoides*, P.m.= *Patiria miniata*, L.h.= *Leptasterias hexactis*).¹ = due to logistical constraints, Harbor Seal Arch (HSA) was not sampled.

Table 8. Sea star and *Haliotis cracherodii* searches in fall 2009.

Site	Sampling Date	Seastars in 30 min	Abalone in plots	Abalone search*
Cuyler Harbor, SMI	11/16	141 P.o.	x	0
Crook Point, SMI	11/14	154 P.o.	0	52
Otter Harbor, SMI	11/13	130 P.o., 16 P.g., 3 P.m.	0	180
Harris Point, SMI	11/15	19 P.o., 2 P.g., 4 L.h, 3 P.h., 10 P.m.	1	14
Fossil Reef, SRI	1/15/10	nc	nc	nc
Johnson's Lee, SRI	1/11/10	396 P.o.	0	3
Ford Point, SRI	1/13/10	304 P.o.	1	11
Northwest-Talcott, SRI	1/14/10	1 P.o., 2 P.g., 1 P.m.	0	0
East Point, SRI	1/12/10	652 P.o., 3 P.m.	x	11
Fraser Cove, SCI	11/1	263 P.o.	x	0
Trailer, SCI	11/4	217 P.o.	x	14
Willows Anchorage, SCI	11/2	294 P.o.	x	114
Scorpion Rock, SCI	12/1	133 P.o., 1 P.g.	x	9
Prisoner's Harbor, SCI	11/1	62 P.o.	x	1
Orizaba Cove, SCI	12/14	517 P.o., 1 P.m., 1 P.h.	x	8
Cat Rock, ANI	11/30	7 P.o.	0	3
South Frenchy's Cove, ANI	12/2	34 P.o.	x	0
Middle Anacapa-West	12/15	110 P.o.	x	10 ¹
Sea Lion Rookery, SBI	10/16	1024 P.o.	0	0
Landing Cove, SBI	10/15	381 P.o.	x	0

*30-minute timed search except at Otter harbor and Willows Anchorage (see text). (x indicates no plot or transect, nc indicates no count performed, P.o.= *Pisaster ochraceus*, P.g.=*P. giganteus*, P.b.= *Pisaster brevispinous*, P.h.=*Pycnopodia helianthoides*, P.m.= *Patiria miniata*, L.h.= *Leptasterias hexactis*). ¹ = due to logistical constraints, Harbor Seal Arch (HSA) was not sampled.

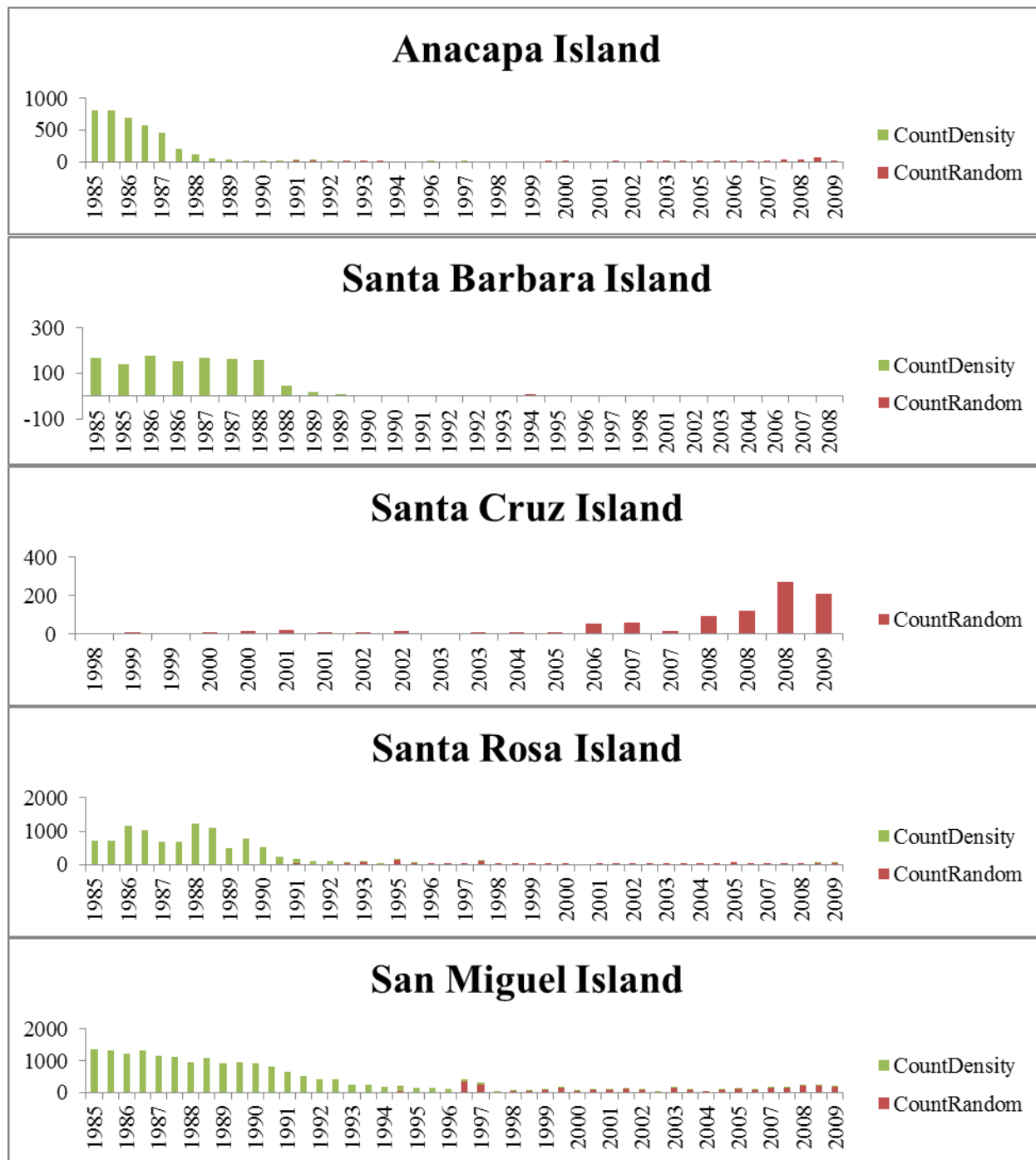


Figure 12. *Haliotis cracherodii* density and counts for all years at each island. CountDensity is the number of abalone per m². CountRandom is the number of abalone from timed searches. Note differences in scale between plots. Both types of counts use the same scale on left. (NPS monitoring at Santa Cruz began in 1998). Random counts began in the early 1990s, at different times for different islands.

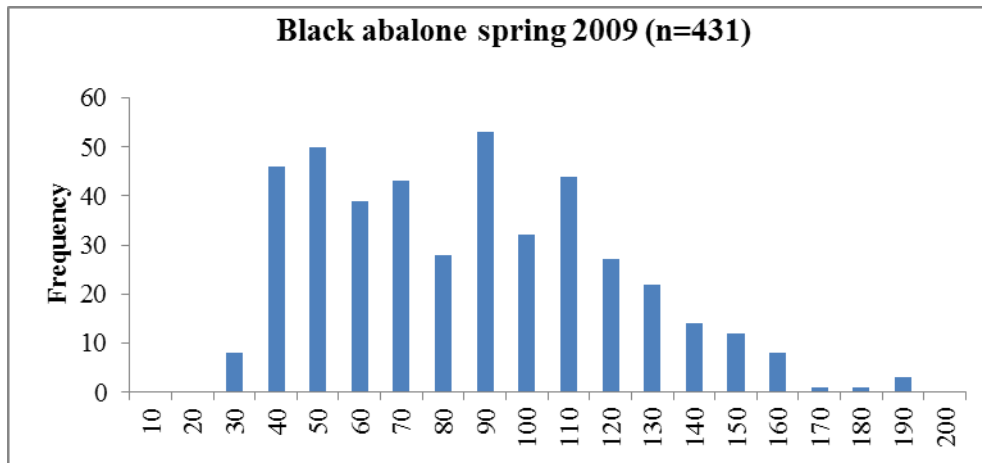


Figure 13. *Haliotis cracherodii* size distribution in spring 2009, all sites combined.

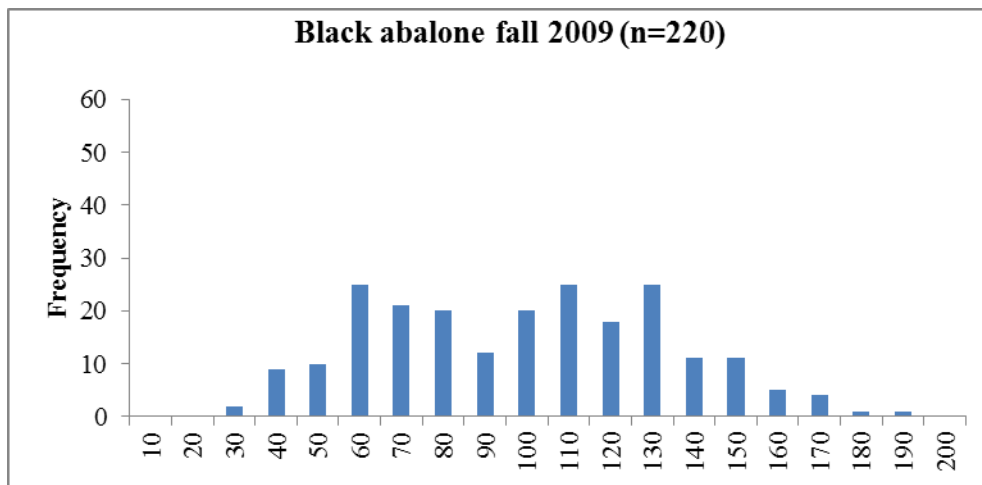


Figure 14. *Haliotis cracherodii* size distribution in fall 2009, all sites combined.

2010 Monitoring

Counts and size distribution of *H. cracherodii* were combined by island in table 9. A total of 435 *H. cracherodii* were found at Willows Anchorage during a multi-day survey in June (summer season). During routine monitoring, no abalone were found at Cuyler Harbor, Fraser Cove or South Frenchy's Cove. Rocky intertidal monitoring was not done in spring at Santa Barbara Island, Santa Rosa Island or at Orizaba Cove on Santa Cruz. Additional abalone searches (30-minute timed-intervals) were conducted at five ad hoc sites located east and west of Orizaba Cove and west of Willows Anchorage. At two areas west of Willows Anchorage (South #1-2), a combined total of 162 *H. cracherodii* were observed. A total of 117 individuals were measured with a size range of 20-160 mm. Three areas near Orizaba Cove (North #1-3), yielded a total of 54 *H. cracherodii* where sizes ranged from 28-115 mm (Figure 15).

Table 10 shows the counts of abalone and seastars in spring 2010 at each of the sites. Extended counts were made at Otter Harbor and Willows Anchorage. Only one *H. cracherodii* was found inside a fixed plot in spring 2010. Table 11 shows the abalone counts in fall 2010. We had good conditions and were able to find more abalone at most sites in the fall compared to the spring. With good working conditions at Otter Harbor we found 159 abalone, though we felt we should have been able to find more, leading us to suspect the population is slowly declining there.

During regular intertidal monitoring, 18 *H. cracherodii* were found at Middle Anacapa Island in spring; however, an additional five were found after the 30-minute count. This was an increase compared to surveys conducted in 2009, but fewer than the total number of individuals located in 2008. In the fall sample we found a total of 67 *H. cracherodii* between the Middle West and Harbor Seal Arch areas (Table 11). Middle Anacapa Island, similar to several north-facing sites on Santa Cruz Island, has experienced a near total loss of mussels, *Mytilus californianus*, since 2008. The significant reduction of mussel communities may impact *H. cracherodii* recruitment since juveniles often live among the mussels. It may have also made the young abalone more visible. We will continue to monitor mussels at these sites. *Pisaster ochraceus* abundance is high at all these sites, and is the likely cause of the mussel decline. However, *Pisaster* are also very abundant at several sites on the south sides of the islands, yet major declines of mussel populations have not been seen at most south-facing sites. The high abundances of *P. ochraceus* in the intertidal as well as *P. gigantea* and *Pycnopodia helianthoides* in the shallow subtidal zone at Santa Cruz Island (observed on SCUBA surveys in September 2010) is of some concern as these seastars are known to prey on abalone. A lack of steady recruitment may, in part, explain the failure of mussels to recover at some sites.

Scorpion Rock experienced an apparent increase in abalone. In recent years, only one individual has been located in the vicinity of Area A and typically no abalone are observed at Area B. In spring, eight *H. cracherodii* were found at Area A and 11 individuals were located in Area B (Table 10). In the fall survey we found 16 total in the two areas (Table 11). Counts at other sites were more consistent with the range of counts we have seen in recent years.

At Trailer, 30 *H. cracherodii* were found a 30-minute search in fall (Table 11), and an additional 70 were found on reefs to the south. Most of these were large and very few <60 mm were found. In the fall, *H. cracherodii* were sampled at Valley Anchorage on Santa Cruz Island and 217 were found in two and a half hours of measuring and searching.

Size frequencies for black abalone grouped by island are presented in Figures 16-21. Anacapa and Santa Cruz Island size frequencies indicate the effects of recruitment in recent years with the populations skewed towards smaller animals. The opposite is true at San Miguel Island where we continue to find very few juvenile abalone and thus the population is dominated by older individuals. Size distributions at each island were similar in both spring and fall.

We spent two days at Otter Harbor in February (winter season) and three days at Willows Anchorage in June (summer season) focusing on black abalone. Site-wide counts of black abalone were conducted and new tags were deployed at both locations. Ledges and crevices were mapped at both sites to facilitate the description of movement patterns of tagged abalone.

At Otter Harbor, 17 *H. cracherodii* were tagged in February. Two of these new tags were placed on abalone that had been previously tagged but were no longer identifiable. Twenty-three previously tagged *H. cracherodii* were located, though only 13 animals could be identified by their tags. One shell had remnants of epoxy indicating a lost tag and the other tags could not be read due to malfunction or breakage. We measured 151 *H. cracherodii* but were unable to reach all areas due to the incoming tide. Two empty (and un-tagged) shells were found; one fresh shell (148 mm) with a small amount of muscle tissue remaining, and one older shell (96 mm) with the appearance of dullness or growth on the inner part of the shell. During the regular monitoring in April at Otter Harbor we found 20 tagged abalone and measured 125 individuals. That total is lower than recent counts; however, sampling was hampered by a large swell.

A small but highly rugose area on the northeast part of San Miguel Island, (Willow Canyon) was searched in spring (50-minute timed search) yielding 16 *H. cracherodii*. Willow Canyon has harbored moderate numbers of *H. cracherodii* in past years. Though we do not monitor that area regularly, we occasionally conduct surveys there. Access to Willow Canyon has become difficult due to increased use by pinnipeds.

At Willows Anchorage on Santa Cruz Island, 13 *H. cracherodii* (43-97 mm) were tagged with double tags (PIT and vinyl fish tag) in June (Figure 22). Searches yielded 259 *H. cracherodii*, including numerous juveniles (Figure 23) and 11 juvenile *H. rufescens* (Figure 24) in the main monitoring area. At least 25 tagged abalone were found including some that Tal Ben-Horin tagged in October 2010 (not reported here). A strong effort was put into searching for abalone on the western half of the reef where we often do not have time to monitor, resulting in 132 *H. cracherodii* counted. Four empty juvenile abalone shells (2 red and 2 black) were found and measured. Many of the abalone tagged on the first day disappeared by the second or third day of monitoring, and presumably went into crevices or under boulders. Forty-eight hours after tagging, one *H. cracherodii* was found 4.7 meters from the location it was originally tagged. Three other tagged *H. cracherodii* crossed a small sand channel located approximately two meters from their original tagging location. Based on other tagging experience at Anacapa (Haaker unpublished) it seems some abalone will stay put while others disappear only to reappear later. We have observed abalone crossing sand channels to other reef portions. Presumably those abalone are temporarily more vulnerable to predation and being injured by waves.

The reef at Otter Harbor is bedrock with both large and small crevices that provide good abalone habitat (Figure 25). We found one withered *H. cracherodii* in February at Otter Harbor and one

shell with muscle tissue remaining which is not typical of predated abalone. Another *H. cracherodii* was found that was weak, though not especially withered. It was not holding onto the rock when first found and did not react to touch. It was still alive the next day however, and was firmly gripping the rock at that time. A withered *H. cracherodii*, with a foot muscle about half as large as it should be was also found there in April (Figure 26). Conditions have been generally cold during the last year so it was surprising to see these symptoms which are more prevalent during warm water conditions.

Temperatures within abalone habitats were recorded at Willows Anchorage, Otter Harbor, Middle Anacapa, Northwest Talcott, Fossil Reef, and Johnson's Lee.

Conclusions

Juvenile *H. cracherodii* have appeared in the populations at several sites on Santa Cruz and Anacapa Islands since 2007. These represent the first real increases in population that we have seen since at least the early 1990's. *Haliotis cracherodii* populations however are still less than one-percent of historic densities, before the Withering Syndrome (WS) disease nearly wiped them out in the 1980's. Four, or possibly five, black abalone were found between 2008 and 2010 that exhibited symptoms of WS at Otter Harbor (one appeared weak but not especially withered). Another was found dead with most of the muscle still in the shell, which may or may not be related to WS. No significant juvenile recruitment has been found at Santa Barbara Island, the south side of Anacapa Island, Santa Rosa Island or San Miguel Island. At San Miguel Island, about 200 adult abalone have survived at one monitored site. Despite the fair number of adults and seemingly good habitat, very few juveniles have been found there in the last 15 years.

Fixed monitoring plots established in 1985 are no longer useful for monitoring due to the low densities and rarely have any abalone in them. Timed searches or whole reef censuses provide a good indication of the area population, but comparisons are difficult due to changes in conditions and variability between sites.

Nearest-neighbor distances seem to indicate that abalone aggregate with others of their species. They may just have preference for the same habitat qualities but there may be other advantages to aggregating such as safety in numbers or an enhanced ability to capture drift kelp. Enhanced spawning success will hopefully result from this behavior.

Tagging abalone has been inconclusive mostly. Some abalone appeared to stay in the same crevice for years either not moving or returning to the same location after short forays. Other abalone, particularly smaller individuals appear to move around quite a bit. Of over 200 abalone tagged at the two areas, only about one-quarter are re-sighted after a year. There are a few that have been followed for nearly four years. A few have reappeared after being missed for several months indicating there may be hiding places we cannot see. Known tag loss has been low. Only five confirmed deaths of tagged abalone have occurred since 2007. No cause of death could be determined for any of the shells found.

Table 9. *Haliotis cracherodii* counts from 2010 sampling.

Island Code	Year	Season	Count Random	Count InPlot	Mean Size	St Dev	Min Size	Max Size
AN	2010	spring	29	0	61.34	24.81	19	130
AN	2010	3	70	0	61.39	24.69	22	120
SC	2010	spring	198	0	67.29	22.58	23	163
SC	2010	summer	435	0	56.21	23.45	14	163
SC	2010	3	675	0	64.30	28.49	20	186
SM	2010	winter	174	0	100.86	25.72	30	162
SM	2010	spring	177	0	107.48	26.35	45	163
SM	2010	3	182	1	108.19	26.50	30	165

Data from sites are combined by island. CountRandom is the number of abalones from 30-minute search; CountInPlot is the number of abalones found in fixed plots.

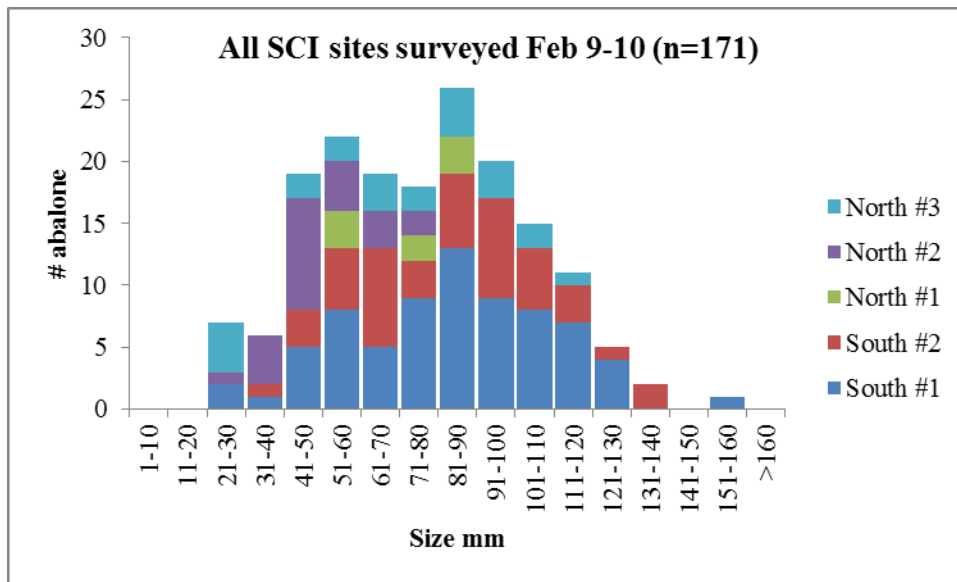


Figure 15. *Haliotis cracherodii* size distributions at Santa Cruz Island, February 2010.

Table 10. Sea star and *Haliotis cracherodii* searches in spring 2010.

Site	Sampling Date	Seastars in 30 min	Abalone in plots	Abalone search*
Cuyler Harbor, SMI	4/18	137 P.o.	x	0
Crook Point, SMI	4/20	83 P.o.	0	17
Otter Harbor, SMI	4/21	130 P.o., 16 P.g., 3 P.m.	0	125
Harris Point, SMI	4/19	30 P.o., 2 P.g., 3 P.h., 8 P.m., 2 L.h.	1	19
Fossil Reef, SRI	nc			
Johnson's Lee, SRI	nc			
Ford Point, SRI	nc			
Northwest-Talcott, SRI	nc			
East Point, SRI	nc			
Fraser Cove, SCI	3/24	297 P.o.	x	0
Trailer, SCI	3/26	105 P.o. 1 P.m.	x	7
Willows Anchorage, SCI	3/25	497 P.o., 1 P.g., P.m.	X	153
Scorpion Rock, SCI	3/28	128 P.o.	x	19
Prisoner's Harbor, SCI	3/23	49 P.o.	x	1
Orizaba Cove, SCI	nc			
Cat Rock, ANI	3/11	20 P.o.	0	6
South Frenchy's Cove, ANI	3/11	0	x	0
Middle Anacapa-West	3/12	286 P.o.	0	18

Nc= no counts, Santa Rosa Island was not sampled in spring 2010. *30-minute timed search except at Otter harbor and Willows Anchorage (see text). (x indicates no plot or transect, nc indicates no count performed, P.o.= *Pisaster ochraceus*, P.g.= *P. giganteus*, P.b.= *Pisaster brevispinous*, P.h.= *Pycnopodia helianthoides*, P.m.= *Patiria miniata*, L.h.= *Leptasterias hexactis*).

Table 11. *Haliotis cracherodii* searches in fall 2010.

Site	Sampling Date	Abalone in plots	Abalone search
Cuyler Harbor, SMI	12/7	x	0
Crook Point, SMI	12/6	nc	nc
Otter Harbor, SMI	12/4	0	159 (120min)
Harris Point, SMI	12/5	1	24 (45min)
Fraser Cove, SCI	11/19	x	0 (30min)
Trailer, SCI	11/18	x	30 (30min)
Willows Anchorage, SCI	11/21	x	180 (70min)
Scorpion Rock, SCI	12/3	x	4 (site A), 12 (site B)
Prisoner's Harbor, SCI	11/17	x	1 (30min)
Orizaba Cove, SCI	11/3	x	5 (incomplete survey)
Cat Rock, ANI	11/4	0	3 (30min)
South Frenchy's Cove, ANI	11/5	x	0 (30min)
Middle Anacapa-West	12/2	0	24 (photo-site) 43 (HSA)
Sea Lion Rookery, SBI	10/7	0	0 (30min)
Landing Cove, SBI	10/6	x	2 (30min)

Nc= no counts, Santa Rosa Island was not sampled in fall 2010. *actual search time in parenthesis. (x indicates no plot or transect, nc indicates no count performed).

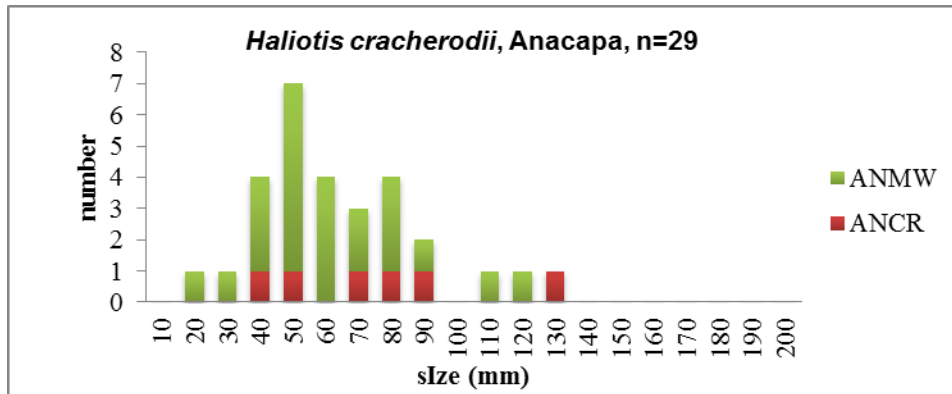


Figure 16. *Haliotis cracherodii* size distributions at Anacapa Island, spring 2010.

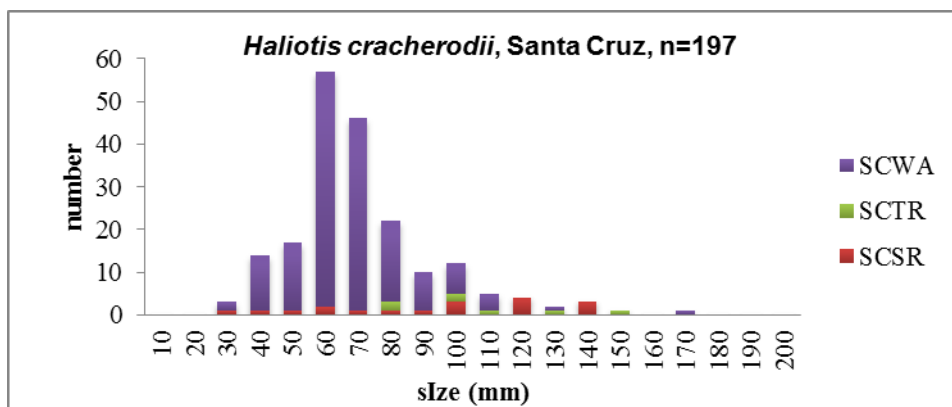


Figure 17. *Haliotis cracherodii* size distributions at Santa Cruz Island, spring 2010.

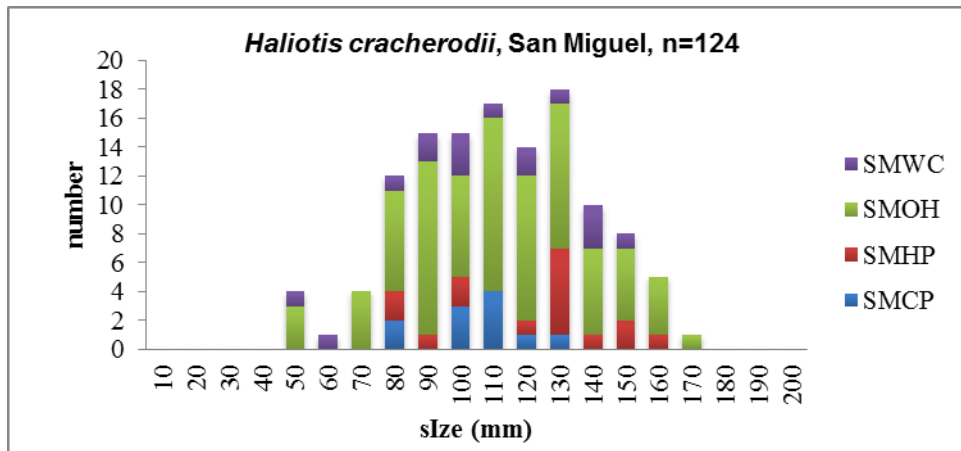


Figure 18. *Haliotis cracherodii* size distributions at San Miguel Island, spring 2010.

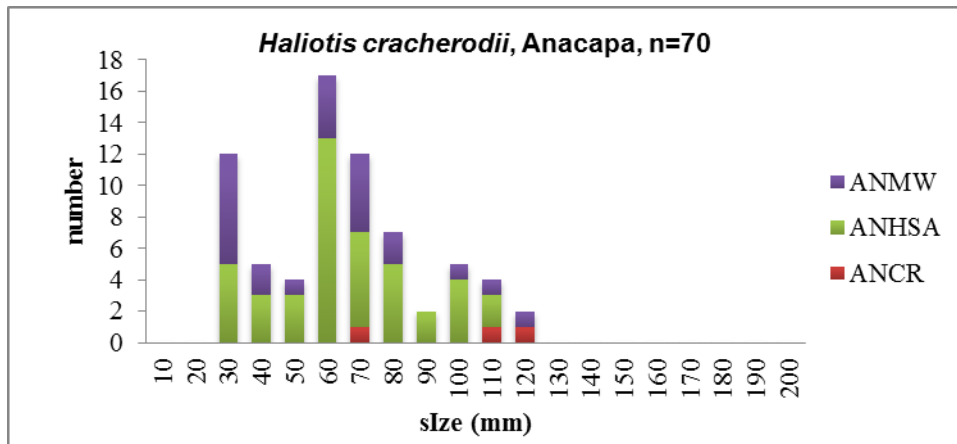


Figure 19. *Haliotis cracherodii* size distributions at Anacapa Island, fall 2010.

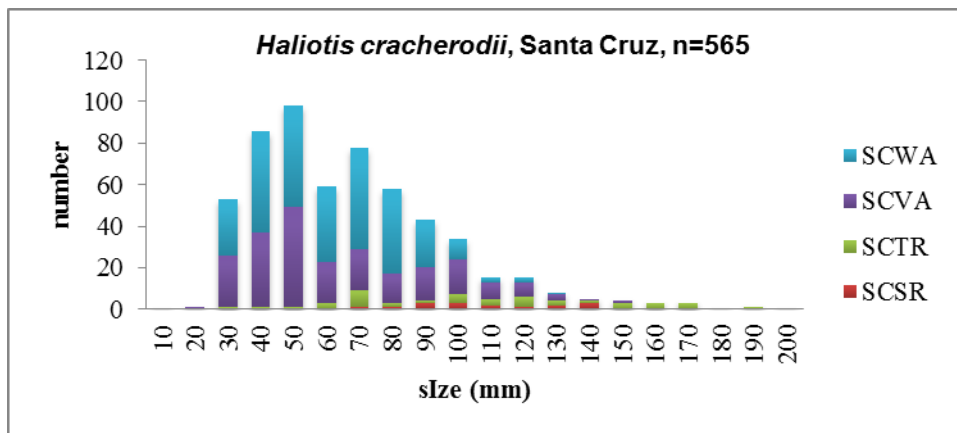


Figure 20. *Haliotis cracherodii* size distributions at Santa Cruz Island, fall 2010.

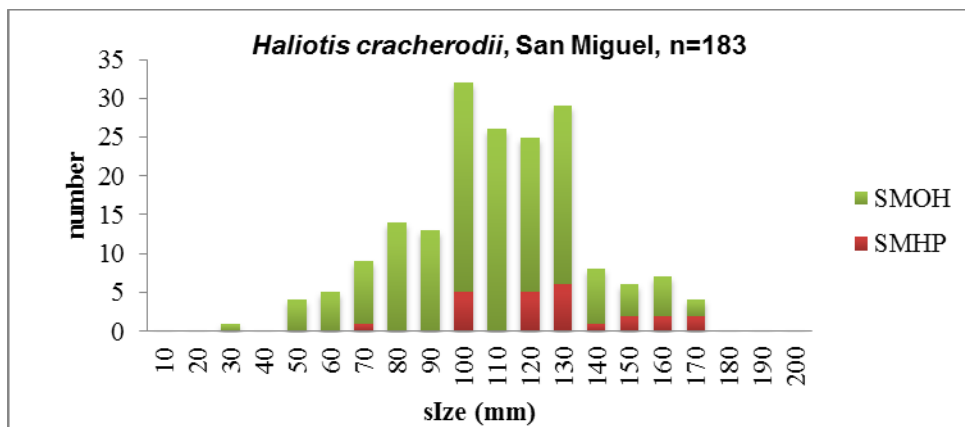


Figure 21. *Haliotis cracherodii* size distributions at San Miguel Island, fall 2010.



Figure 22. Black abalone double tagged with vinyl number tag and PIT tag.



Figure 23. Juvenile black abalone at Willows Anchorage.



Figure 24. Juvenile red abalone at Willows Anchorage, one of 11 found in June 2010.



Figure 25. Measuring black abalone at Otter Harbor site. Otter Harbor has abundant crevices providing protection for abalone. Some crevices are more accessible for monitoring than others (Ann Vileisis Photo).



Figure 26. A withered black abalone at Otter Harbor site. The foot muscle of a healthy abalone would fill the shell. Withered abalone have difficulty holding onto the reef in heavy waves exposing them to predators (Ann Vileisis Photo).

Literature Cited

- Chambers, M. D., H. Hurn, C. S. Friedman, and G. R. VanBlaricom. 2005. Drift card simulation of larval dispersal from San Nicolas Island, California, during black abalone spawning season. Pages 421-434 in D. K. Garcelon and C. A. Schwemm, editors. Proceedings of the Sixth California Islands Symposium, December 1-3, 2003, Ventura, CA. National Park Service Technical Publication CHIS-05-01, Institute for Wildlife Studies, Arcata, CA.
- Chambers, M. D., G. R. VanBlaricom, L. Hauser, F. Utter, and C. S. Friedman. 2006. Genetic structure of black abalone (*Haliotis cracherodii*) populations in the California islands and central California coast: Impacts of larval dispersal and decimation from withering syndrome. *Journal of Experimental Marine Biology and Ecology* **331**:173-185.
- Dailey, M. D., J. W. Anderson, D. J. Reish, and D. S. Gorsline. 1993. The southern California Bight: background and setting. In Dailey, M. D., D. J. Reish, and J. W. Anderson (eds.) *Ecology of the Southern California Bight, A Synthesis and Interpretation*. University of California Press, Berkeley, CA.
- Engle, John M. 2008. Unified Monitoring Protocols for the Multi-Agency Rocky Intertidal Network (November 2008 Update). OCS Study MMS 08. Minerals Management Service. Camarillo, CA.
- Engle, J. M. D. L. Martin, J. Altstatt, R. F. Ambrose, and P. T. Raimondi. 1998. Rocky Intertidal Monitoring Handbook for Santa Cruz Island. Santa Cruz Island Shoreline Inventory, Appendix A. Prepared for: California Coastal Commission.
- Engle J. M. and D. V. Richards. 2001. New and unusual marine invertebrates discovered at the California Channel Islands during the 1997-1998 El Nino. *Southern California Academy of Sciences*. 100(3):186-198.
- Friedman, C. S., K. B. Andree, K. A. Beauchamp, J. D. Moore, T. T. Robbins, J. D. Shields, and R. P. Hedrick. 2000. '*Candidatus Xenohaliotis californiensis*', a newly described pathogen of abalone, *Haliotis* spp., along the west coast of North America. *International Journal of Systematic and Evolutionary Microbiology* 50:847-855.
- Friedman, C. S., W. Biggs, J. D. Shields, P. L. Haaker, C. Chun, and R. P. Hedrick. 1997. An examination of four potential etiologies of WS: Temperature, food availability, renal coccidia, and Rickettsiales-like procaryotes. in *Third International Abalone Symposium: Biology, fisheries, and culture*, Monterey, CA, October 26-31, 1997.
- Friedman, C. S., W. Biggs, J. D. Shields, and R. P. Hedrick. 2002. Transmission of withering syndrome in black abalone, *Haliotis cracherodii*, Leach. *Journal of Shellfish Research* 21:817-824.

- Gardner, G. R., J. C. Harshbarger, J. L. Lake, T. K. Sawyer, K. L. Price, M. D. Stephenson, P. L. Haaker, and H. A. Togstad. 1995. Association of prokaryotes with symptomatic appearance of withering syndrome in black abalone *Haliotis cracherodii*. *Journal of Invertebrate Pathology* 66:111-120.
- Haaker, P.L., D. O. Parker, C. S. Y. Chun. 1995. Growth of black abalone, *Haliotis cracherodii* Leach, at San Miguel Island and Point Arguello, California. *J. Shellfish Research*. 14:519-525.
- Haaker, P. L., D. V. Richards, C. S. Friedman, G. E. Davis, D. O. Parker, and H. A. Togstad. 1992. Mass mortality and withering syndrome in black abalone, *Haliotis cracherodii*, in California. Pages 214-224 in S. A. Shepherd, M. J. Tegner, and S. A. Guzmán del Próo, editors. *Abalone of the World*. Blackwell Scientific Publications, Oxford, England.
- Hamm, D. E., and R. S. Burton. 2000. Population genetics of black abalone, *Haliotis cracherodii*, along the central California coast. *Journal of Experimental Marine Biology and Ecology* 254:235-247.
- Lafferty, K. D., and A. M. Kuris. 1993. Mass mortality of abalone *Haliotis cracherodii* on the California Channel Islands: tests of epidemiological hypotheses. *Marine Ecology Progress Series* 96:239-248.
- Richards, D. V. 1988. Rocky intertidal ecological monitoring at Channel Islands National Park, California 1986-1987. *Channel Islands National Park Natural Science Reports*, CHIS-88-001.
- Richards, D. V. and G. E. Davis. 1988. *Rocky Intertidal Communities Monitoring Handbook*. National Park Service. Channel Islands National Park. Ventura, CA. NTIS.
- Richards, D. V. and G. E. Davis. 1993. Early warnings of modern population collapse in black abalone *Haliotis cracherodii*, Leach, 1814 at the California Channel Islands. *Journal of Shellfish Research* 12(2): 189-194.
- Richards, D. V. 1998. *Rocky Intertidal Monitoring, Channel Islands National Park, 1997 Annual Report*. Technical Report CHIS-98-07.
- Richards, D. V. and D. Lerma. 2000. *Rocky Intertidal Community Monitoring, Channel Islands National Park, 1998 Annual Report*. Channel Islands National Park Technical Report 2000-03.
- Richards, D. V., D. Lerma, and P. J. Rich. 2010. *Rocky Intertidal Community Monitoring at Channel Islands National Park, 2002 Annual Report*. Natural Resource Technical Report NPS/CHIS/NRTR—2010/362. National Park Service, Fort Collins, CO.
- VanBlaricom, G., M. Neuman, J. Butler, A. DeVogelaere, R. Gustafson, C. Mobley, D. Richards, S. Rumsey, and B. Taylor. 2009. *Status Review Report for Black Abalone (Haliotis cracherodii Leach, 1814)*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Long Beach, CA

Appendix A Tagged Abalone Records

Abalone tagged with Passive Integrated Transponder (PIT) tags (Biomark TX1400SST) are reported along with the dates of recapture. Red indicates initial tagging. Codes in columns of Otter Harbor table refer to crevice location where individual was found. Reconciling past location to current mapping scheme was not always clear and questionable locations are designated with a question mark (?). Numbers on Willows Anchorage table refer to sizes recorded on that date (~indicates estimated size).

Tagging data from Otter Harbor, San Miguel Island														
Pit tag number/ visual number	2/13 /2007	2/14/ 2007	2/15/ 2007	5/20/ 2007	1/19/ 2008	2/18-20/ 2008	5/10/ 2008	1/22/ 2009	4/4/ 2009	11/17 /2009	2/24-25/ 2010	4/21/ 2010	12/4/ 2010	Notes
985161000041118	x	x	x	C14?		C14?	C14?	C14?	C14?					
985161000041285	x	x	x	C14?	C14 ?	C14?								
985161000042242	x	x	x	C14? ?										
985161000042579	x	x	x					Shell C12						
985161000042776		x	x	OR3	x	OR3	OR3							
985161000042831			x											
985161000043020	x	x	x											
985161000043142 /901						C3	C3	C3	C3	C3	C3	C3	C3	
985161000043265 /916						x								
985161000043939	x		x											
985161000044712		x	x											
985161000961078		x	x	C4	x	x								
985161000962582											C14or15			
985161000963446			x											
985161000966083	x	x				C14?	empty shell							*dbl tagged with 1302443
985161000966856	x		x	C14?										
985161000969580 /924											x	C18	C18	
985161000967254 /913						x								previously tagged but non-functioning
985161000967614		x		C6?					x					
985161000967731	x	x	x											
985161000968028			x	C14?										
985161000969457						x	x	x	C7		C7*			*pit tag not working
985161000969580 /924											C18			
985161000970154						C5	C5	C5	C5					

[illegible]

Tagging data from Otter Harbor, San Miguel Island														
Pit tag number/ visual number	2/13 /2007	2/14/ 2007	2/15/ 2007	5/20/ 2007	1/19/ 2008	2/18-20/ 2008	5/10/ 2008	1/22/ 2009	4/4/ 2009	11/17 /2009	2/24-25/ 2010	4/21/ 2010	12/4/ 2010	Notes
985161000975929		x	x											
985161000976079 /900						x	C4?	C3- C4?	C3?					
985161000976116		x	x		x									
985161000976296	x													
985161000976394		x	x	C7	x		C7							
985161000976525 /922											C13	C12	C13	
985161000976741 /920											C14			
985161000977323			x	C21	x				C21					
985161000977462		x	x											
985161000978031		x	x	C3?										
985161000979182 /991											C3	C3	C3	
985161000979731 /976											C5			
985161000979912							C3?							
985161000981050	x		x											
985161000982147		x												
985161000982930 /914	x	x	x	x	x	x	C14?	C14?	C14 *		C14		C14	*tag failure
985161000983335 /910						X*	C4	C4	C4	x	C4		C4	*previous tag not functioning
985161000983343		x	x	C5?										
985161000983643	x	x	x											
985161000983679	x	x	x	C16- 17?	x									
985161001295627 /911						C6?	C10?	C20?			C20*		C19	*vis tag not seen
985161001295755 /950											C13	C13		
985161001296810		x	x	C4	x	x	x	C4	C4					

Tagging data from Otter Harbor, San Miguel Island														
Pit tag number/ visual number	2/13 /2007	2/14/ 2007	2/15/ 2007	5/20/ 2007	1/19/ 2008	2/18-20/ 2008	5/10/ 2008	1/22/ 2009	4/4/ 2009	11/17 /2009	2/24-25/ 2010	4/21/ 2010	12/4/ 2010	Notes
985161001299443		x	x	C1	x	C1	C1		C1		C1	C1		
985161001299755													C13	
985161001299912 /902						x	x	C3	C3		C3	C3		
985161001300153			x	C16-17	x									
985161001300261 /903						C7	C7		C7		C7			
985161001300454		x	x	x										
985161001300789			x	C21										
985161001301089			x	C16- 17?										
985161001301836	x								C12- 13					
985161001302075 /906						x					C1	C1		
985161001302100		x	x	C7?										
985161001302443			x	C14- 16?	x	x*								double tagged 966083
985161001302589	x	x	x	C21	x									
985161001302723	x	x	x	C12- 13?										
985161001302817		x	x											
985161001302830		x	x		x			OR3						
985161001302847											C8	C9	C7	
985161001302932 /941											OR1		C4	
985161001303478 /942											C18	C18	C18	
985161001303489	x	x	x											
985161001303371 3/973											C18			
985161001303813		x	x	C3?	x	x	C3	C3						
985161001303832			x	C16- 17?	x	C19?								

Tagging data from Otter Harbor, San Miguel Island														
Pit tag number/ visual number	2/13/ 2007	2/14/ 2007	2/15/ 2007	5/20/ 2007	1/19/ 2008	2/18-20/ 2008	5/10/ 2008	1/22/ 2009	4/4/ 2009	11/17/ 2009	2/24-25/ 2010	4/21/ 2010	12/4/ 2010	Notes
985161001303929		x	x	C7?										
985161001304621		x	x											
985161001305122	x	x	x	C15?	x	x	C15?	x	C14- 15?	x	C15	C16	C16	
985161001305473		x	x											
494A0D4B19/951											C3	C3	C3	
484C5D1530/940											C5		C5	
445777420B/930											C7	C7	C7	
Totals 101	23	45	58	37	25	36	26	22	19	5	31			

[illegible]

Tagging data from Willows Anchorage, Santa Cruz Island														
PIT tag number/ visual number	12/21/ 2006	1/31/ 2007	3/28/ 2007	3/29/ 2007	6/18/ 2007	9/27/ 2007	3/18/ 2008	7/18/ 2008	4/29 20/09	6/15/ 2010	6/16/ 2010	6/17/ 2010	11/21/2 011	11/22/2 011
9851610009712 40	56	nm	50	50										
9851610009721 99/912							56	61						
9851610009727 65		97												
9851610009728 19				~63										
9851610009729 56	98				98									
9851610009733 95				51				65						
9851610009735 75				~53										
9851610009740 94	45		47	50	53									
9851610009743 44				70		~61								
9851610009745 94		82	82	83	84									
9851610009747 05		70	mortality											
9851610009747 17	93	nm			86	~103	101	108						
9851610009748 34				51	50	69								
9851610009748 76/810							92							
9851610009749 41				~59										
9851610009750 61	89													
9851610009751 23		52												
9851610009752 53				65	74	~83								

[illegible]

Tagging data from Willows Anchorage, Santa Cruz Island														
PIT tag number/ visual number	12/21/ 2006	1/31/ 2007	3/28/ 2007	3/29/ 2007	6/18/ 2007	9/27/ 2007	3/18/ 2008	7/18/ 2008	4/29 20/09	6/15/ 2010	6/16/ 2010	6/17/ 2010	11/21/2 011	11/22/2 011
9851610013003 54				70	78	~81	76							
9851610013005 53				64	84									
9851610013007 51	90	nm		~89	96	95								
9851610013008 91		63	68	64	77									
9851610013014 61		42	45	45										
9851610013016 17		44	47											
9851610013018 65	89-93													
9851610013027 05	90													
9851610013033 13	66	nm	68	66	73									
9851610013034 42	72				83	92								
9851610013036 87					124		120							
9851610013039 21/809							72		94					
9851610013043 06		76	nm	~75										
9851610013049 13		70												
9851610013050 25	58	nm	59	63										
9851610013054 54/804							65							
48433C5263/86 7										90		89	c3	100 c3
484B117628/98 5										71				

484E17256B/97 9										66	x			
485F472C41/94 4										88			89 c17	c17
492D63013D/99 8										97	94			c14
4932161D7E/96 3										64	x	65	c8	73 c8
494756675D/99 2										43				
494A1B2873/99 9										83				c5
49584D4656/93 4										82		x		
4A29036A55993										66.5				
4A4E66121C/96 6										80		79		
4A4F3A7D1F/92 3										75				
9851210084142 37/931										94		x		
Totals 102	28	36	23	41	28	17	19	6	6	14	3	6		

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 159/115245, June 2012

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA™