FINAL ENDANGERED SPECIES ACT (ESA) RECOVERY PLAN
FOR
BLACK ABALONE
(*Haliotis cracherodii*)

November 2020

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West Coast Region
National Marine Fisheries Service
National Oceanic and Atmospheric Administration

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Prepared by
Protected Resources Division
West Coast Region
National Marine Fisheries Service

OLIVER.CHRISTOPHER.WAYNE.1408430670 Digitally signed by OLIVER.CHRISTOPHER.WAYNE.1408430670 Date: 2020.11.18 09:30:38 -05'00'

Approved: _____

Assistant Administrator for Fisheries
National Marine Fisheries Service
National Oceanic and Atmospheric Administration

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ADDITIONAL COPIES MAY BE OBTAINED FROM:

National Marine Fisheries Service
501 West Ocean Boulevard, Suite 4200
Long Beach, CA 90802

Recovery plans can also be downloaded from the NOAA Fisheries Black Abalone webpage:
https://www.fisheries.noaa.gov/species/black-abalone#conservation-management

GUIDE TO THE PLAN

NMFS developed this final Recovery Plan pursuant to the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.). This Recovery Plan reflects features of a recovery planning approach (termed the 3-part framework) developed by the U.S. Fish and Wildlife Service (USFWS) and adopted by NMFS as an optional approach to recovery planning. Under the 3-part framework, the Recovery Plan focuses on the ESA statutory requirements, which are to identify, to the maximum extent practicable, recovery criteria, recovery actions, and time and cost estimates. More in-depth scientific information and analyses, as well as activities that address the site-specific recovery actions, are contained in supplemental information made available on the NOAA Fisheries Black Abalone Webpage (https://www.fisheries.noaa.gov/species/black-abalone).

The major sections of this Recovery Plan include:

- Part 1. **Background**, providing a summary of black abalone biology, status, threats, and conservation measures that affect the species' recovery potential.
- Part 2. **Recovery Strategy**, laying out the long-term guiding principles for the criteria and actions that comprise the black abalone recovery program.
- Part 3. **Recovery Goals, Objectives, and Criteria**, describing the desired outcomes (goals) of the Recovery Plan, the conditions necessary to achieve these outcomes (objectives), and the values we will use to measure progress toward recovery (criteria).
- Part 4. **Recovery Actions**, describing the long-term actions needed to achieve the Recovery Criteria and general implementation responsibilities.
- Part 5. **Time and Cost Estimates** (Implementation Schedule) to achieve the goal of recovering and delisting the species.

Supplemental material available on the NOAA Fisheries Black Abalone Webpage:

- **Five-Year Status Review**, providing details about the species' biology, status, and threats.
- **Five-year Recovery Implementation Strategy (RIS)** to implement recovery actions in the short term. This RIS fits within the long-term implementation strategy and site-specific recovery actions identified in this Recovery Plan.

The draft recovery plan was reviewed by the public and two peer reviewers. To prepare the final Recovery Plan, we considered all comments received during the review period and made relevant revisions in response. The Five-Year Status Review and RIS are made available for informational purposes but are not subject to formal public review. We expect to update these documents as we implement the Recovery Plan and more information becomes available.

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Black Abalone Recovery Team

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EXECUTIVE SUMMARY

CURRENT SPECIES STATUS

In January 2009, we (NMFS) listed the black abalone (*Haliotis cracherodii* Leach, 1814) as endangered throughout its range from Point Arena, California, to Bahia Tortugas, Mexico (74 FR 1937, 14 January 2009). In October 2011, we designated black abalone critical habitat, to encompass rocky intertidal and subtidal habitat (to 6 m depth) along segments of the California coast from Del Mar Landing (Sonoma County) to the Palos Verdes Peninsula (Los Angeles County), and on the offshore islands (76 FR 66806, 27 October 2011).

In the mid-1900s, black abalone were abundant along the coast of central and southern California and supported commercial and recreational harvest. However, abundances may have been abnormally high in southern California, especially at the Channel Islands, due to reduced predation pressure resulting from the removal of sea otters and indigenous peoples from these areas.

In the mid-1980s, black abalone populations began to decline dramatically due to the disease called withering syndrome, which caused mass mortalities over a short period of time. Based on long-term monitoring data since the mid-1970s, black abalone populations declined by more than 80% throughout southern California and as far north as the Monterey/San Luis Obispo County line. Less severe declines (approximately 50%) have been documented even further north, into southern Monterey County.

Most populations affected by the disease remain at low densities. The species' biology (broadcast spawning, limited larval dispersal) may limit or slow natural recovery, although recruitment is occurring and a few local populations are increasing in numbers. The disease has also affected populations in Baja California, but little is known about the species' status there. Populations north of the Monterey/San Luis Obispo County line are exposed to the pathogen, but have not yet been affected by the disease. We consider populations in the area between Pacific Grove and the Monterey/San Luis Obispo County line to be representative of healthy, natural populations.

Recovery will require protection of healthy populations to the north, restoration of disease-impacted populations to the south, continued long-term monitoring throughout the species' range, and research on the species' biology and response to threats, such as disease and oil spills, to inform management and conservation actions.

HABITAT REQUIREMENTS AND LIMITING FACTORS

Black abalone occupy rocky intertidal and subtidal habitats from the upper intertidal to 6 m depth. They are most commonly observed in the middle and lower intertidal, in habitats with complex surfaces and deep crevices that provide shelter for juvenile recruitment and adult survival. Crustose coralline algae are believed to be an important component of juvenile settlement habitat, whereas attached or drift macroalgae are important food resources for post-metamorphic juvenile and adult black abalone.

We identified withering syndrome as the primary factor in the decline of black abalone. The disease caused mass mortalities in black abalone populations throughout southern California, resulting in low densities and potentially reduced genetic diversity. The disease appears to spread northward along the coast with ocean (sea surface temperature) warming events. Withering syndrome continues to pose a threat to black abalone, including populations north of the Monterey/San Luis Obispo County line that have not yet experienced high levels of mortality from the disease. Commercial and recreational harvest of black abalone also contributed to declines, until the State of California prohibited harvest in 1993. Illegal harvest continues to pose a threat, particularly along remote stretches of the central California coast where black abalone can be found in relatively high numbers in some areas.

Other threats to black abalone include: other diseases, contaminant spills and spill response activities, habitat loss, and ocean acidification. Other abalone diseases have emerged on a global scale over the past several decades and could have devastating effects if they spread to black abalone. We need to evaluate the susceptibility of black abalone to these diseases, as well as establish strict regulations to minimize the potential for their introduction to wild populations. Contaminant spills, particularly oil spills, and associated response activities pose a threat to black abalone and nearshore rocky habitat. Careful planning, preparation, and coordination to guide spill response activities will be important to assess and minimize impacts to black abalone and their habitat. Impacts to habitat can also result from landslides, coastal construction (e.g., coastal armoring, breakwater repairs), beach nourishment projects, and shifts in invertebrate and algal communities that occur when black abalone decline in an area. Finally, ocean acidification is an emerging threat that could hinder the settlement, growth, development, and survival of young abalone. At this time, however, our understanding of the potential effects of ocean acidification is limited and further studies are needed to assess the risk posed by this threat and the actions that can be taken.

RECOVERY GOALS, OBJECTIVES, AND CRITERIA

The goal of this Recovery Plan is to restore black abalone populations in the wild such that the species can be downlisted to threatened status, and subsequently delisted and removed from the Endangered Species List. To achieve this goal, we have two objectives:

1. increase the abundance, productivity, local spatial structure/distribution, and genetic diversity of black abalone populations to levels that support the species' long-term survival, viability, and resilience to existing and emerging threats; and
2. sufficiently address the threats of concern, including contaminant spills, spill response activities, illegal harvest, habitat loss, and potential introductions of new/emerging pathogens.

To develop the Recovery Plan, we convened a Black Abalone Recovery Team (BART), consisting of research biologists and resource managers from several agencies and institutions with expertise on abalone, rocky intertidal and subtidal habitats, and conservation. The BART developed several Demographic and Threats-based Recovery Criteria to evaluate the species' status and progress toward recovery.

The ESA states that to the maximum extent practicable, recovery plans shall include "objective, measurable criteria which, when met, would result in a determination… that the species be removed from the [ESA] list." The BART designed the Demographic and Threats-based Recovery Criteria to serve as those objective and measurable criteria. The Demographic Recovery Criteria represent the demographic characteristics (abundance, productivity, spatial structure, diversity) of the species when it has recovered in the wild. The Threats-based Recovery Criteria represent the conditions that need to be met to (a) reduce and/or mitigate threats that have contributed to the species' extinction risk and (b) allow the species to sustain a recovered status. The BART developed the Recovery Criteria using the best available information, identified assumptions, and expert consensus.

Demographic Recovery Criteria

The BART identified five Demographic Recovery Criteria to describe the demographic characteristics of recovered, viable populations. The Demographic Recovery Criteria focus on local densities, spatial distribution, and productivity. These criteria will be used to evaluate the species' recovery and to ensure that populations throughout the species' range are viable and resilient to existing and emerging threats. Section 3.3 (pp. 20) explains how we developed and how we propose to measure the Criteria. Appendix B summarizes results from a preliminary assessment of the Criteria using long-term monitoring data through 2015/2016.

1. *Geographic range occupied:* Black abalone continue to occur throughout their current geographic range, determined by the annual presence of individuals in all Regions over at least the past five years.
2. *Habitat-based density*: The observed density of black abalone is at least the expected density based on the habitat, at a representative subset of study sites for at least the past five years.
3. *Recruitment*: Black abalone recruit successfully at a representative subset of study sites, determined by evidence of recruitment events observed in at least two non-consecutive years over the past ten years.
4. *Size structure*: Black abalone populations are characterized by a broad distribution of size classes representing multiple cohorts that are stable, at a representative subset of study sites over at least the past five years. Size classes should include small adults (i.e., 50 to 100 mm in shell length, or SL) and large adults (i.e., greater than 100 mm SL).
5. *Population trend*: Population growth for reproductively mature individuals (greater than 50 mm SL) is stable or increasing at a representative subset of SubRegions and study sites over at least the past ten years, indicating that juveniles are surviving to adulthood to reproduce and maintain or increase populations over time.

The Geographic Range Occupied criterion considers the large-scale spatial distribution of black abalone across their range. The Density criterion considers whether local populations have the numbers and spatial distribution to support successful reproduction (addressed in the Recruitment criterion). The Size Structure criterion considers whether populations consist of multiple cohorts, whereas the Population Growth criterion considers whether survival is sufficient to contribute to

stable and/or growing populations. By achieving each of these demographic criteria, we expect to also maintain or improve genetic diversity, to support the species' resilience in the face of existing and emerging threats.

We did not include an overall abundance criterion, for two reasons. First, we do not have sufficient information to estimate a reasonable target for overall abundance. Second, factors such as small-scale abundance, density, and spatial distribution at the local population level are a better indicator of viability than overall abundance across the species' range.

We also did not include a genetic diversity criterion, because achieving the other demographic criteria will indirectly address the preservation of genetic diversity. We also do not have the data to evaluate historical levels of genetic diversity.

The Demographic Recovery Criteria apply to black abalone within the following five geographic Regions and their SubRegions (Figure ES 1):

- North-Central California Region: Del Mar Landing to Pescadero State Beach (3 SubRegions)
- Central California Region: Pescadero State Beach to Government Point (5 SubRegions)
- Southern California mainland Region: Government Point to U.S.-Mexico border (4 SubRegions)
- Channel Islands Region: Channel Islands off southern California (8 SubRegions)
- Baja California Region: U.S.-Mexico border to Punto Abreojos (3 SubRegions)

We identified Regions and SubRegions to account for variation in the historical and current status of black abalone along different segments of the species' range and to allow for differences in how we apply the Recovery Criteria to each Region. For example, black abalone populations are naturally low in the North-Central California Region and would not be expected to reach the density and recruitment levels identified in the Recovery Criteria, even when black abalone are recovered. Thus, only the Geographic Range Occupied Criterion applies to the North-Central California Region. These Regions and SubRegions are not Recovery Units or Management Units; that is, they are not essential to the recovery of the entire listed entity, nor do they reflect different management needs or authorities.

The Demographic Recovery Criteria are the same for downlisting and delisting, and differ only in the number of SubRegions that should meet the criteria (i.e., the criteria should be met in more SubRegions in order to delist the species; see Table 2 and Table 3). Criteria 2 through 5 (Habitat-based density, Recruitment, Size structure, and Population trend) apply only to the Central California, Southern California Mainland, and Channel Islands Regions. Criteria 2 through 5 do not apply to the North-Central California Region because populations in this Region are naturally low, and species recovery would not be affected as long as populations remain at current levels or increase. Criteria 2 through 5 do not apply to the Baja California Region because it is uncertain whether we can obtain data to assess these criteria. In addition, information is not available to

understand how population structure and growth in this Region may affect species' recovery. Our current assessment of the species is that downlisting and delisting goals can be achieved even if the North-Central and Baja California Regions only meet the Geographic Range Occupied criterion.

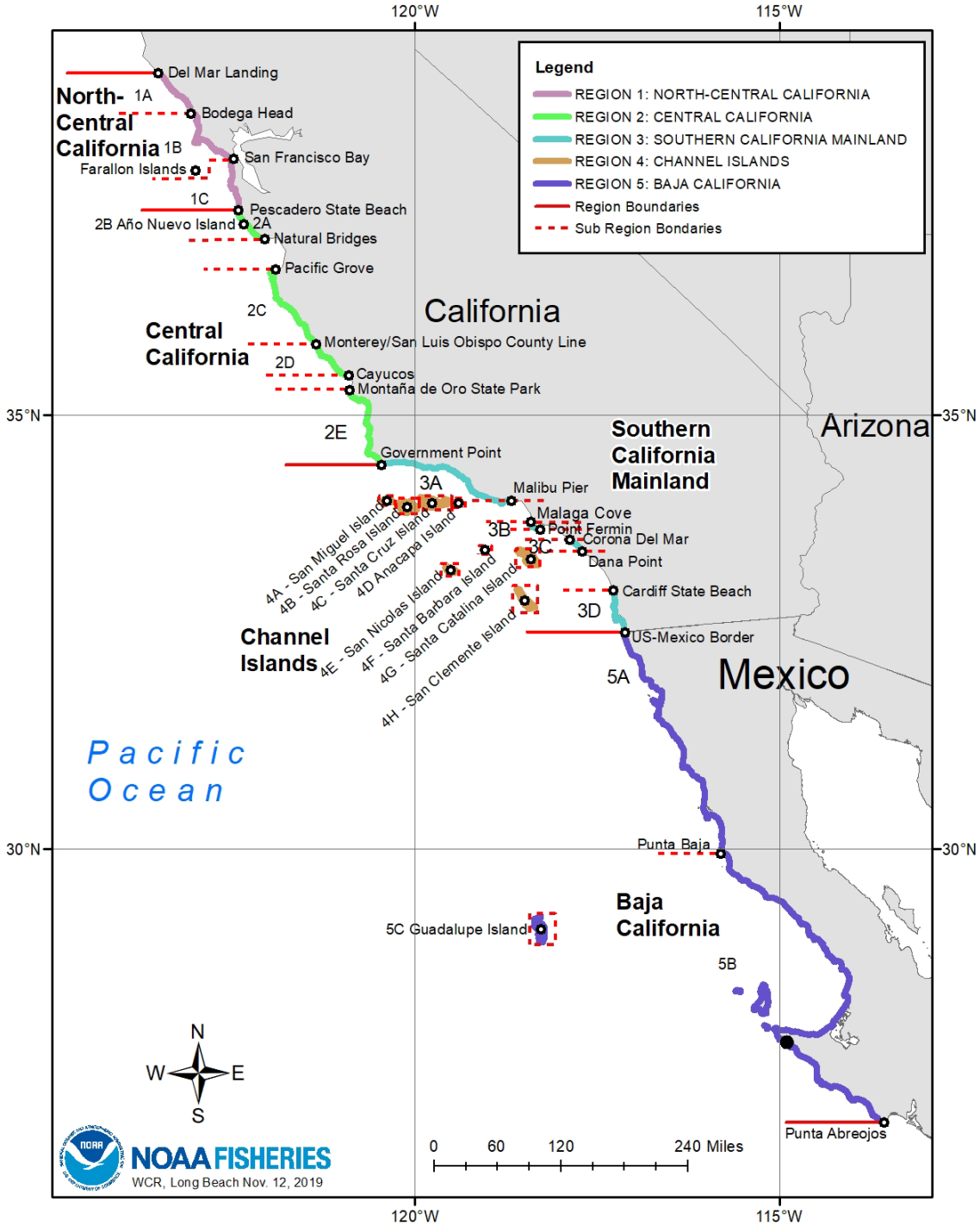

Figure ES 1. Map of Regions and SubRegions, by Richard Morse.

Threats-based Criteria

The BART identified 12 Threats-based Recovery Criteria to address the threats to black abalone. The Threats-based Recovery Criteria represent the conditions needed to minimize the impacts of threats and support the species' long-term viability. We organized the Criteria according to the five ESA listing factors. The Criteria are the same for both downlisting and delisting the species. The BART agreed that this was appropriate, because the Criteria focus on maintaining existing conditions and protections, developing plans, or coordinating with entities to address threats. How the species responds to these conditions, as measured by the Demographic Recovery Criteria, will determine whether the species should be downlisted or delisted. Section 3.3 (pp. 38) provides a more detailed description of the Threats-based Recovery Criteria.

LISTING FACTOR 1: DESTRUCTION, MODIFICATION, OR CURTAILMENT OF HABITAT OR RANGE

1. *Habitat quantity and quality:* The quantity and quality of black abalone habitat is sufficient to support and maintain viable black abalone populations.
2. *Emergency response guidance:* Emergency response plans are in place for black abalone to minimize effects on water quality, habitat, and black abalone populations during and following events such as contaminant spills, landslides, and vessel groundings.

LISTING FACTOR 2: OVERUTILIZATION FOR COMMERCIAL, RECREATIONAL, SCIENTIFIC, OR EDUCATIONAL PURPOSES

3. *Harvest regulations:* In California, harvest of black abalone remains prohibited and regulations for other abalone species are designed to protect black abalone. In Mexico, harvest of black abalone is prohibited (i.e., no federal permits are issued that allow fishing for black abalone).
4. *CDFW Abalone Recovery and Management Plan (ARMP):* The CDFW ARMP remains in place and reflects updated information adequate to ensure that black abalone will be managed to maintain the population demographics outlined in this Recovery Plan.
5. *Research and monitoring planning and coordination:* A research and monitoring plan is in place that ensures coordination among researchers and permitting agencies on research and monitoring activities, requests for permits, and permit processing.

LISTING FACTOR 3: DISEASE/PREDATION

6. *Disease research and risk management plan:* A disease research and risk management plan is in place to adequately study, monitor, and manage for diseases that affect, or may affect, black abalone in the wild and in captivity.
7. *Disease outbreaks:* Over the past ten years across all Regions, (a) evidence of a lethal outbreak of withering syndrome and/or any outbreak of other emerging diseases has not been observed in any wild black abalone populations; and (b) evidence of an outbreak of an emerging disease, that is potentially harmful and to which black abalone may be susceptible, has not been observed in captive abalone populations with a connection to state waters (e.g., effluent is not treated specifically to remove pathogens before discharge to the ocean).

LISTING FACTOR 4: INADEQUATE REGULATORY MECHANISMS

8. *Illegal take and other sources of mortality due to human activities:* State and Federal coordination (e.g., an interagency (state/federal) task force, cooperative agreement) is established to enforce regulations to protect black abalone populations, and strives to effectively alleviate or eliminate further loss of black abalone from illegal take and other human activities, as feasible (e.g., vessel groundings, landslides).
9. *State and Federal regulations regarding disease and pathogen transmission:* State and Federal regulations are in place and enforced that adequately minimize the potential for transmission of diseases and pathogens, known to be potentially harmful to black abalone, through import and within-state movement of abalone and any marine species.
10. *Coordination with Mexico and Canada on illegal trade:* Coordination with Mexico and Canada (e.g., through cooperative agreements, international task force) is implemented to adequately deter illegal international trade.
11. *Regulations in Mexico:* Regulatory mechanisms implemented by the Mexican authorities adequately protect populations of black abalone from illegal take and trade to ensure the species' long-term viability in Mexico.

LISTING FACTOR 5: OTHER FACTORS AFFECTING THE SPECIES' CONTINUED EXISTENCE

12. *Ocean acidification and elevated water temperatures:* Thermal/pH tolerance of black abalone and ocean acidification effects on black abalone are evaluated, and locations where populations are most at risk are identified. If feasible, actions are taken to address the effects of ocean acidification and elevated water temperatures at these locations to ensure the species' long-term viability.

RECOVERY STRATEGY AND ACTIONS

The purpose of this Recovery Plan is to provide a clear strategy to recover black abalone throughout its range. The Recovery Strategy will involve (see Section 2.2, pp. 17):

- Continued long-term monitoring of black abalone populations throughout their range, including Baja California;
- Restoring populations in southern California and Baja California that have experienced significant declines;
- Maintaining healthy populations in Central and North-Central California;
- Planning, coordination, and research to address current and emerging threats, such as disease, spills, illegal take, and ocean acidification; and
- Outreach and education with the public and law enforcement to support recovery efforts.

The BART identified eight major Recovery Actions to recover black abalone (see Section 4 on pp. 44 for more details):

1. **Continue to assess and monitor black abalone populations throughout their range in the wild in California and Mexico**, in cooperation with other Federal agencies, State agencies, university researchers, non-governmental organizations, and the Mexican government and institutions. This includes developing non-invasive, minimally harmful tools to evaluate population demographics (e.g., sex ratios, reproductive condition) and health.
2. **Evaluate genetic structure and diversity of wild black abalone populations** across local, regional and range-wide spatial scales.
3. **Develop and implement plans to restore black abalone populations not currently meeting the Demographic Recovery Criteria**, by enhancing local populations and/or supporting natural recovery. Restoration efforts may include habitat restoration to enhance recruitment, aggregation and translocation of individuals to increase local densities, and captive breeding and outplanting to increase densities and/or reintroduce black abalone where they have been extirpated.
4. **Develop a plan to remove black abalone from the wild in response to events such as oil spills, landslides, and vessel groundings** (i.e., of vessels carrying fuels or other substances potentially harmful to black abalone). Plans would include removing abalone before (preemptive removal) as well as after exposure (non-preemptive).
5. **Protect and restore black abalone habitat from threats** such as episodic events (e.g., oil spills, vessel groundings, sedimentation) and more chronic issues (e.g., coastal development, shifts in biota following the decline in black abalone).
6. **Continue, refine, and expand research on withering syndrome, other abalone diseases, and ocean acidification.** Research is needed to improve our understanding of the effects on black abalone individuals and populations, to inform efforts to increase the species' resiliency against these effects and to protect populations (e.g., minimize potential pathways for introducing pathogens to wild populations).
7. **Maintain and enhance binational coordination with Mexico.** Regular communication and collaboration on research, monitoring, and funding opportunities will be important to evaluate the species' status and to support recovery in Mexico.
8. **Develop and implement enforcement, public outreach, and education plans.** Further coordination on enforcement will be important to track and combat illegal take and illegal trade, while outreach and education will be critical to raise the public's awareness and support of the species' recovery.

ESTIMATED DATE AND COST OF RECOVERY:

At this time, we cannot estimate the total time to recovery with much certainty. The total time to recovery will depend on several factors including: (a) our ability to address threats such as disease and spills, which are difficult to manage with much certainty; (b) the species' biological constraints, such as episodic recruitment events; for example, recovery could occur at a slower or faster rate if catastrophic declines or significant recruitment events occur over a period of a few years, respectively; (c) the effectiveness of the recommended actions to achieve the Recovery

Criteria and any adaptations needed as we learn more about the species and its threats; and (d) the availability of funding to carry out the recovery actions.

We can estimate that recovery will likely take decades and at a minimum about 20 years. To generate a minimum estimated cost for recovery, we assumed that annual costs for each activity would be similar to the estimated costs for the first five years of implementation. We also estimated the frequency at which each activity would be conducted over the minimum 20-year period. We estimate that recovery will cost approximately $16 million for the minimum time frame of 20 years (see Cost Estimates Table below).

Cost Estimates Table: Estimated cost (in thousands of dollars) of carrying out recovery actions (RAs) during the first five years of implementation and for a minimum total time to recovery of 20 years.

Year	RA 1	RA 2	RA 3	RA 4	RA 5	RA 6	RA 7	RA 8	TOTAL
FY1	349	125	90	0	57	325	5	28	**979**
FY2	254	150	90	0	57	650	47	26	**1274**
FY3	380	115	90	155	215	650	47	6	**1658**
FY4	386	60	295	155	25	650	22	4	**1597**
FY5	272	60	230	155	25	200	22	16	**980**
TOTAL (FY1-5)	**1641**	**510**	**794**	**465**	**379**	**2475**	**143**	**80**	**6487**
TOTAL (FY1-20)	**4670**	**920**	**1580**	**465**	**2216**	**5625**	**590**	**202**	**16268**

ACRONYMS

ARMP	Abalone Recovery and Management Plan
BART	Black Abalone Recovery Team
BML	Bodega Marine Laboratory
BOEM	Bureau of Ocean Energy Management
Caltrans	California Department of Transportation
CDFW	California Department of Fish and Wildlife
CICESE	Center for Scientific Research and Higher Education
CINMS	Channel Islands National Marine Sanctuary
CMA	Cabrillo Marine Aquarium
CPP	California State Polytechnic University, Pomona
CSUF	California State University, Fullerton
ENSO	El Niño – Southern Oscillation
ESA	Endangered Species Act
ESI	Environmental Sensitivity Index
FY	Fiscal Year
GFNMS	Greater Farallones National Marine Sanctuary
MBNMS	Monterey Bay National Marine Sanctuary
MARINe	Multi-Agency Rocky Intertidal Network
MHHW	Mean higher high water
MLLW	Mean lower low water
NMFS	National Marine Fisheries Service
NMS	National Marine Sanctuaries
NPS	National Park Service
OLE	Office of Law Enforcement (NOAA)
OSPR	Office of Spill Prevention and Response (CDFW)
PISCO	Partnership for Interdisciplinary Studies of Coastal Oceans
qPCR	Quantitative Polymerase Chain Reaction
RA	Recovery Action
SL	Shell length
SNP	Single nucleotide polymorphism
SWFSC	NMFS Southwest Fisheries Science Center
UCD	University of California, Davis
UCLA	University of California, Los Angeles
UCSB	University of California, Santa Barbara
UCSC	University of California, Santa Cruz
USACE	United States Army Corps of Engineers
USCBP	United States Customs and Border Protection
USCG	United States Coast Guard
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UW	University of Washington

GLOSSARY

Endangered: In danger of extinction throughout all or a significant portion of the species' range.

Expected density: The density of black abalone that a study site can support, based on the habitat at the site. The expected density may vary by SubRegion and will be estimated using the best available information and the guidance in the population restoration plan to be developed under Recovery Action 3.1.

Observed density: The density of black abalone observed and estimated at a study site during monitoring surveys.

Occupy: In Demographic Criterion 1 (Geographic range occupied), the term "occupy" refers to living individuals of black abalone found in suitable natural habitat.

Recruitment event: In Demographic Criterion 3 (Recruitment), the term "recruitment event" refers to the addition of new individuals to a local population of black abalone due to larval settlement and survival of juveniles. A recruitment event can be detected by the observation of small juvenile black abalone (≤ 30 mm shell length).

Region: A segment of the species' geographic range, identified using major biogeographic boundaries, the black abalone critical habitat designation, and what is known about black abalone populations and habitats. Each Region consists of three or more SubRegions.

Reproductively viable population: A population that is capable of reproducing successfully, based on having sufficient numbers and densities of male and female abalone that are spatially distributed such that the distance between males and females is within the distance needed to allow a high probability of fertilization success.

Running cumulative 5-year proportion: In Demographic Criterion 4 (Size structure), the term "running cumulative 5-year proportion" refers to the cumulative proportion of individuals within the specified size class, calculated over the most recent 5-year period for which data are available.

Self-sustaining: A population that can maintain itself without external support (i.e., human intervention).

Study sites: Black abalone monitoring sites that have been established and surveyed on at least an annual cycle (generally) for at least 5 years. Appendix A lists the existing study sites. This list will be updated as sites are added and/or removed.

SubRegion: A part of the larger Region, identified based on the specific areas delineated in the black abalone critical habitat designation and similarities in black abalone status and trends.

Threatened: Likely to become endangered within the foreseeable future throughout all or a significant portion of the species' range.

Viable: A population with sufficient abundance, productivity, spatial structure, and diversity to support long-term, self-sustaining survival and resilience to existing and emerging threats. The Demographic Recovery Criteria in this Recovery Plan describe the demographic characteristics expected of viable black abalone populations.

1 BACKGROUND

The purpose of this Recovery Plan is to guide the recovery of endangered black abalone (*Haliotis cracherodii* Leach, 1814). This recovery plan is an advisory document and contains recommendations to address threats, recover populations, and ensure the species' long-term viability in the wild.

This section provides the background needed to understand the Recovery Strategy and Program presented later in this plan, including the recovery goals, objectives, criteria, and actions. In this section, we present a brief overview of the species' status, biology, and critical habitat, as well as the reasons for listing under the ESA, conservation efforts, and biological constraints and needs. This background is based on information in the Recovery Outline (NMFS 2016) and in the Black Abalone Five-Year Status Review (NMFS 2018), which provides a more detailed assessment of the species' status and is regularly updated.

1.1 Species' Biology and Status

NMFS listed black abalone as endangered under the ESA on 14 January 2009 (74 FR 1937) and designated critical habitat on 27 October 2011 (76 FR 66806). The Status Review (VanBlaricom et al. 2009) concluded that black abalone have a high probability of extinction within the next 30 years, primarily due to the disease called withering syndrome. This disease caused mass mortalities and near extirpation of black abalone in southern California and continues to threaten the species throughout its range. The 2018 Five-Year Status Review (NMFS 2018) concluded that black abalone remain endangered, despite some improvements in the species' status and our understanding of the threats. Other threats that contribute to the risk of extinction include illegal harvest, elevated sea-surface temperatures (which increase disease transmission and pathogenicity), contaminant spills, and other abalone diseases.

For each ESA-listed species under NMFS' jurisdiction, we must assign a species recovery priority number to prioritize recovery planning and implementation. We assigned black abalone a recovery priority number of 5C, out of a range of 1 (high) to 11 (low) (84 FR 18243; 30 April 2019). This recovery priority number was based on the species' moderate to high demographic risk; a moderate to high understanding of major threats; the high degree to which the United States has jurisdiction, authority, or influence over major threats; and a moderate to high certainty that management or protective actions will be effective. The "C" indicates a potential for conflicts with economic interests (e.g., if restrictions are needed to minimize or avoid effects on rocky intertidal habitats and coastal water quality). Previously, we had assigned black abalone a recovery priority number of 5 (out of a range of 1 to 12) based on guidelines published in 1990 (55 FR 24296; 15 June 1990). This was based on the species' moderate extinction risk, high recovery potential, and potential for conflicts with economic interests.

Geographic distribution, habitat, and population structure

Black abalone are marine snails with one shell, typically with 5 to 9 open respiratory pores, an anterior head, and a large muscular foot (Cox 1960). They are one of seven abalone species on the North American Pacific Coast. Black abalone occupy rocky habitats from the upper intertidal to subtidal depths of ~6 m. Historically, black abalone occurred from Crescent City (Del Norte County, California) to southern Baja California (Geiger 2004). Their current range is from Point Arena, California, to Bahia Tortugas, Mexico, including offshore islands (Figure 1; 74 FR 1937, 14 January 2009). This range represents where black abalone populations have been consistently observed in recent years; individual black abalone have been reported north or south of this area historically.

Black abalone are most commonly observed in the mid to low intertidal, in complex habitats with deep crevices that provide shelter for juvenile recruitment and adult survival (Leighton 1959, Cox 1960, Leighton and Boolootian 1963, Douros 1985, Douros 1987, Miller and Lawrenz-Miller 1993, VanBlaricom et al. 1993, Haaker et al. 1995, Leighton 2005). They feed on macroalgae, such as *Macrocystis pyrifera* (giant kelp), *Egregia menziesii* (feather boa kelp), and *Eisenia arborea* (southern sea palm) that occur as drift in the intertidal. They are able to withstand extreme variations in temperature, salinity, moisture, and wave action, and are usually strongly aggregated, sometimes stacking two or three (or more) deep atop one another (Cox 1960, Douros 1987, Leighton 2005). Genetic studies indicate limited larval dispersal, with populations composed predominantly of locally spawned individuals (Hamm and Burton 2000, Chambers et al. 2006, Gruenthal and Burton 2008).

A potential subspecies *H. cracherodii californiensis* has been described from Guadalupe Island off the Baja California coast, primarily based on differences in the number, size, and spacing of the respiratory pores (Abbott 1974, Howorth 1978). Geiger's (1998) reassessment considers this and all the previously described subspecies of black abalone to be varieties that represent either ecomorphs or examples of shell deformations of the single species, *Haliotis cracherodii*. Recent genetic analyses indicate that black abalone on Guadalupe Island are genetically different from black abalone populations sampled along the California and Baja California coast, but additional biological and genetic studies are needed to confirm whether these abalone represent a subspecies (Cepeda Ochoa 2019). At this time, we consider black abalone at Guadalupe Island to be part of the single species, *Haliotis cracherodii*.

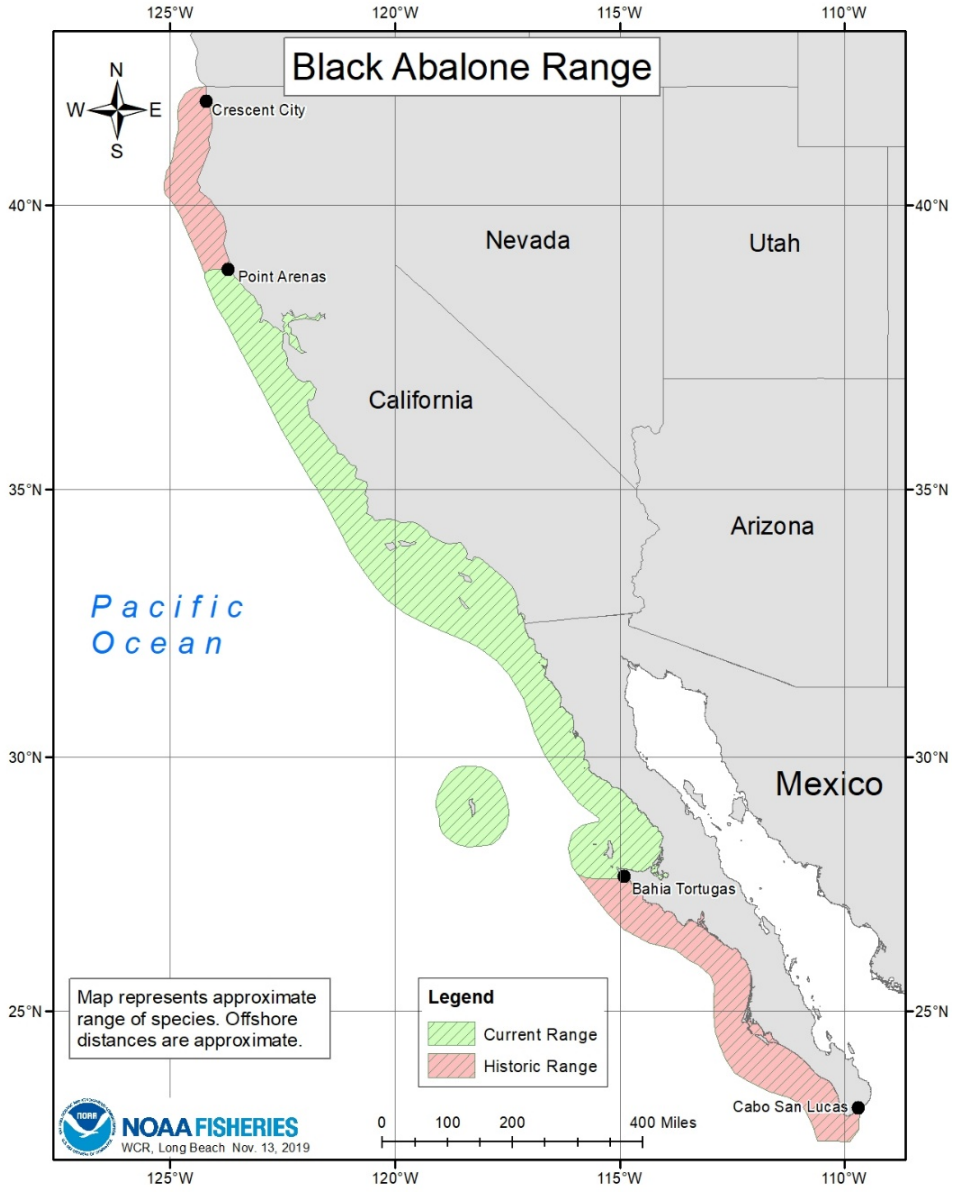

Figure 1. Geographic range of black abalone. Map by Richard Morse.

Life history and reproduction

The general life cycle of abalone includes a short planktonic larval stage, a cryptic juvenile stage, and an adult stage with separate sexes. As broadcast spawners, black abalone must be in close proximity (e.g., within several meters) to one another to successfully reproduce. Based on laboratory studies with black abalone and other abalone species, they are believed to have a short planktonic larval stage (about 3-10 days) (TERA Corp 1982a; McShane 1992). Crustose coralline algae induce larval settlement (Morse et al. 1979) and also serve as a food source for post-

metamorphic juveniles (Leighton 1959, Leighton and Boolootian 1963, Bergen 1971). Juveniles also feed on epilithic microbial and diatom films, and shift to attached and drift macroalgae as they become adults (Leighton 1959, Cox 1962, Leighton and Boolotian 1963, Webber and Giese 1969, Bergen 1971, Hines and Pearse 1982, Douros 1987). Abalone reach reproductive maturity at a size of about 50 mm shell length (SL) in females and about 40 mm SL in males (Leighton 1959, Ault 1985) and have a life span of approximately 30 years (VanBlaricom et al. 2009). Spawning has not been observed in the wild, but likely occurs from spring to early autumn (Leighton 1959, Leighton and Boolootian 1963, Webber and Giese 1969, Leighton 2005). Figure 2 diagrams the general life cycle of abalone.

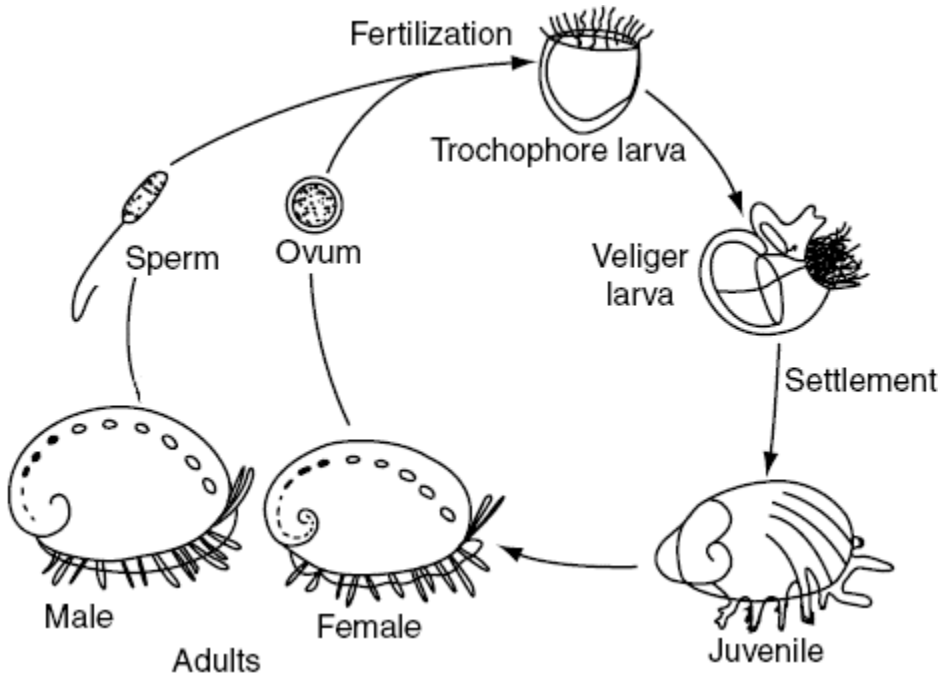

Figure 2. Abalone life cycle (from CDFW).

Population trends and status

Our understanding of black abalone populations prior to withering syndrome is based on fisheries landings data and fishery-independent survey data from the late 1970s and 1980s. Black abalone are believed to be naturally rare at the northern and southern extremes of their range (Morris et al. 1980; P. Raimondi, pers. comm., cited in VanBlaricom et al. 2009). In the mid-1900s, black abalone were most abundant south of Monterey, particularly at the Channel Islands off southern California (Cox 1960, Karpov et al. 2000). Rogers-Bennett et al. (2002) estimated a baseline abundance of 3.54 million black abalone in California, based on landings data from the peak of the commercial and recreational fisheries (1972-1981). This estimate provides a historical perspective on patterns in abundance and a reference point to compare modern day trends. We note, however, that black abalone abundances in the 1970s to early 1980s had reached

extraordinarily high levels, particularly at the Channel Islands, possibly in response to a number of factors, including: the elimination of subsistence harvests by indigenous peoples; large reductions in sea otter populations; limited access to the islands by recreational harvesters; and potentially lower market value (and, thus, reduced commercial harvest) of black abalone compared to other abalone species. Thus, our understanding of black abalone abundance and distribution for this time period may not accurately represent conditions prior to the modern abalone fishery in California.

Beginning in the mid-1980s, black abalone populations in southern California began to experience mass mortalities and decline dramatically due to the spread of withering syndrome (Tissot 1995). Withering syndrome is a disease caused by a pathogen called *Candidatus* Xenohaliotis californiensis that affects the animal's digestion and causes starvation, leading to foot muscle atrophy, lethargy, and death (Friedman et al. 2000, Friedman et al. 2002, Braid et al. 2005). Populations as far north as Cambria declined in abundance by more than 80%; populations south of Point Conception declined by more than 90% (Figure 3; Neuman et al. 2010). Less severe declines occurred in populations north of Cambria to southern Monterey County. The disease also affected black abalone in Baja California (Altstatt et al. 1996; Pedro Sierra-Rodriquez, pers. comm., cited in VanBlaricom et al. 2009) but little is known about the species' status there.

Since the initial mass mortalities and declines, densities in southern California remain low (0 to 0.5 abalone per m^2; Neuman et al. 2010). However, since the early 2000s, researchers have observed recruitment and increasing abundance at several locations (Richards and Whitaker 2012, Eckdahl 2015; VanBlaricom 2017, unpublished data), indicating that successful reproduction and recruitment are influenced by more than just density.

Figure 3. Photographs of a long-term monitoring site from 1986 to 1999, showing decline in black abalone decline. Photos: Brian Tissot, Humboldt State University

Populations north of the Monterey/San Luis Obispo County line have not yet exhibited signs of the disease (pers. comm. with Melissa Miner, UCSC, 2 August 2017). All black abalone in the wild are likely infected with the pathogen. The pathogen has been detected in coastal marine waters off central (Friedman and Finley 2003) and southern California (Moore et al. 2002) up to south Sonoma County (pers. comm. with Jim Moore, California Department of Fish and Wildlife (CDFW)/Bodega Marine Lab (BML), 20 Nov 2015), and has also been found at Southeast

Farallon Island (pers. comm. with Jim Moore, CDFW/BML, cited in VanBlaricom et al. 2009). Abalone may be infected without showing symptoms, but once symptoms develop, the animals succumb rapidly (Friedman et al. 1997a, Friedman et al. 2000, Friedman et al. 2002).

Elevated water temperatures accelerate disease transmission and mortality rates (Friedman et al. 1997, Raimondi et al. 2002, Harley and Rogers-Bennett 2004, Vilchis et al. 2005). The disease's northward progression along the coast is likely associated with sea-surface warming events (Tissot 1995, Altstatt et al. 1996, Raimondi et al. 2002), and poses a threat to the remaining healthy populations. Two factors could reduce the threat of withering syndrome on black abalone:

(1) a bacteriophage that infects the pathogen, reduces its ability to cause disease, and improves the survival of infected abalone (Friedman and Crosson 2012, Crosson et al. 2014, Friedman et al. 2014a, b); and
(2) the potential for genetically-based disease resistance (VanBlaricom et al. 2009, Friedman et al. 2014a).

1.2 Critical habitat

NMFS designated critical habitat for black abalone on 27 October 2011 (76 FR 66806). Critical habitat encompasses rocky intertidal and subtidal habitat (from the mean higher high water, MHHW, line to a depth of -6 m relative to the mean lower low water, MLLW, line) within five segments of the California coast between Del Mar Landing State Marine Reserve to the Palos Verdes Peninsula, as well as on the offshore islands (Figure 4).

San Nicolas and San Clemente Island were not eligible for designation because the U.S. Navy's integrated natural resource management plans for these islands were determined to provide protections and benefits to black abalone. We also did not designate segments of the southern California coast where black abalone historically occurred but had not been observed or were rare between 2005 to 2010. We did not designate these areas because of potentially high economic impacts, or because we lacked information to evaluate their historical importance to the species and thus were able to determine that the areas *may be essential*, but not that they *are essential*, to the conservation of black abalone.

Essential habitat features include:

- rocky substrata (e.g., rocky benches formed from consolidated rock or large boulders that provide complex crevice habitat);
- food resources (e.g., macroalgae);
- juvenile settlement habitat (rocky substrates with crustose coralline algae and crevices or cryptic biogenic structures);
- suitable water quality (e.g., temperature, salinity, pH) for normal survival, settlement, growth, and behavior; and
- suitable nearshore circulation patterns to support successful fertilization and larval settlement within appropriate habitat.

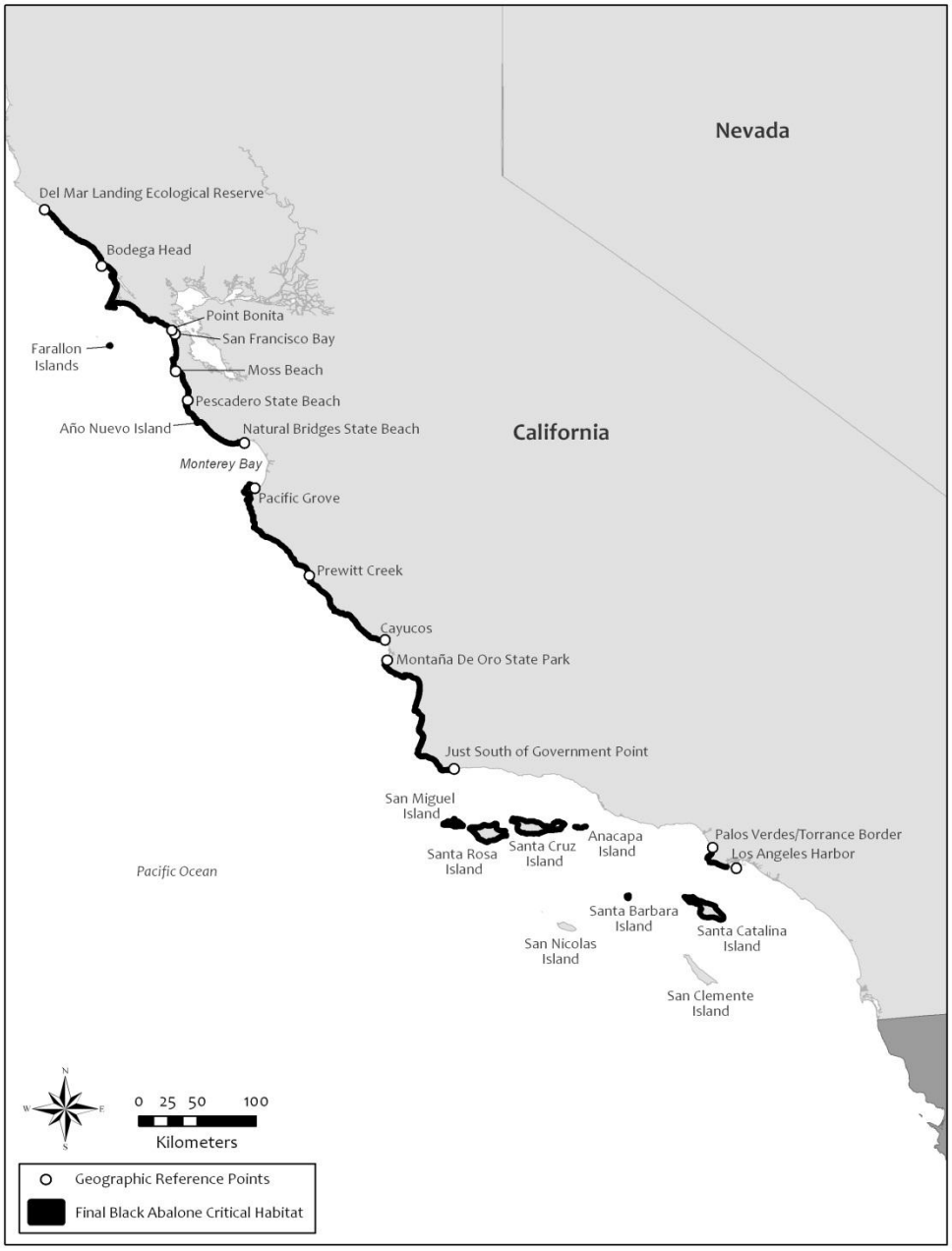

Figure 4. Designated black abalone critical habitat. Map by Mathew Dorsey.

1.3 Threats to Species Viability

This section summarizes the threats that led NMFS to list black abalone as endangered under the ESA, as well as future and emerging threats to the species. Section 3.3 discusses the proposed threats-based recovery criteria to address these threats.

Withering Syndrome: The 2009 final listing rule identified the disease called withering syndrome as the main factor in the decline of black abalone. Withering syndrome is caused by a bacterium

that infects the abalone's digestive tissues and results in starvation and shrinkage of the abalone's foot muscle. The animal eventually falls off the substrate and dies, or is eaten by another organism. The disease caused mass mortalities in black abalone populations throughout southern California, resulting in low densities and potentially reduced genetic diversity. As described above, future impacts on black abalone populations may be ameliorated by the potential for genetic resistance to the disease (Friedman et al. 2014a) and the presence of a bacteriophage that infects and reduces the ability of the pathogen to cause disease (Friedman and Crosson 2012, Friedman et al. 2014a, b).

Elevated water temperatures: Elevated water temperatures can affect black abalone by reducing survival and growth, as well as by influencing disease transmission, kelp growth, and harmful algal blooms. The indirect effects may be of more concern than the direct effects on black abalone. Laboratory studies indicate that black abalone can tolerate a wide range of temperatures in the absence of withering syndrome (TERA Corp 1982b). But, in the presence of withering syndrome, elevated water temperatures appear to accelerate disease transmission and mortality rates (Friedman et al. 1997, Raimondi et al. 2002, Harley and Rogers-Bennett 2004, Vilchis et al. 2005, Ben-Horin et al. 2013). However, as stated above, the potential for genetic resistance and the presence of the bacteriophage may reduce the lethal effects of withering syndrome on black abalone, even in the presence of elevated water temperatures.

Elevated water temperatures may also affect black abalone populations indirectly by reducing the growth of kelp and other macroalgae, which are important food resources for black abalone, or by contributing to harmful algal blooms, which can kill abalone (De Wit et al. 2014). The geographic scale of effects may also vary, from local areas affected by anthropogenic sources of thermal effluent (e.g., thermal discharges from coastal power plant facilities) to broad regions affected by long- and short-term climate change (e.g., global climate change, ENSO events, and marine heat waves).

Harvest and Illegal Take: Activities that contribute to mortality include historical harvest of black abalone (prior to 1993 when the fishery was closed) and ongoing illegal take of black abalone, particularly along remote stretches of the central California coast where numbers of black abalone are relatively high. These activities have and continue to reduce the numbers of black abalone in the wild, further reducing the ability of local populations to reproduce and sustain themselves over the long term.

Other abalone diseases: Other abalone diseases have emerged over the past several decades in abalone populations outside of California and include herpes virus infection (ganglioneuritis), viral amyotrophia, *Perkinsus olseni* infection, vibriosis, and shell deformities (sabellidosis). To date, no outbreaks have been observed in wild black abalone populations and these diseases have not been identified as a major source of mortality in the recent past or currently for black abalone. However, black abalone are potentially susceptible to these diseases. Multiple sources and pathways exist for pathogens or invasive species to be introduced to wild populations, including aquaculture facilities and the movement of abalone (e.g., import, transfer) for aquaculture,

research, and food/hobby markets. Strict regulations are needed to ensure adequate monitoring whenever animals are imported and/or transported between facilities, to protect wild populations from potentially devastating pathogens and invasive species.

Spills and spill response activities: The BART primarily focused on oil spills, recognizing that spills of other materials could also affect black abalone and their habitat. Little information exists on the potential effects of spills on black abalone. Effects could include injury or mortality and the destruction of other intertidal organisms that black abalone rely upon for settlement cues (e.g., crustose coralline algae), food (e.g., diatoms, macroalgae), and shelter. The effects may vary widely, depending on the type and amount of material involved in the spill, the location, local environmental conditions, and the status of affected populations and habitats. The location, frequency, and timing of spills cannot be predicted, although risk may be greater in areas adjacent to offshore oil fields or large, industrial coastal cities that experience heavy vessel traffic.

In 2015, three black abalone were found within the impact zone for the Refugio oil spill in Santa Barbara County, CA (pers. comm. with Jack Engle, UCSB, and Pete Raimondi, UCSC, on 5-6 June 2015). The effects of the spill on black abalone and their habitat are still under evaluation. In 1997, the Torch/Platform Irene oil spill off the Santa Barbara County coast affected 20 acres of abalone habitat and directly oiled at least one black abalone (Torch/Platform Irene Oil Spill: Final Restoration Plan and Environmental Assessment - Oct 2007). Careful planning and coordination are needed to guide spill response and post-monitoring activities, to minimize and assess damage to abalone and their habitat.

Ocean acidification: Ocean acidification is an emerging threat that could hinder normal growth, development, and survival of abalone by altering pH levels, carbonate availability, and the growth of crustose coralline algae (an important component of juvenile settlement habitat). To date, no studies have been conducted on the effects of ocean acidification on black abalone. However, red abalone have been the subject of multiple laboratory studies to evaluate the effects of low pH, either on its own or in combination with other stressors (e.g., low dissolved oxygen, elevated temperatures).

Zippay and Hofman (2010) found that low pH resulted in decreased thermal tolerance in some, but not all, larval stages. Kim et al. (2013) observed significantly reduced survival in juveniles following prolonged exposure to low oxygen, but not to both low oxygen and low pH (mimicking upwelling conditions). Prolonged exposure to low oxygen and low pH did significantly reduce the average shell growth rates, but also resulted in increased variation in growth, with some individuals growing faster under these conditions. These results indicate phenotypic plasticity or genetic variation exists in red abalone and may promote adaptation to changing ocean conditions (Kim et al. 2013, De Wit and Palumbi 2013). Boch et al. (2017) evaluated the effects of pH, dissolved oxygen, and temperature on fertilization rates, and observed lower fertilization rates with low pH, but no discernable effect from the dissolved oxygen levels tested. Interestingly, warmer water temperatures actually reduced the negative effects of low pH on fertilization rates.

The results of this study highlight the complex interactions between multiple stressors and the difficulty in applying lab results to real world conditions.

Laboratory studies have also been conducted on other abalone species within the range of black abalone (e.g., *Haliotis fulgens*: Tripp-Valdez et al. 2017; *H. kamtschatkana*: Crim et al. 2011) and worldwide (e.g., *H. iris*: Cunningham et al. 2016, Cummings et al. 2019; *H. tuberculata*: Wessel et al. 2018, Auzoux-Bordenave et al. 2019). The results of these studies vary. For example, studies focused solely on the effects of low pH found delayed development, shell abnormalities, and reduced survival and growth in larval *H. tuberculata* (Wessel et al. 2018) and *H. kamtschatkana* (Crim et al. 2011), as well as reduced shell growth, weight, and strength in juvenile *H. tuberculata* (Auzoux-Bordenave et al. 2019) and *H. iris* (Cunningham et al. 2016). Cummings et al. (2019) examined the effects of low pH at two different water temperatures and observed changes in shell characteristics, but no significant effects on survival, growth rate, or condition in juvenile *H. iris*; responses varied with temperature. Tripp-Valdez et al. (2017) observed reduced thermal tolerance in juvenile *H. fulgens* when exposed to low dissolved oxygen or both low pH and low dissolved oxygen, but not when only exposed to low pH.

Overall, the available information indicates that ocean acidification affects abalone, but the effects vary by species, life stage, the degree to which pH levels decrease, and the presence of other stressors. For black abalone in particular, our understanding of ocean acidification effects is highly uncertain, due to the lack of studies on this species, as well as variability in local conditions throughout the coast, natural variation in ocean pH, and species adaptability. Black abalone may be better able to adapt to the effects of ocean acidification than other calcifying marine organisms, because they experience natural fluctuations in pH levels in the intertidal and in the California Current Ecosystem (Feely et al. 2004, Feely et al. 2008, Feely et al. 2009, Hauri et al. 2009). Additional studies are needed to evaluate the potential effects of ocean acidification on black abalone and to identify actions to address the effects. Future studies should examine effects of multiple stressors on different life stages.

Activities and/or conditions that contribute to substrate alteration and/or destruction: Examples include coastal development, breakwater repairs, beach nourishment, recreational access, cable repairs, nearshore military operations, sea level rise, sedimentation events, and benthic community shifts (following the decline of black abalone). In most cases, the activities and their associated effects are narrow in geographic scope, occur infrequently, or have uncertain or indirect effects on black abalone. In some cases, such as with sea level rise and sedimentation, there is the potential for more widespread effects. However, the effects on black abalone are uncertain and/or low. For example, in May 2017, a landslide along the central California coast buried about a quarter mile of coastline, likely including black abalone habitat. Following the landslide, erosion has moved sediment further north and south along the coast, burying and unburying rocky intertidal habitat adjacent to the landslide. Black abalone habitat was affected but the extent of effects is still unknown. Regular monitoring of sediment movement indicates that sediments have not moved further north along the coast, where larger numbers of black abalone have been observed.

Predation: Abalone have many predators, including other gastropods, octopuses, lobsters, sea stars, fish, and sea otters (Ault 1985, Estes and VanBlaricom 1985, Shepherd and Breen 1992). Predation rates are not known at this time and the effect of predation on the status and recovery of black abalone is uncertain. Sea otter predation has been highlighted as a concern because sea otters are also protected under the ESA and are able to significantly reduce the abundance and size distributions of red abalone (Lowry and Pearse 1973, Cooper et al. 1977, Wendell 1994, Fanshawe et al. 2003). However, the level of sea otter predation on black abalone is uncertain, given that black abalone are intertidal and sea otters exhibit different predation strategies, specializing on certain prey items. Recent studies indicate a positive association between sea otters and black abalone (i.e., increasing numbers of both species) at San Nicolas Island (VanBlaricom 2017, unpublished data) and in areas that have not been affected by withering syndrome along the central California coast (Raimondi et al. 2015). The relationship between the two species is not completely understood and may change as populations of sea otters and black abalone increase. Sea otter predation may pose a low to moderate threat to the species' recovery. However, we do not address this threat in the threats-based criteria. Instead, we plan to address any potential threat of sea otter predation by working with the U.S. Fish and Wildlife Service to coordinate recovery efforts for the two species.

Environmental pollutants and toxins: Limited information exists on the effects of environmental pollutants and toxins on black abalone. Three specific cases have been documented. First, declines in black abalone growth and reproduction were observed at Palos Verdes in the late 1950s and early 1960s, due to the combined effects of an El Niño event and large-volume domestic sewage discharge (Leighton 1959, Cox 1962, Miller and Lawrenz-Miller 1993). Second, a black abalone and red abalone mortality event occurred in Diablo Cove in the 1970s, due to the local power plant's release of effluent containing toxic levels of copper (Martin et al. 1977). Third, at least one black abalone died (and possibly more) due to ballast released during the grounding of the S/V Blue Mist near Point Piedras Blancas in 2014 (Lonhart et al. 2014).

Entrainment and/or impingement of early life stages: Entrainment or impingement of larval black abalone may occur at ocean intakes, associated with facilities such as coastal power plants, desalination plants, and liquefied natural gas terminals. Given the low number of intakes along the coast and the small area affected (likely limited to the area directly around the intake), larval entrainment and impingement likely pose a low risk to species recovery and are not addressed in the threats-based recovery criteria.

1.4 Conservation Efforts

Black abalone conservation efforts have been underway for decades and include long-term monitoring to inform species status and ecosystem assessments; research on the species' biology, ecology, population dynamics, and disease; and regulatory protections regarding harvest, habitat, aquaculture, and abalone trade. Most of these efforts are ongoing and will continue to play an important role in black abalone recovery.

Researchers and resource managers throughout California continue to support and invest in long-term monitoring of black abalone populations, which is critical for implementing and tracking the species' recovery. Long-term monitoring of black abalone populations has been conducted in some areas since the mid-1970s (see Table 1). Long-term monitoring data have provided valuable information on population trends and the progression of withering syndrome along the coast. The Multi-Agency Rocky Intertidal Network (MARINe), a partnership of agencies, universities, and private groups, plays a significant role in not only conducting intertidal surveys with standardized protocols, but also making the information accessible through a shared database to resource managers, researchers, and the public. Through MARINe, survey efforts are coordinated and data are collated to provide a picture of trends throughout the species' range. Surveys have been and continue to be funded by the Bureau of Ocean Energy Management (BOEM), NMFS, and many other partners.

Table 1. Data sources for long-term monitoring studies in California (adapted and updated from Table 1 in Neuman et al. 2010). See Appendix A for a summary of survey techniques and current leads for surveys at the study sites.

Data Source	Study Location
Pete Raimondi and Melissa Miner (University of California at Santa Cruz), BOEM, and MARINe	Pigeon Point to Cayucos; Purisima to Government Point
Tenera Environmental (John Steinbeck)	Diablo Canyon
Alan and Susanne Miller (California State University at Long Beach)	Palos Verdes Peninsula
National Park Service (Dan Richards and Stephen Whitaker) and MARINe	Northern Channel Islands
Brian Tissot (Washington State University)	Santa Cruz Island
Glenn VanBlaricom (University of Washington and U.S. Geological Survey)	San Nicolas Island
U.S. Department of Defense, Navy (Jessica Bredvik and Suzanne Graham) and MARINe	San Clemente Island

Disease research was initiated following the mass mortalities of black abalone in the 1980s and 1990s. This research provides critical information on the effects of withering syndrome with and without the bacteriophage, the distribution of *Candidatus* Xenohaliotis californiensis and the bacteriophage throughout the coast, the role of *Candidatus* Xenohaliotis californiensis effluent (from abalone culture facilities) in disease transmission, and the potential for genetically-based disease resistance.

Ongoing research on abalone reproduction and recruitment dynamics (e.g., how the distance between individuals affects fertilization success) will be critical to evaluate population viability and to guide enhancement efforts. Studies are also underway to develop captive breeding methods for black abalone, to support a better understanding of the species' reproduction and early life

stages, as well as future laboratory research and outplanting efforts.

Commercial and recreational harvest of black abalone have been prohibited in California since 1993. Passage of the Thompson bill (AB 663) in 1997 created a moratorium on taking, possessing, or landing abalone for commercial or recreational purposes in ocean waters south of San Francisco, including all offshore islands. Illegal take remains a problem, leading CDFW to prioritize enforcement against illegal take of abalone. Areas designated as National Marine Sanctuaries, National Parks (e.g., Channel Islands National Park), or State marine reserves and marine conservation areas provide an added level of enforcement. California also closely monitors state aquaculture facilities and strictly regulates the transfer of abalone (e.g., imports, transport between facilities) for aquaculture, research, and food/hobby markets, to minimize the potential for spreading pathogens and invasives between facilities and to wild populations.

1.5 Overall Recovery Status and Biological Constraints and Needs

Black abalone populations throughout California face high demographic risks associated with their abundance, growth and productivity, spatial structure and connectivity, and diversity (VanBlaricom et al. 2009). Severe declines have occurred over a large portion of the species' range, due primarily to withering syndrome. Long-term monitoring indicates that populations affected by withering syndrome remain at low abundance and density. The disease appears to progress northward along the coast with sea surface warming events, threatening the remaining healthy populations (Raimondi et al. 2002). However, the bacteriophage and potential genetic resistance could ameliorate the disease's effects (Friedman et al. 2014a, b). In addition to withering syndrome, threats of concern include illegal take, contaminant spills and associated response activities, elevated water temperatures, ocean acidification, and the potential introduction of other pathogens known to affect abalone. For some of these threats, the effects on black abalone are highly uncertain, given the unpredictability of their occurrence (spills, introduction of pathogens) and the lack of information on species-specific effects. Research and monitoring will be critical to inform management decisions, recovery planning, and recovery efforts.

The species' biology (e.g., relatively long-lived, broadcast spawners, limited larval dispersal) may limit or slow natural recovery, although recruitment is occurring and numbers are increasing in a few localized areas. Successful reproduction depends on spatial and temporal synchrony among spawning individuals; that is, males and females spawning simultaneously in close proximity to one another (within meters) have the greatest likelihood of reproductive success. Natural recovery of severely-reduced populations is likely a slow process, because having few reproductive adults reduces reproductive success and subsequent recruitment of larval abalone. Studies indicate that a critical minimum adult density is needed to support successful reproduction and recruitment, though estimates of this critical density vary (Babcock and Keesing 1999: 0.15 – 0.20 abalone per m^2; Neuman et al. 2010: 0.34 abalone per m^2; Tissot 2007: 0.75 – 1.1 abalone per m^2).

To recover black abalone, we will need to:

(a) protect the healthy populations not yet affected by the disease, but likely infected with the pathogen, and
(b) increase the abundance and density of disease-impacted populations to healthy, viable levels, which may be lower than the extraordinarily high abundances in the mid-1900s.

Research and monitoring are needed to develop methods to protect and enhance populations and to evaluate the dynamics and effects of withering syndrome and other abalone diseases. Long-term monitoring throughout the species' range, including in Baja California, will be critical to evaluating the species' status, trends, and population dynamics. Finally, further study is needed on several aspects of black abalone biology and life history. In particular, information is limited on the species' spawning habits (e.g., habitat, seasons, environmental triggers, frequency) and recruitment dynamics, largely due to the difficulties associated with working in rocky intertidal habitats, the cryptic nature of newly settled larvae and juveniles, and the lack of consistent methods to spawn black abalone in captivity. Recovery of the species will involve addressing these data gaps to inform recovery efforts and assess the species' progress toward recovery.

2 RECOVERY STRATEGY

The purpose of this Recovery Plan is to establish a strategy to rebuild and ensure the long-term viability of black abalone in the wild. We envision that when black abalone are recovered, they will have sufficient recruitment and survival to support populations that are viable over the long-term and resilient to known and emerging threats. We also envision that threats to the species and their habitat will be sufficiently addressed to ensure a high probability of survival into the future. By achieving these goals, black abalone will no longer be in danger of extinction and can be removed from the Federal list of endangered and threatened species.

This Recovery Strategy section presents and justifies the recommended recovery program for black abalone. Under "Key Facts and Assumptions," we summarize the main concerns identified in the Background (Section 1) regarding the species' demography, threats, biological constraints, and needs. These Key Facts and Assumptions form the basis for the recommended recovery program. Under "Primary Focus and Justification," we identify the main components of the recommended recovery program that are needed to address these main concerns.

2.1 Key Facts and Assumptions

Long-term monitoring of black abalone throughout California has provided critical data to inform our assessment of the species' status and recovery needs. Black abalone once supported commercial and recreational fisheries in California and Mexico, with extremely (and likely abnormally) high densities in southern California, especially on the northern Channel Islands. Beginning in the 1980s, black abalone experienced severe declines from southern California north into San Luis Obispo County. Although commercial and recreational harvest contributed to these declines, the primary cause was withering syndrome, a disease that resulted in mass mortalities of black abalone. In affected populations, numbers declined by 80 to 100%. Populations in parts of southern California continue to persist at low densities.

As stated in the Background (Section 1), populations north of the Monterey/San Luis Obispo County line have not yet been affected by the disease and are considered robust and healthy. However, the northward progression of withering syndrome along the coast poses an imminent threat to these populations. Genetically-based disease resistance, apparent in a few locations, and a recently-discovered bacteriophage that reduces the impact of withering syndrome could ameliorate the disease's effects on black abalone. In addition to withering syndrome, other factors have the potential to affect black abalone and their habitat, including illegal harvest, contaminant spills and associated response activities, ocean warming, ocean acidification, and the potential introduction of other pathogens known to affect abalone. The effects of these threats on black abalone are highly uncertain, given the unpredictability of their occurrence and the lack of information on species-specific effects. Research and monitoring will be critical to better

understand these effects and to inform management decisions, recovery planning, and recovery efforts.

Based on this information, we made the following assumptions and conclusions:

Assumption: In most mainland black abalone populations south of the Monterey/San Luis Obispo County line, surviving animals are too far apart to successfully spawn and reproduce at the levels needed to support natural recovery. Natural recruitment and increasing numbers have been observed in some areas, but these phenomena may not be occurring at the scale or scope necessary for natural recovery. In addition, larval dispersal distances are generally thought to be short and thus recruitment in one area may not contribute substantially to recovery in other areas.

Conclusion: Black abalone populations on the mainland coast of southern California and at most of the Channel Islands are below natural, self-sustaining levels, and active restoration efforts (e.g., habitat restoration, aggregation or translocation of individuals, captive breeding and outplanting) may be required to support recovery.

Assumption: Black abalone populations north of the Monterey/San Luis Obispo County line have not yet been affected by withering syndrome and remain at natural, healthy levels.

Conclusion: Black abalone populations north of the Monterey/San Luis Obispo County line are representative of natural, healthy populations and should be protected and maintained. In particular, populations between Pacific Grove and the Monterey/San Luis Obispo County line are considered robust and viable. We note that this stretch of coastline from Pacific Grove to the Monterey/San Luis Obispo County line spans only about 110 kilometers, a small fraction of the species' former range. Also, black abalone populations there have declined in recent years due to illegal harvest and are likely infected with the pathogen that causes withering syndrome (see Section 1.1), but have not yet developed the disease due to low water temperatures.

Assumption: The impacts of withering syndrome will continue to move northward along the coast with warm water events and cause mortalities, although the presence of genetically-based disease resistance or the presence of the bacteriophage, with its ability to reduce the disease's pathogenicity, may limit the severity and scope of disease effects.

Conclusion: Mass mortalities resulting from withering syndrome and elevated water temperatures are a primary threat to species recovery. Continued research and monitoring are needed to evaluate and address this threat.

2.2 Primary Focus and Justification of Recovery Efforts

The proposed recovery program consists of several components designed to address the most pressing knowledge gaps, critical demographic factors, and key threats to black abalone. Some will be addressed simultaneously and some will necessarily follow others. The main components of the recovery program are:

Continue to monitor and assess the status and health of black abalone populations throughout their range in the wild in California and Mexico. Long-term monitoring programs have and will continue to form the basis for evaluating the species' status and progress toward recovery. We should continue existing long-term monitoring programs and expand or establish new programs where needed. For example, expanded efforts may be needed in Baja California where we have very little information on the species' historical and current status. Monitoring will not only involve tracking population trends but also health (disease) and genetic diversity in California and Baja California. Thus, health and genetic monitoring protocols should be developed and coordinated with researchers in Mexico. This monitoring will inform the other components of the recovery strategy, including population and habitat protection and restoration efforts; disease research; and enforcement, outreach, and education. Regular communication and coordination on research, monitoring, and funding opportunities will be important to evaluate the species' status and support recovery throughout their range.

Restore populations in southern California and Baja California that have experienced significant declines. Disease-induced mass mortalities caused black abalone numbers to decline by more than 80% at long-term monitoring sites south of Monterey. Most of these populations persist at low densities or have been locally extirpated. To recover populations, we should evaluate and implement restoration efforts, where needed, to enhance local populations and/or support natural recovery. Our goal would be to restore populations to healthy, viable levels, which may be less than the extraordinarily high densities and abundances observed prior to the disease. Potential restoration tools include habitat restoration, local aggregation of individuals, translocation of individuals, and captive breeding and outplanting. Research and pilot studies are needed to evaluate the feasibility and efficacy of these tools. At the same time, we should further develop plans to guide restoration efforts and ensure adequate consideration and management of risks, incorporating information gained from genetic analysis, disease/health monitoring, and research.

Protect remaining healthy populations in central and north-central California. Black abalone populations north of Monterey have not yet been affected by withering syndrome and are relatively healthy and robust. However, withering syndrome continues to pose a threat to these populations, as well as other factors, including illegal harvest, ocean acidification, and localized events and activities such as oil spills, vessel groundings, landslides, and sedimentation from coastal armoring and beach nourishment projects. Efforts are needed to address these threats to protect black abalone and their habitat, particularly in areas that provide high quality habitat and that may have previously supported sustainable populations.

Plan, coordinate, and conduct research to address current and emerging threats, such as disease, contaminant spills, illegal take, and ocean acidification. Threats to black abalone include episodic events that are difficult to predict, as well as chronic issues that have and will continue to affect the species. For unpredictable events like spills, we need to plan ahead and coordinate with entities to develop appropriate response plans and guidance for decision making. For regulatory issues such as illegal harvest and trade, we should coordinate with Federal and State enforcement and with Mexico and Canada to track illegal activities, support enforcement measures, and apply appropriate penalties to deter further violations. For ongoing issues like disease and ocean acidification, we need to conduct additional research to identify the effects on black abalone, the mechanisms for those effects, what populations are most vulnerable, and ways to minimize the potential adverse effects.

Outreach and education with the public to support recovery efforts. Outreach and education will be critical to raise public awareness about the species and about what the public can do to protect and recover black abalone along our coast. This can range from reporting suspected poachers to promoting responsible practices in live trade of abalone (e.g., for aquaculture, hobby, pet industry purposes) and supporting healthy oceans.

3 RECOVERY GOAL, OBJECTIVES, and CRITERIA

3.1 Recovery Goal

The goal of this Recovery Plan is to **restore black abalone populations in the wild** such that the species can be downlisted to threatened status and subsequently delisted (i.e., removed from the Endangered Species List). Recovery includes restoring black abalone throughout their range, including in Baja California, and will require collaboration with agencies and partners throughout California as well as Mexico.

The following sections discuss the recovery objectives and criteria. The recovery objectives describe the conditions necessary to achieve the recovery goal. The recovery criteria are the targets, or values, used to measure progress toward achieving the recovery objectives.

3.2 Recovery Objectives

The first objective is to increase the abundance, productivity, spatial structure, and diversity of black abalone populations to levels that support the species' long-term survival, viability, and resilience to threats. To achieve this objective, we need to:

- protect and maintain currently robust populations;
- promote increased survival and reproductive success in populations that have experienced severe declines; and
- establish populations where they have become locally extirpated (due to disease or other threats).

To sustain populations over the long-term, we need to address the effects of past threats (i.e., severe declines due to withering syndrome), as well as the effects of ongoing and emerging threats that could affect species recovery into the future (e.g., disease, poaching, ocean acidification, ocean warming). To assess population viability over time, we should continue long-term monitoring throughout California and expand efforts where needed.

The second objective is to sufficiently address the threats of concern, as identified by the BART in the threats assessment. Threats of concern include contaminant spills, spill response activities (e.g., clean-up efforts, use of chemical cleaners and dispersants), illegal harvest, and potential introductions of pathogens. These threats could have a severe effect on black abalone populations at the local (spill events, poaching cases) as well as species-wide (pathogens) scale.

To evaluate progress toward each of these recovery objectives and the overall goal, we developed the Recovery Criteria described below. The Demographic Recovery Criteria primarily address the first objective and the Threats-based Recovery Criteria primarily address the second objective. Because the two objectives relate to and affect one another, some of the criteria may address both objectives.

3.3 Recovery Criteria

The ESA states that to the maximum extent practicable, recovery plans shall include "objective, measurable criteria which, when met, would result in a determination… that the species be removed from the [ESA] list." The BART designed the Demographic and Threats-based Recovery Criteria to serve as those objective and measurable criteria. We believe that achieving the conditions of the Recovery Criteria would result in a determination to downlist and delist the species. Thus, the recovery criteria will be used to evaluate the species' progress toward recovery. The Demographic Recovery Criteria represent the demographic characteristics (abundance, productivity, spatial structure, diversity) we would expect when the species has improved in status from endangered to threatened (downlisting criteria) and when the species is recovered (delisting criteria). The Threats-based Recovery Criteria represent the conditions needed to minimize the effects of the threats and support the species' long-term viability.

We developed the Recovery Criteria using the best available information (including peer reviewed literature, gray literature, unpublished data), identified assumptions, and expert consensus. In some cases, the BART was able to define quantitative Recovery Criteria because supporting information, such as models or data, was available. In cases where the best available information was limited, the BART defined qualitative, measurable Recovery Criteria that can be modified as more information becomes available.

Geographic Regions

The Demographic and Threat-based Recovery Criteria refer to five geographic Regions, each consisting of several SubRegions (Figure 5 and 6). These Regions and SubRegions are not Recovery Units or Management Units (defined as special units that are essential to the recovery of the entire listed entity, or that reflect different management needs or authorities). Instead, we identified the Regions to account for variation in the historical and current status of black abalone along different segments of the species' range, and to allow for differences in how the Recovery Criteria are applied across Regions. For example, some of the Demographic Recovery Criteria do not apply to all five Regions, because the BART agreed that achieving those criteria in all five Regions is not necessary for species recovery (for more details, see "Demographic Recovery Criteria: Population Density, Structure, and Growth" on pp. 31).

The BART defined the Regions and SubRegions using major biogeographical boundaries, the specific areas identified in the critical habitat designation, and what is known about black abalone populations and habitats, based largely on MARINe data and observations by BART members involved in long-term monitoring. The number of SubRegions varies by Region.

The Demographic Recovery Criteria also refer to "study sites," which are the basic unit for evaluating the Demographic Recovery Criteria. Each Region and SubRegion contains study sites that have been established for at least five years and where long-term monitoring of black abalone is conducted at least annually. Researchers have also established sites that are monitored less frequently or have only been surveyed once; however, the frequency of monitoring at these sites

is not sufficient to evaluate the Demographic Recovery Criteria. Appendix A lists the known, existing study sites within each Region and SubRegion and summarizes the following information for each study site: entities involved in monitoring surveys, frequency of monitoring, the date the site was established, the last date the site was surveyed, site dimensions, and survey methods. This list will be updated as study sites are added or removed.

Below, we list and describe each Region and its SubRegions.

REGION 1 – NORTH CENTRAL CALIFORNIA: DEL MAR LANDING TO PESCADERO STATE BEACH

This Region encompasses the northernmost limit of the species' current range. Long-term monitoring data indicate that black abalone populations within this Region are naturally low. There are fewer monitoring sites and fewer black abalone than in other Regions. Populations naturally fluctuate from year to year, declining to zero black abalone in some years at certain study sites. Habitat features (e.g., rocky substrate, water quality) are generally considered to be in good condition (NMFS 2011). We delineated the following SubRegions based on the specific areas identified in the critical habitat designation (NMFS 2011):

- 1A – Del Mar Landing to Bodega Head
- 1B – Bodega Head to San Francisco Bay, including the Farallon Islands
- 1C – San Francisco Bay to Pescadero State Beach

REGION 2 – CENTRAL CALIFORNIA: PESCADERO STATE BEACH TO GOVERNMENT POINT

This Region encompasses a significant portion of the current population of black abalone along the mainland California coast. This Region contains black abalone populations that have not experienced declines due to withering syndrome (from southern Monterey County north to Pescadero), as well as populations that have experienced declines due to withering syndrome (south of Monterey/San Luis Obispo County Line). The primary threats within this Region are disease and illegal harvest. Pescadero State Beach was selected as the boundary between the North-Central and Central California Regions, because black abalone populations are naturally more abundant at study sites south of Pescadero State Beach compared to sites to the north. The SubRegion from Pacific Grove to the Monterey/San Luis Obispo County line contains black abalone populations that are considered healthy, robust, and viable. The SubRegion from the Monterey/San Luis Obispo County Line to Cayucos represents a transition zone between the healthy, non-disease impacted populations to the north, and severely impacted populations to the south. The SubRegion from Montaña de Oro State Park to Government Point has been severely impacted by disease, but was included in this Region because habitat and oceanographic conditions are more similar to other Central California SubRegions than to those along the Southern California mainland. We delineated the following SubRegions based on the specific areas identified in the critical habitat designation (NMFS 2011):

- 2A – Pescadero State Beach to Natural Bridges State Beach
- 2B – Año Nuevo Island
- 2C – Pacific Grove to Monterey/San Luis Obispo County Line
- 2D – Monterey/San Luis Obispo County Line to Cayucos
- 2E – Montaña de Oro State Park to Government Point

REGION 3 – SOUTHERN CALIFORNIA MAINLAND: GOVERNMENT POINT TO THE U.S. MEXICO BORDER

This Region encompasses study sites where black abalone have been severely affected by withering syndrome. Government Point was selected as the boundary between the Central and Southern California mainland Regions because of its proximity to Point Conception (a well-recognized biogeographical boundary) and because it is the southern-most long-term study site for Central California. Black abalone populations within this Region have been locally extirpated or generally remain at low densities. At most study sites, black abalone focused surveys have not been conducted for several years. However, annual monitoring for other intertidal species is conducted at many sites and includes surveys in habitat that could support black abalone. In recent years, habitat evaluation surveys resulted in the discovery of black abalone at sites in Palos Verdes and Orange County where the species was thought to be absent (Eckdahl 2015), indicating that some recruitment is occurring. We delineated the following SubRegions based on the specific areas identified in the critical habitat designation (NMFS 2011), as well as the best available information on historically occupied areas and rocky habitat along the coast.

- 3A – Government Point to Malibu Pier
- 3B – Palos Verdes Peninsula (Malaga Cove to Point Fermin)
- 3C – Corona Del Mar State Beach to Dana Point
- 3D – Cardiff State Beach to US-Mexico border

REGION 4 – CHANNEL ISLANDS

This Region encompasses the eight Channel Islands, identified as a separate Region from the Southern California mainland Region based on differences in habitat and the status of black abalone populations. Populations at the islands have been severely affected by withering syndrome and generally remain at low densities. However, recruitment and increasing numbers have been observed at a few study sites, namely on San Nicolas and Santa Cruz Islands. We delineated the following SubRegions based on the specific areas identified in the critical habitat designation (NMFS 2011):

- 4A – San Miguel Island
- 4B – Santa Rosa Island
- 4C – Santa Cruz Island
- 4D – Anacapa Island
- 4E – Santa Barbara Island
- 4F – San Nicolas Island
- 4G – Santa Catalina Island
- 4H – San Clemente Island

REGION 5 – BAJA CALIFORNIA: U.S.-MEXICO BORDER TO PUNTA ABREOJOS

This Region encompasses the southernmost limit of the species' known range. Information about black abalone in this Region is based on a few surveys conducted in the early 2000s. We

delineated the following SubRegions based on biogeographic boundaries and the limited information available on the areas historically and currently occupied by black abalone.

- 5A – US-Mexico border to Punta Baja
- 5B – Punta Baja to Punta Abreojos, including islands
- 5C – Guadalupe Island

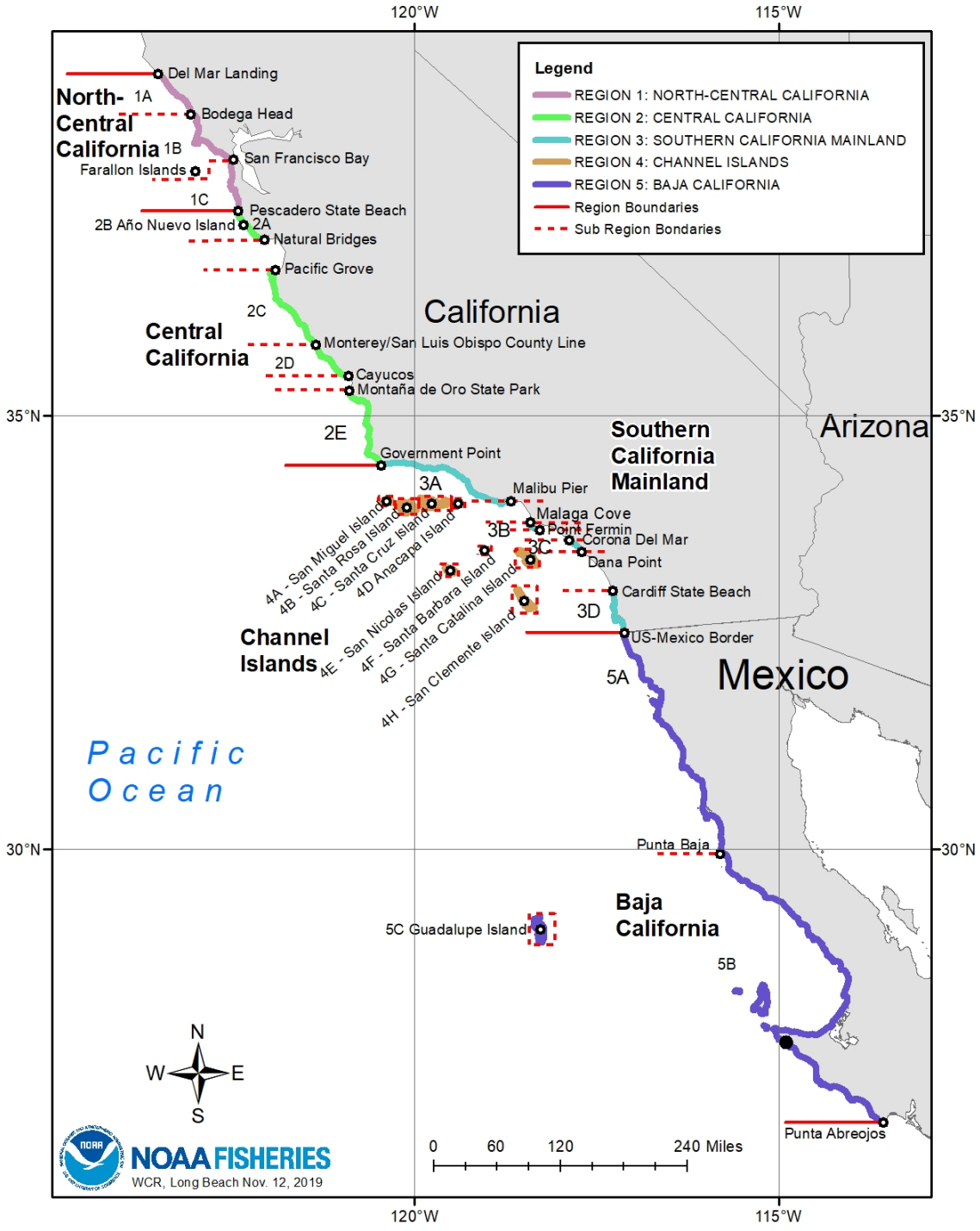

Figure 5. Map of Regions and SubRegions, by Richard Morse.

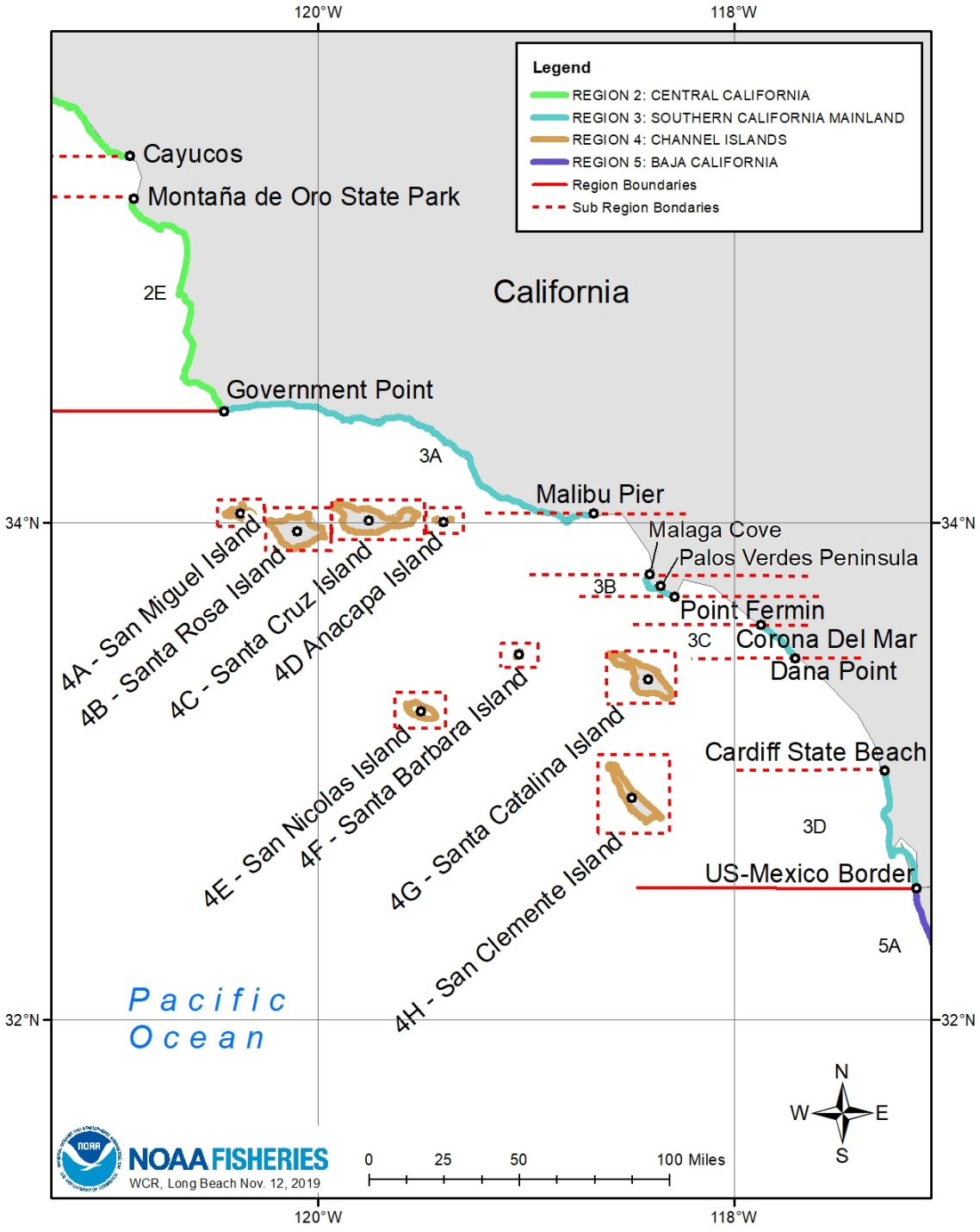

Figure 6. Close-up map of the Southern California mainland Region and Channel Islands Region, by Richard Morse.

Demographic Recovery Criteria

As documented in the final listing decision (74 FR 1937) and Five-Year Status Review (NMFS 2018), NMFS concluded that black abalone have a high extinction risk, based on several factors: severe population declines, low local densities, low population growth and productivity, a spatial structure that limits connectivity between populations, the potential loss of genetic diversity, and the continued threat of disease (withering syndrome). To address these risks, we developed five Demographic Recovery Criteria that focus on local densities, spatial distribution, size structure, recruitment, and productivity.

The Demographic Recovery Criteria (Table 2, Table 3, and Figure 7) describe the characteristics of recovered, viable black abalone populations and are to be used to evaluate the species' recovery. The Geographic Range Occupied criterion considers the large-scale spatial distribution of black abalone across their range. The Density criterion considers whether local populations have the numbers and small-scale spatial distribution to support successful reproduction, addressed in the Recruitment criterion. The Size Structure criterion considers whether populations consist of multiple cohorts, whereas the Population Growth criterion considers whether sufficient numbers of individuals are surviving to contribute to stable and/or growing populations. By achieving each of these Criteria, we expect to also maintain or improve genetic diversity to support the species' resilience in the face of existing and emerging threats.

The Criteria are the same for both downlisting and delisting and differ only in the number of SubRegions within each Region that should meet the conditions for each criterion (Table 3). All five Demographic Recovery Criteria apply to the Central California, Southern California mainland, and Channel Islands Regions. However, only the Geographic Range Occupied criterion applies to the North-Central and Baja California Regions. This means that populations in the North-Central and Baja California Regions would not need to meet the other Demographic Recovery Criteria (Habitat-based density, Recruitment, Size structure, and Population trend) in order to consider downlisting or delisting the species. Populations in the North-Central California Region are naturally low. We expect that species recovery would not be affected as long as populations there remain at current levels or increase. In the Baja California Region, we lack information to understand how population status there may affect species recovery. As we obtain more information, we may decide to apply the other Demographic Recovery Criteria to this Region. However, our current assessment of the species is that downlisting and delisting goals can be achieved even if this Region only meets the Geographic Range Occupied criterion.

Below, we describe the Demographic Recovery Criteria, how they were developed, and how we propose to assess each at this time. By design, the Criteria are broad whereas the methods for assessing them are specific. We developed the proposed methods using the best available information and the current level of sampling efforts. To assess the Criteria, we will use the most recent monitoring data for the study sites and adapt our methods as we learn more over time.

To evaluate whether our proposed methods are appropriate for assessing the Criteria, we did a test run using long-term monitoring data through 2015/2016. This test run also allowed us to evaluate

the current status of black abalone against the Demographic Recovery Criteria. Appendix B summarizes the results of our analysis. Overall, none of the SubRegions met all of the Demographic Recovery Criteria. Only one SubRegion (from Pacific Grove to the Monterey/San Luis Obispo County line in the Central California Region) met four out of the five criteria (all but the Population Trend Criterion). In this SubRegion, black abalone populations are generally considered robust and healthy, but are subject to illegal harvest, which may contribute to declining trends at some study sites.

Table 2. Demographic Recovery Criteria for black abalone.

GEOGRAPHIC RANGE OCCUPIED	
Criterion 1:	***Geographic range occupied*** **Black abalone continue to occur throughout their current geographic range, determined by the annual presence of individuals in all Regions over at least the past five years.**
POPULATION DENSITY, STRUCTURE, AND GROWTH Criteria 2 through 5 apply only to the Central California, Southern California mainland, and Channel Islands Regions (for details see the "Demographic Recovery Criteria – Population Density, Structure, and Growth" section, pp. 31).	
Criterion 2:	***Habitat-based density*** **The observed density of black abalone is at least the expected density based on the habitat, at a representative subset of study sites for at least the past five years.**
Criterion 3:	***Recruitment*** **Black abalone recruit successfully at a representative subset of study sites, determined by evidence of recruitment events observed in at least two non-consecutive years over the past ten years.**
Criterion 4:	***Size Structure*** **Black abalone populations are characterized by a broad distribution of size classes representing multiple cohorts that are stable, at a representative subset of study sites over at least the past five years. Size classes should include small adults (i.e., 50 to 100 mm in shell length, or SL) and large adults (i.e., greater than 100 mm SL).**
Criterion 5:	***Population trend*** **Population growth for reproductively mature black abalone (greater than 50 mm SL) is stable or increasing at a representative subset of SubRegions and study sites over at least the past ten years, indicating that juveniles are surviving to adulthood to reproduce and maintain or increase populations over time.**

Table 3. Summary of the Demographic Recovery Criteria and the number of SubRegions per Region within which the criteria should be met in order to downlist or delist black abalone.

DOWNLISTING To downlist black abalone, the following Demographic Recovery Criteria should be met within the specified number of SubRegions per Region below:	**DELISTING** To delist black abalone, the following Demographic Recovery Criteria should be met within the specified number of SubRegions per Region below:
Criterion 1: Geographic range occupied • North Central California Region: At least two of the three SubRegions. • Central California Region: All SubRegions. • Southern California mainland Region: At least three of the four SubRegions, including SubRegion 3B (Palos Verdes Peninsula). • Channel Islands Region: At least seven of the eight SubRegions. • Baja California Region: All SubRegions.	***Criterion 1: Geographic range occupied*** • North Central California Region: At least two of the three SubRegions. • Central California Region: All SubRegions. • Southern California mainland Region: At least three of the four SubRegions, including SubRegion 3B (Palos Verdes Peninsula). • Channel Islands Region: At least seven of the eight SubRegions. • Baja California Region: All SubRegions.
Criterion 2: Habitat-based density ***Criterion 3: Recruitment*** ***Criterion 4: Size Structure*** ***Criterion 5: Population trend*** ● North Central California Region: Not applicable. ● Central California Region: At least three of the five SubRegions. ● Southern California mainland Region: At least one of the four SubRegions. ● Channel Islands Region: At least four of the eight SubRegions. ● Baja California Region: Not applicable.	***Criterion 2: Habitat-based density*** ***Criterion 3: Recruitment*** ***Criterion 4: Size Structure*** ***Criterion 5: Population trend*** ● North Central California Region: Not applicable. ● Central California Region: At least four of the five SubRegions. ● Southern California mainland Region: At least two of the four SubRegions. ● Channel Islands Region: At least six of the eight SubRegions. ● Baja California Region: Not applicable.

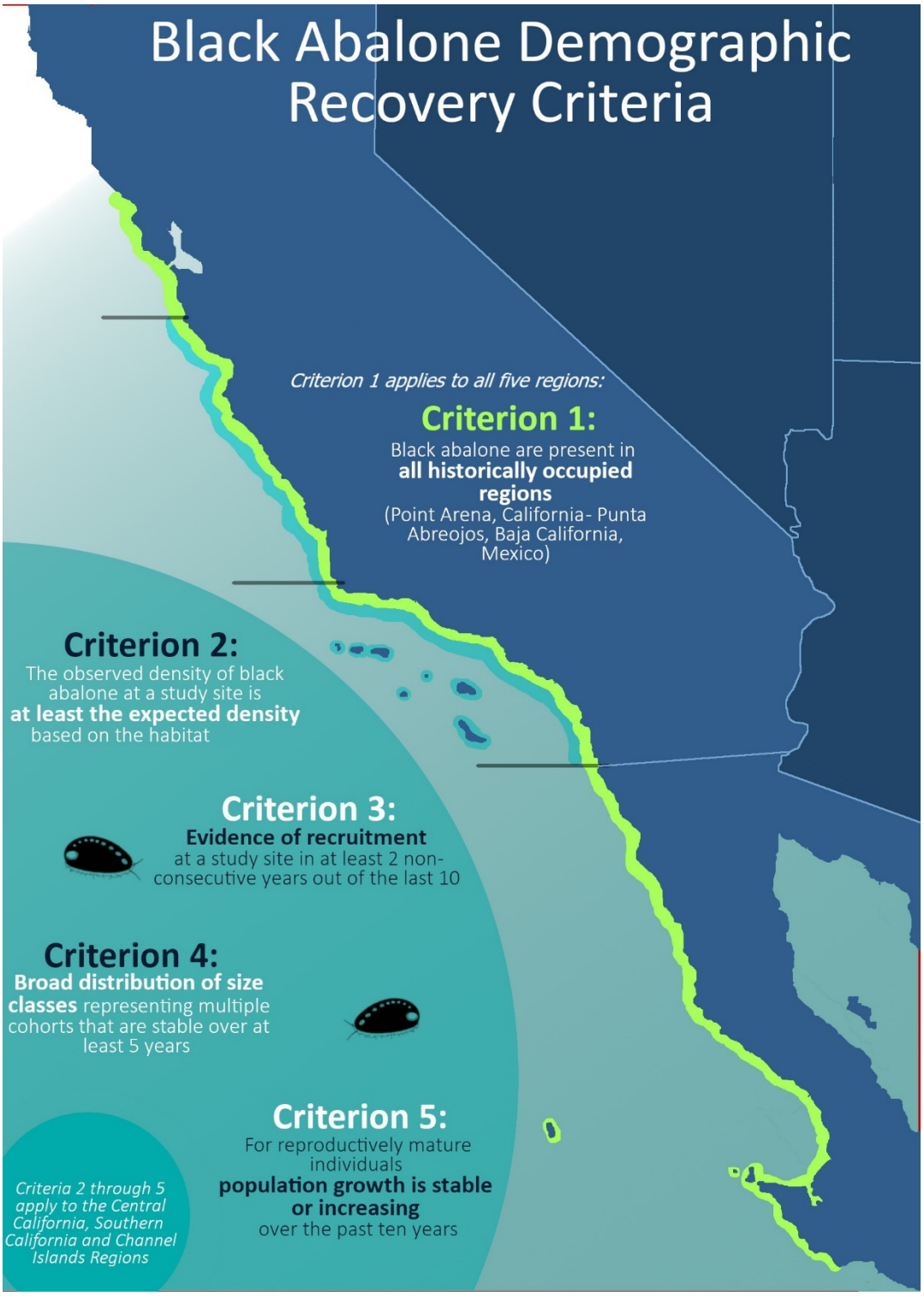

Figure 7. Demographic Recovery Criteria for black abalone recovery. Criterion 1 applies to all Regions, whereas Criteria 2 to 5 apply only to the Central California, Southern California Mainland, and Channel Islands Regions. By C. Lachnit, A. Thomasdotter, and K. Blessing.

GEOGRAPHIC RANGE OCCUPIED

Criterion 1: ***Geographic range occupied***

Black abalone continue to occur throughout their current geographic range, determined by the annual presence of individuals in all Regions over at least the past five years.

We propose to measure this criterion as follows: This criterion is met if, in each year of at least the past five years, black abalone are present in the specified number of SubRegions within each Region, as listed below. This applies for both downlisting and delisting.

- *North Central California Region: At least two of the three SubRegions.*
- *Central California Region: All SubRegions.*
- *Southern California Mainland Region: At least three of the four SubRegions, including SubRegion 3B (Palos Verdes Peninsula).*
- *Channel Islands Region: At least seven of the eight SubRegions.*
- *Baja California Region: All SubRegions.*

This criterion addresses the large-scale spatial distribution of black abalone across their geographic range from North-Central California to Baja California (small-scale distribution at the local level is addressed in the criteria under "Population density, structure, and growth"). This criterion may be redundant to the other criteria, but is important because it is the only criterion that applies to the North-Central and Baja California Regions.

The best available data indicate that the species' current range extends from Point Arena, California, to Punta Abreojos, Baja California, Mexico, although little information is available on black abalone populations in Baja California. As black abalone recover, they should continue to occupy each of the five Regions and all or a subset of the SubRegions within each Region.

For the purposes of this plan, we classify a Region/SubRegion as "occupied" if there is a documented observation of at least one black abalone in each year of the past five years. We consider the presence of one black abalone as enough to classify a SubRegion as "occupied" because black abalone numbers are naturally low in some areas. For example, black abalone populations are naturally small in the North-Central California Region, where researchers may observe only one black abalone at a study site in some years. We also recognize that sufficient densities of black abalone are needed to support recovery. This is addressed by the other Demographic Recovery Criteria.

Five years is a reasonable time frame over which to evaluate presence because it is short enough that the information is current, and long enough for multiple surveys to be conducted within each SubRegion. The five year time frame also matches with the five year status review updates, allowing us to use information from these updates to evaluate this criterion. We recognize that in some years, factors such as weather, road conditions, lack of access, or budget shortfalls may prevent researchers from conducting annual surveys at a site or sites. In these cases, we can infer

the presence of black abalone based on observations from the years prior to and following, assuming that adults present in one year were likely present in the previous year.

Within the North-Central California Region, the best available information indicates black abalone were present in all three SubRegions in at least one year from 2010 and 2016 (Miner 2017, MARINe unpublished data).

Within the Central California Region, the best available information indicates black abalone were present in four of the five SubRegions in each year from 2010 and 2016 (Miner 2017, MARINe unpublished data). Black abalone presence on Año Nuevo Island is not known because surveys were not conducted during this time period. The BART agreed that maintaining occupancy in all five SubRegions is necessary for species recovery. The primary threats to black abalone within this Region are disease and illegal harvest.

Within the Southern California mainland Region, the best available information indicates black abalone were present in at least three of the four SubRegions for at least a few years from 2010 and 2016 (Eckdahl 2015; Miner 2017, MARINe unpublished data). In recent surveys conducted in 2012 – 2015, black abalone were found in SubRegions 3A, 3B, and 3C (Government Point to Malibu Pier, Palos Verdes Peninsula, and Corona Del Mar to Dana Point), but not in SubRegion 3D (Cardiff State Beach to the US-Mexico border) (pers. comm. with J. Engle and Pete Raimondi, 5-6 June 2015; Eckdahl 2015). The BART agreed that maintaining black abalone presence in SubRegion 3B (Palos Verdes Peninsula) was important because out of the four SubRegions, this SubRegion has the longest record of black abalone presence.

Within the Channel Islands Region, the best available information indicates black abalone were present in at least seven of the eight SubRegions/Islands in each year from 2010 and 2016 (Miner 2017, MARINe unpublished data; VanBlaricom 2017, unpublished data). Although documented at Santa Catalina Island in the past, black abalone were not observed during two recent surveys conducted in 2011 (Neuman et al. 2011) and 2016 (Obaza et al. 2016).

Within the Baja California Region, very little information is available on black abalone populations. Black abalone were documented as present in all three SubRegions in 2004 and 2005, based on surveys at sites along the mainland and offshore islands in 2002, 2004, and 2005 (Miner 2005; Sierra-Rodriguez et al. 2006, cited in VanBlaricom et al. 2009). Black abalone, including recruits, were observed at sites in northern Baja California as recently as 2016 (pers. comm. with Fabiola Lafarga, CICESE, 20 October 2016). Additional monitoring efforts have recently been established in northern Baja California (pers comm. with Pete Raimondi, UCSC, 23 July 2019).

POPULATION DENSITY, STRUCTURE, AND GROWTH

We developed several criteria to measure whether individuals in local populations are dense enough and close enough to one another to support reproduction, recruitment, and survival at the levels needed to ensure population growth and resilience.

Reproductive viability depends on the density of individuals as well as their spatial distribution at

a study site. A reproductively viable population must have sufficient numbers of males and females in close proximity to allow a high probability of fertilization success. Ideally, we could define the minimum number of individuals and minimum distance needed. However, critical information is not available, such as ideal sex ratios, the minimum number of abalone required, the maximum distance between individuals beyond which reproduction is unlikely to occur (estimated to be a few meters; Babcock and Keesing 1999), and the number and/or configuration of such groups needed within a site. Instead, the Demographic Recovery Criteria focus on other metrics that can be readily measured, including density, recruitment, size structure, and population growth. We assume that if the population at a site meets these criteria, then the spatial structure of black abalone at the site is sufficient to support reproduction, recruitment, and survival.

The following criteria for density, recruitment, size structure, and population growth apply only to the Central California, Southern California mainland, and Channel Islands Regions. These criteria do not apply to the North-Central California Region because historical information indicates that populations in this Region are naturally low, and species recovery would not be affected as long as populations remain at existing levels or increase. These criteria also do not apply to the Baja California Region because, at this time, information is not available to understand how population structure and growth in this Region will affect the species' recovery. In the future, we may apply these criteria to the Baja California Region as we learn more about black abalone populations there.

The criteria should be met within the specified number of SubRegions per Region as listed below in order to downlist or delist the species.

For downlisting:

- Central California Region: At least three of the five SubRegions.
- Southern California mainland Region: At least one of the four SubRegions.
- Channel Islands Region: At least four of the eight SubRegions.

For delisting:

- Central California Region: At least four of the five SubRegions.
- Southern California mainland Region: At least two of the four SubRegions.
- Channel Islands Region: At least six of the eight SubRegions.

The criteria do not need to be met for all study sites within a SubRegion, nor for all SubRegions within a Region. Some study sites and SubRegions may naturally have lower densities or recruitment levels and may not reach the levels described in the criteria. For example, for the Southern California mainland Region, we recognize that black abalone numbers are naturally lower in some SubRegions due to the influence of sand movement on the habitat, as well as the proximity of some study sites to large human populations. Therefore, we specify that only two out of the four SubRegions should meet the criteria in order to consider delisting.

Criterion 2: ***Habitat-based density***

The observed density of black abalone is at least the expected density based on the habitat, at a representative subset of study sites for at least the past five years.

We propose to measure this criterion as follows: A SubRegion meets this criterion if, in each year over the past five years, the observed density of black abalone is at least the expected density at 50% or more of the study sites within the SubRegion. The expected density is based on the habitat at that particular study site (quantity and quality), may vary by SubRegion, and will be estimated using the best available data (see Recovery Action 3.1). We recognize that monitoring may not occur in some years for logistical reasons (e.g., weather, accessibility). To assess this criterion, data should be collected in at least three out of the five years, with no more than a one year gap.

This criterion evaluates whether black abalone are at densities indicative of healthy populations. For black abalone, small-scale density (at the study sites) is more relevant than overall density across a SubRegion or Region, because successful reproduction and recruitment depends on the number and spatial distribution of individuals at the site-level, rather than at the SubRegional or Regional level.

This criterion differentiates between "observed" and "expected" densities. The observed density is the density of black abalone observed and estimated by researchers during annual surveys at the study sites. The expected density is the density of black abalone that a study site can support, based on the habitat at the site. The expected density may vary by SubRegion and will be estimated using the best available information and the guidance to be developed in the population restoration plan (see Recovery Action 3.1).

The habitat quantity and quality determines the expected density for a study site. Habitat surveys have been conducted throughout most of the California coast to generate habitat-based density and abundance estimates for black abalone (Raimondi and Miner 2016, MARINe unpublished data). In these surveys, habitat was categorized into three categories based on the rocky substrate: good (deep cracks, crevices, and overhangs); moderate (shallow cracks or crevices, depressions in bedrock); and poor (flat or bare surfaces) (see general methods described in George et al. 2009). As expected, the average black abalone densities were greatest in good quality habitat and lowest in poor quality habitat. These habitat survey methods can be applied at each study site to determine the proportion of good, moderate, and poor habitat at each site.

We recognize that although geomorphology (the rocky substrate) is an important factor, it is not the only factor to consider in evaluating habitat quality. Other factors include the proximity of food resources and human populations, as well as water temperatures and site-specific natural processes (e.g., natural sand influence). We also recognize that because of these and other factors, the expected densities for good, moderate, and poor habitat may differ among Regions and SubRegions. For example, the expected densities for good quality habitat in the Southern

California mainland SubRegions may be lower than the expected densities for good quality habitat in the Central California SubRegions. These factors will be considered and guidance will be provided in the population restoration plan to be developed under Recovery Action 3.1 (see *RECOVERY ACTION 3*).

To meet this criterion, black abalone populations do not need to achieve the expected densities at all sites within a SubRegion. We recognize that habitat features can change over time (e.g., shifts in algal and invertebrate communities, movement of boulders, filling in of cracks and crevices with sediment). Also, the relationship between habitat quality and black abalone density does not hold true for all study sites. In addition, there are many examples of sites that contain good quality habitat but do not have black abalone, historically or presently. To address this concern, we will evaluate this criterion using sites that historically and/or presently support black abalone (see Appendix A for a list of existing study sites).

For our test run analysis of this criterion (see Appendix B), we estimated the expected density of black abalone based on data for the SubRegion from Pacific Grove to the Monterey/San Luis Obispo County line. Populations in this SubRegion are considered healthy, have not yet experienced declines due to withering syndrome, and reflect densities in the presence of sea otter predation. We recognize that other factors need to be considered in future analyses.

In particular, careful consideration will be needed to estimate expected densities specifically for southern California and the Channel Islands. Long-term monitoring data are available for the 1970s and 1980s prior to the disease outbreak, but the densities in that period almost certainly were unusually high (due to the removal of sea otter and anthropogenic predation pressure on black abalone) and not representative of healthy populations. Currently, most populations persist at low densities and a few have increased in numbers, but we do not know how well recent/current densities represent healthy populations. Region-specific expected densities will be addressed in the population restoration plan (see *RECOVERY ACTION 3*).

Criterion 3: ***Recruitment***

Black abalone recruit successfully at a representative subset of study sites, determined by evidence of recruitment events observed in at least two non-consecutive years over the past ten years.

We propose to measure this criterion as follows: A SubRegion meets this criterion if, within at least two non-consecutive years out of the last ten years, evidence of a black abalone recruitment event has been observed at 50% or more of the study sites within the SubRegion.

This criterion focuses on recruitment as an indicator of reproductively viable populations. Numerous factors affect recruitment success in broadcast spawners like black abalone. Long-term monitoring data show that recruitment can be highly variable, with evidence of annual recruitment in some populations (e.g., at San Nicolas Island; VanBlaricom 2017, unpublished data) or pulses every few years, even in populations considered to be robust (Miner 2016, MARINe unpublished data).

Based on long-term monitoring data for robust populations, we currently define "evidence of black abalone recruitment events" as the presence of at least ten black abalone recruits (animals ≤ 30 mm SL) at a site. Given what is known about black abalone growth rates (about 2 mm per month in the first year; TERA Corp 1982a; VanBlaricom 2016, unpublished data), new recruits may be about 20-25 mm SL by the end of the first year. However, individuals 20-25 mm SL or smaller are very difficult to observe in the field, whereas animals 25-30 mm SL are more detectable (unpublished observations by BART, 11-14 Oct 2016). Thus, we identify recruits as individuals ≤ 30 mm SL, recognizing this size range could include small animals that recruited to the site within the last one to two years. This criterion specifies that recruitment events should be observed in at least two non-consecutive years within the last 10 years, to ensure that the animals observed represent separate recruitment events and are not animals from the previous year's recruitment event that remain in the ≤ 30 mm SL size range.

Criterion 4: ***Size Structure***

Black abalone populations are characterized by a broad distribution of size classes representing multiple cohorts that are stable, at a representative subset of study sites over at least the past five years. Size classes should include small adults (i.e., 50 to 100 mm SL) and large adults (i.e., greater than 100 mm SL).

We propose to measure this criterion as follows: A SubRegion meets this criterion if at least 50% of the study sites have a size structure consisting of at least 40% small adults (50 to 100 mm SL) and at least 10% large adults (> 100 mm SL). We will evaluate size structure based on the most recent five-year running cumulative proportion, at study sites that have at least 50 individual black abalone to ensure an appropriate sample size. We recognize that monitoring may not occur in some years for logistical reasons (e.g., weather, accessibility). To assess this criterion, data should be collected in at least three out of the five years, with no more than a one year gap.

This criterion uses size structure as an indicator that recruits are surviving to adulthood and that the population consists of multiple cohorts. Long-term monitoring data from central California sites (where sea otters are present and populations have not yet been impacted by withering syndrome) indicate that a robust population is comprised of at least 40% intermediate-sized adults (50 to 100 mm SL) and at least 10% large adults (> 100 mm SL) (Raimondi and Miner 2016, MARINe unpublished data). We may refine this as more information becomes available in the future. A running cumulative 5-year proportion accounts for variable recruitment and survival from year to year.

We propose a minimum sample size of at least 50 black abalone to adequately evaluate the size structure at a study site. We estimated this minimum sample size based on data from the central California sites (Raimondi 2016, MARINe unpublished data). This minimum of at least 50 black abalone applies to the study sites and should not be extrapolated to the whole population to estimate a target minimum for overall abundance.

Criterion 5: ***Population trend***

Population growth for reproductively mature individuals (greater than 50 mm SL) is stable or increasing at a representative subset of SubRegions and study sites over at least the past ten years, indicating that juveniles are surviving to adulthood to reproduce and maintain or increase populations over time.

We propose to measure this criterion as follows: A SubRegion meets this criterion if, over the last ten years, the average population growth rate for individuals greater than 50 mm in shell length (i.e., reproductively mature individuals) is:

(a) stable or increasing when averaged across all study sites within the SubRegion (overall SubRegion-wide average);
(b) stable or increasing for at least 50% of the individual study sites within the SubRegion (individual site averages); and
(c) greater than or equal to the minimum rate expected for a healthy SubRegion, for each individual study site within the SubRegion.

We recognize that monitoring may not occur in some years for logistical reasons (e.g., weather, accessibility). To assess this criterion, data should be collected in at least six out of the ten years, with no more than a one year gap.

This criterion evaluates whether survival is sufficient to achieve stable or increasing population growth for species recovery. We focus on reproductively mature individuals (e.g., individuals greater than 50 mm SL), to remove the effect of recruitment pulses on the estimated population growth rate. We propose to evaluate population growth in two ways: (1) for each SubRegion as a whole, to assess the status of black abalone across all study sites within a SubRegion; and (2) for each study site within a SubRegion, to assess the status of black abalone at each site and whether a majority (at least 50%) of the sites have stable or increasing population growth.

We also propose to apply a minimum growth rate to each study site. Healthy populations are dynamic and, within a SubRegion, the population growth rates may be stable at some sites and increasing or decreasing at others. We expect the average ten-year population growth rate for each study site to exceed a minimum rate, estimated based on data for healthy populations. For example, from 2009-2016, the average ten-year population growth rate (r) was as low as -0.05 for some study sites within the SubRegion from Pacific Grove to the Monterey/San Luis Obispo County line, where populations are considered healthy (Miner and Raimondi 2017, MARINe unpublished data). We would consider declines greater than this value to be outside of the desired range.

In summary, for a SubRegion to meet this criterion, all of the following conditions need to be met: the average population growth rate is stable or increasing when averaged across all study sites (overall SubRegion-wide average) and, for individual study sites, the average population growth rate is stable or increasing in at least 50% of the study sites and greater than or equal to

the minimum (e.g., -0.05) in each study site. As more information becomes available, we may refine our methods for evaluating this criterion.

ABUNDANCE

We did not include an overall abundance criterion, for two reasons. First, we do not have sufficient information to estimate a reasonable target for overall abundance. Existing abundance estimates include such high uncertainty that they are not useful or applicable for assessing recovery. For example, Rogers-Bennett et al. (2002) estimated the historical, pre-exploitation abundance of black abalone in California to be at least 3.54 million. However, this estimate was based on fishery landings during the height of the black abalone fishery when landings were largely from the Channel Islands off southern California. At that time, black abalone abundance estimates may have been abnormally high in southern California, especially at the Channel Islands. Fishery-independent monitoring has been conducted since the 1970s throughout California. However, these data are not appropriate for estimating an overall abundance target, because they do not include the period prior to the modern fishery. Also, the monitoring sites were selected in areas with good habitat and high black abalone numbers. Thus, the data are useful for evaluating trends over time, but not for estimating overall abundance.

Second, local population abundance, density, and spatial distribution are better indicators of population viability than the overall abundance across the species' range. For example, because black abalone are broadcast spawners, reproductive success depends on the number of individuals, their proximity to one another, and their ability to synchronize spawning at the local scale, rather than the total number of black abalone across their range.

DIVERSITY

We did not include a criterion for genetic diversity, because achieving the other demographic criteria will indirectly address the preservation of genetic diversity. Instead, we identify recovery actions to (see *RECOVERY ACTION 2* and other recovery actions for more details):

- monitor and evaluate current and future levels of genetic diversity, and
- consider genetic management when implementing recovery actions such as translocation, captive breeding, and outplanting.

Maintaining genetic diversity is important to support the species' ability to withstand environmental variability and disease. Genetic diversity has been evaluated at broad spatial scales across the species' U.S. range using allozymes, mitochondrial DNA sequencing, and microsatellite genotyping (Hamm and Burton 2000, Chambers et al. 2006, Gruenthal and Burton 2008, Beldade et al. 2012). However, we do not have the genetic samples and data to evaluate historical levels of genetic diversity and whether genetic diversity was affected by the severe population declines experienced in the 1980s and 1990s due to disease. Suggested research topics include:

- evaluating historical and current levels of genetic diversity and population structure;
- monitoring genetic diversity and population structure into the future;
- determining whether the mass mortalities in the 1980s and 1990s resulted in reduced genetic diversity and, if so, speculating how this may have affected population resilience; and
- assaying whether any genetic variants are associated with resistance to disease and the effects of ocean acidification.

Threats-based Criteria

The Threat-based Recovery Criteria describe what is needed to adequately reduce or mitigate the threats to support the long-term survival and recovery of black abalone. The same criteria apply for both downlisting and delisting the species. The BART agreed that the same conditions apply for downlisting and delisting, because the criteria focus on maintaining existing conditions and protections, developing plans, or coordinating with entities to address threats. What will determine whether the species should be downlisted or delisted will be how the species responds to these conditions, as measured by the Demographic Recovery Criteria.

We organized the threats criteria according to the five ESA listing factors that are considered when determining whether a species is endangered or threatened, and also when reclassifying or delisting any listed species:

(a) The present or threatened destruction, modification or curtailment of its habitat or range;
(b) Overutilization for commercial, recreational, scientific, or educational purposes;
(c) Disease or predation;
(d) Inadequacy of existing regulatory mechanisms; or
(e) Other natural or manmade factors affecting its continued existence.

LISTING FACTOR 1: THE PRESENT OR THREATENED DESTRUCTION, MODIFICATION, OR CURTAILMENT OF HABITAT OR RANGE

Criterion 1: ***Habitat quantity and quality***

The quantity and quality of black abalone habitat is sufficient to support and maintain viable black abalone populations.

The critical habitat designation (76 FR 66806; October 27, 2011) encompasses approximately 360 square kilometers of rocky intertidal and subtidal habitat within five segments of the California coast, as well as on the offshore islands. This criterion seeks to maintain existing critical habitat for black abalone, recognizing that some loss may be unavoidable due to natural causes (e.g., landslides, sediment movement, competition with encrusting organisms for rocky

habitat) or anthropogenic effects (e.g., activities that increase sedimentation into rocky intertidal habitats; sea level rise). When considering downlisting or delisting the species, we will evaluate any changes to and effects on critical habitat since its designation, as well as changes in the species' range and distribution. Where needed, we will maintain and restore critical habitat features (i.e., rocky substrates with cracks and crevices, crustose coralline algae, food resources such as kelp) to support black abalone populations. For example, factors such as sedimentation and overabundant sea urchin populations (due to overfishing of sea urchin predators) have resulted in the loss of kelp forests. Restoration efforts may include controlling sea urchin populations and planting kelp.

Criterion 2: ***Emergency response guidance***

An emergency response plan is in place for black abalone to minimize effects on water quality, habitat, and black abalone populations. The plan provides a decision tree and guidance regarding preemptive collection vs. leaving animals in place when confronted with an imminent threat. The plan also provides best practices for monitoring effects on water quality, habitat, and black abalone populations during and after an event such as a spill, landslide, or vessel grounding. The plan is developed by NMFS in coordination with the appropriate partners (e.g., CDFW Office of Spill Prevention and Response, National Marine Sanctuaries (NMS), U.S. Coast Guard (USCG)) and is linked to existing Regional Contingency Plans and Area Contingency Plans that are used during a spill, or other plans for events that pose an imminent threat to abalone.

LISTING FACTOR 2: OVERUTILIZATION FOR COMMERCIAL, RECREATIONAL, SCIENTIFIC, OR EDUCATIONAL PURPOSES

Criterion 3: ***Harvest regulations***

In California, harvest of black abalone remains prohibited and regulations for other abalone species are designed to protect black abalone. In Mexico, harvest of black abalone is prohibited (i.e., no federal permits are issued that allow fishing for black abalone). These measures limit further reductions in density and genetic diversity. Public outreach and enforcement of existing regulations will help to minimize illegal harvest.

Criterion 4: ***CDFW Abalone Recovery and Management Plan (ARMP)***

The CDFW ARMP remains in place and reflects updated information adequately to ensure that black abalone will be managed to maintain the population demographics outlined in this Recovery Plan. There are assurances of adequate regulatory authority and funding for the state to implement the plan.

Criterion 5: ***Research and monitoring planning and coordination***

A research and monitoring plan is in place that ensures coordination among

researchers and permitting agencies to coordinate research and monitoring activities, requests for permits, and permit processing. The plan is developed by NMFS in coordination with research and monitoring partners and addresses: research coordination (e.g., establish a review process for research ideas); data management and sharing; and regular meetings among researchers to present information, coordinate, and discuss research ideas and recommendations.

LISTING FACTOR 3: DISEASE/PREDATION

The following criteria focus on disease. Although predation is a threat to black abalone populations, the BART agreed that predation is best addressed through the recovery actions. Regarding the threat of sea otter predation, predation pressure may increase as sea otters and black abalone populations recover and increase in abundance. The effects of sea otter predation on black abalone populations need to be monitored over time. An existing Memorandum of Understanding between the USFWS and NMFS ensures that both agencies will coordinate with one another on recovery of sea otters and black abalone.

Criterion 6: ***Disease research and risk management plan***

A disease research and risk management plan is in place to adequately study, monitor, and manage for diseases that affect, or may affect, black abalone in the wild and in captivity.

Criterion 7: ***Disease outbreaks***

Over the past ten years across all Regions:

Evidence of a lethal outbreak of withering syndrome and/or any outbreak of other emerging diseases has not been observed in wild black abalone populations (see below for a description of what constitutes an outbreak)**;**

and

Evidence of an outbreak of an emerging disease, that is potentially harmful and to which black abalone may be susceptible, has not been observed in captive abalone populations with a connection to state waters (e.g., effluent is not treated specifically to remove pathogens before discharge to ocean)**.**

The threats assessment identified withering syndrome and other emerging diseases as primary threats of concern for black abalone recovery. Withering syndrome caused mass mortalities and severe declines in black abalone populations throughout southern California in the 1980s and 1990s. In addition, new abalone diseases are emerging around the world, including in Baja California. The effects of these diseases on black abalone are not yet known, but could be significant.

Because removing disease risk is not possible, this plan focuses on managing and minimizing disease risks to black abalone. Under this criterion, a disease outbreak in the wild or in captivity could represent a risk to black abalone populations. However, a disease outbreak can include a broad range of conditions and population effects and can be difficult to observe in the field. For example, researchers may detect a decline or loss of animals without observing symptomatic

animals. Researchers may also find a large number of empty shells, which could indicate a recent die off or, conversely, favorable conditions (e.g., currents) for shells to accumulate at that site, without any relation to disease. To identify a disease outbreak, the underlying demographic data (e.g., a decline in numbers/density) should be considered along with observations that may indicate disease effects (e.g., withered animals, empty shells). The scale of those observations (e.g., duration, geographic scope, severity) and the environmental context (e.g., oceanographic conditions; cold vs. warm year) should also be considered. For example, researchers observed an increased number of withered black abalone in 2015-2016 (pers. comm. with Karah Ammann, UCSC, on 8 Mar 2016). These observed mortalities should be evaluated within the context of the oceanographic conditions (e.g., an El Niño event, warm water masses) and the population effects.

This criterion specifies that a *lethal* outbreak of withering syndrome has not been observed in wild black abalone populations. All wild black abalone are likely infected with the pathogen that causes withering syndrome, but can remain healthy and live for many years without showing symptoms. The concern regarding withering syndrome is when infected individuals encounter environmental conditions (e.g., elevated water temperatures) that trigger the disease. Once individuals start to show symptoms (e.g., lethargy, shrunken foot muscle), death quickly follows.

For other emerging diseases, the criterion states that an outbreak (lethal or non-lethal) has not been observed, recognizing that other diseases may have lethal or sublethal impacts on wild black abalone populations. In addition, we may be able to detect outbreaks for other diseases prior to lethal impacts. Recovery Action 1 (Section 4 of this plan) will include periodic (annual) monitoring of wild black abalone at study sites throughout the species' range. Those surveys will include health assessments of each individual, such as whether the body is visibly shrunken relative to the shell size. We will use these monitoring data to assess whether a disease outbreak has occurred in wild populations.

LISTING FACTOR 4: INADEQUACY OF EXISTING REGULATORY MECHANISMS

Criterion 8: ***Illegal take and other sources of mortality due to human activities***
State and Federal coordination (e.g., an interagency task force, cooperative agreement) is established to enforce regulations to protect black abalone populations and strives to effectively alleviate or eliminate further loss of black abalone from illegal take and other human activities, as feasible (e.g., vessel groundings, landslides).

Criterion 9: ***State and Federal regulations regarding disease and pathogen transmission***
State and Federal regulations are in place and enforced that adequately minimize the potential for transmission of diseases and pathogens, known to be potentially harmful to black abalone, through import and within-state movement of abalone and any marine species.

Criterion 10: ***Coordination with Mexico and Canada on illegal trade***
Coordination with Mexico and Canada (e.g., through cooperative agreements, international task force) is implemented to adequately deter

illegal international trade.

Criterion 11: ***Regulations in Mexico***

Regulatory mechanisms implemented by the Mexican authorities adequately protect populations of black abalone in Mexico from illegal take and trade to ensure the species' long-term viability in Mexico.

Illegal take of black abalone continues to be a problem in California and Baja California. Although black abalone do not occur in Canada, illegal trade of black abalone through Canada is also potentially an issue. We will coordinate with State and Federal enforcement to address illegal take and trade of black abalone within California, as well as work with authorities in Mexico and Canada to evaluate and deter illegal take and trade of black abalone.

Other sources of mortality for black abalone include:

- vessel groundings (e.g., animals may be killed by damage to the habitat or contamination from metal ballast),
- contaminant spills (e.g., oil spills can smother abalone and have toxic effects),
- shoreline or in-water construction and repair activities (e.g., animals may be exposed to sedimentation, moved, and crushed when building or repairing breakwaters, pier pilings, sea walls), and
- landslides, which can bury habitat and individuals.

We will coordinate with State and Federal regulatory agencies to reduce or eliminate loss of black abalone as feasible. For example, we may work with agencies to minimize vessel or construction activities near critical habitat, and to prevent landslides and/or reduce damage through engineering solutions.

In addition, regulatory mechanisms may play a part in protecting black abalone from diseases and pathogens. Abalone diseases and pathogens have emerged throughout the world and could be transmitted to black abalone populations through live trade of abalone and other marine species. We will evaluate existing regulations and, if needed, work with the appropriate authorities to revise regulations to minimize the risk of transmitting pathogens to black abalone populations.

LISTING FACTOR 5: OTHER NATURAL OR MANMADE FACTORS AFFECTING THE SPECIES' CONTINUED EXISTENCE

Criterion 12: ***Ocean acidification and elevated water temperatures***

Thermal/pH tolerance of black abalone and ocean acidification effects on black abalone are evaluated, and locations where populations are most at risk are identified. If feasible, actions are taken to address the effects of ocean acidification and elevated water temperatures at these locations to ensure the species' long-term viability.

Further studies are needed to evaluate the risks posed by ocean acidification and elevated water temperatures to black abalone. The information gained will

inform our understanding and development actions to address these threats. As discussed in Section 1.3 (Threats to Species Viability), the effects of ocean acidification on black abalone are uncertain given the lack of studies on black abalone and the complexity of natural systems. The effects of elevated water temperatures on black abalone are also not straightforward. For example, elevated water temperatures appeared to accelerate mortality in abalone infected with the pathogen that causes withering syndrome; however, recent studies indicate that genetic resistance and/or the bacteriophage may reduce those lethal effects. Future studies should evaluate effects of multiple stressors on different life stages, to better understand and to identify actions to address the effects of ocean acidification and elevated water temperatures.

4 RECOVERY ACTIONS

4.1 Recovery Action Outline

The Recovery Action Outline lists all of the recommended Recovery Actions needed to alleviate the threats and restore black abalone in the wild. The Outline provides a brief overview of the Recovery Actions, summarized in Figure 8. The next section, Section 4.2 (Recovery Actions: Narrative), describes each action in more detail.

Figure 8. Summary of Recovery Actions. By Catherine Lachnit and Anna Thomasdotter.

RECOVERY ACTIONS

1: ASSESS AND MONITOR BLACK ABALONE POPULATIONS THROUGHOUT THEIR RANGE IN THE WILD	RECOVERY CRITERIA ADDRESSED
1.1. Continue and expand long-term monitoring programs to evaluate population trends and status over time (e.g., density, recruitment, size and spatial structure, growth, sex ratios). 1.1.1. Evaluate monitoring programs to identify ways to improve effectiveness and efficiency. 1.1.2. Evaluate existing monitoring efforts to identify overlapping efforts and where additional monitoring is needed. 1.1.3. Develop plan and process to coordinate data management, analysis, and sharing. 1.2. Evaluate and monitor the health of wild populations. 1.2.1. Incorporate or continue health observations during long-term monitoring. 1.2.2. Develop non-lethal methods to quantify infection with the withering syndrome pathogen and its phage in wild populations.	Demographic: All criteria Threats-based: Criterion 5: Research and monitoring planning and coordination Criterion 7: Disease outbreaks
2: EVALUATE GENETIC STRUCTURE AND DIVERSITY OF WILD BLACK ABALONE POPULATIONS ACROSS LOCAL AND BROAD SPATIAL SCALES	**RECOVERY CRITERIA ADDRESSED**
2.1. Develop a plan for assessing genetic structure across the species' range. 2.2. Develop a plan for resampling black abalone for long-term monitoring and temporal studies. 2.3. Develop genetic methods for identifying the sex of individuals. 2.4. Develop genetic methods for evaluating the health of individuals.	Threats-based: Criterion 6: Disease management plan

3: RESTORE BLACK ABALONE POPULATIONS NOT CURRENTLY MEETING THE DEMOGRAPHIC RECOVERY CRITERIA BY ENHANCING LOCAL POPULATIONS AND SUPPORTING NATURAL RECOVERY.	RECOVERY CRITERIA ADDRESSED
3.1. Develop a population restoration plan. 3.2. Conduct research to develop, evaluate, and apply population restoration methods. 3.2.1. Determine value and efficacy of habitat restoration. 3.2.2. Determine value and efficacy of local aggregation. 3.2.3. Determine value and efficacy of translocation. 3.2.4. Continue research and development of captive propagation and outplanting methods.	Demographic: All criteria Threats-based: Criterion 1: Habitat quantity & quality Criterion 5: Research and monitoring planning and coordination Criterion 12: Ocean acidification and elevated water temperatures
4: DEVELOP PLAN FOR REMOVING BLACK ABALONE FROM THE WILD IN RESPONSE TO EVENTS SUCH AS SPILLS, LANDSLIDES, AND VESSEL GROUNDINGS.	**RECOVERY CRITERIA ADDRESSED**
4.1. Identify and conduct research to develop tools, guidance, and protocols needed to remove black abalone from the wild. 4.1.1. Evaluate the effects of oil and dispersants on black abalone. 4.1.2. Evaluate methods to clean and care for abalone exposed to oil and/or dispersants. 4.2. Develop protocols for removing black abalone from the wild and returning them to the wild. 4.3. Develop protocols for cleaning and caring for abalone exposed to oil and/or dispersants.	Threats-based: Criterion 2: Emergency response guidance
5: PROTECT AND RESTORE BLACK ABALONE HABITAT FROM THREATS	**RECOVERY CRITERIA ADDRESSED**
5.1. Assess the quality and quantity of black abalone habitat throughout their range. 5.2. Develop and implement a plan to protect black abalone habitat in response to episodic events and coastal development plans that may affect black abalone habitat. 5.2.1. Coordinate with Federal and State agencies on permitting. 5.2.2. Evaluate the effects of sedimentation on black abalone and identify high risk areas. 5.3. Develop and apply methods to restore habitat in areas affected by episodic events, sedimentation, and community shifts. 5.4. Reduce threats to kelp forest health throughout the range of black abalone.	Threats-based: Criterion 1: Habitat quantity & quality Criterion 2: Emergency response guidance Criterion 8: Illegal take and other human activities

6: CONTINUE, REFINE, AND EXPAND RESEARCH ON WITHERING SYNDROME, OTHER ABALONE DISEASES, AND OCEAN ACIDIFICATION	RECOVERY CRITERIA ADDRESSED
6.1. Continue and expand research on withering syndrome and its effects on black abalone. 6.2. Develop a model or models to evaluate withering syndrome transmission dynamics. 6.3. Apply disease research and models to population restoration plans and plans to remove abalone from the wild. 6.4. Evaluate potential susceptibility of black abalone to other abalone diseases. 6.5. Review existing regulations regarding live trade of abalone and other marine species and revise regulations as needed to minimize the risk of transmitting pathogens. 6.6. Evaluate pH tolerance and effects of decreasing pH on various life stages of black abalone.	Threats-based: Criterion 6: Disease management plan Criterion 7: Disease outbreaks Criterion 9: Regulations for disease and pathogen transmission Criterion 12: Ocean acidification and elevated water temperatures
7: MAINTAIN AND ENHANCE BINATIONAL COORDINATION WITH MEXICO	**RECOVERY CRITERIA ADDRESSED**
7.1. Develop opportunities for information exchange on a regular basis. 7.2. Coordinate and collaborate on monitoring, research, and funding opportunities.	Demographic: Criterion 1: Geographic range Threats-based: Criterion 3: Harvest regulations Criterion 10: Illegal trade Criterion 11: Regulations in Mexico
8: DEVELOP AND IMPLEMENT ENFORCEMENT, PUBLIC OUTREACH, AND EDUCATION PLANS	**RECOVERY CRITERIA ADDRESSED**
8.1. Coordinate to enforce existing protections and recommend new protections. 8.1.1. Refine CDFW database to track cases and violations involving illegal take. 8.1.2. Develop outreach materials regarding abalone disease risks and illegal take. 8.1.3. Coordinate with Mexico and Canada to identify and address illegal abalone trade. 8.2. Collaborate with outreach and education partners to develop/share key, unified messaging. 8.2.1. Evaluate public perceptions of black abalone and cultural/ecological importance. 8.2.2. Host outreach workshops with key partners to discuss and develop materials. 8.2.3. Develop signage and educational materials for partner facilities and digital media. 8.2.4. Incorporate black abalone key messaging points into existing programs.	Threats-based: Criterion 3: Harvest regulations Criterion 4: CDFW ARMP Criterion 8: Illegal take and other human activities Criterion 9: Regulations for disease and pathogen transmission Criterion 10: Illegal trade Criterion 11: Regulations in Mexico

4.2 Recovery Actions: Narrative

1 ASSESS AND MONITOR BLACK ABALONE POPULATIONS THROUGHOUT THEIR RANGE IN THE WILD.

Continue and expand long-term monitoring of black abalone population (status and health) to evaluate recovery throughout the species' range, in cooperation with other Federal agencies, State agencies, universities, non-governmental organizations, and the Mexican government and institutions.

1.1. **Continue support for existing and expanded long-term monitoring programs to evaluate population trends over time,** including density, recruitment patterns, size structure, spatial structure (e.g., nearest neighbor), growth rates, sex ratios, and habitat characteristics. The long-term monitoring program is a high priority because it provides critical information to inform all of the other recovery actions, to address threats and prevent extinction. Monitoring should also provide data needed to evaluate the Recovery Criteria. This monitoring is already occurring throughout much of the California coast, with support from MARINe, NMFS, and many partners.

1.1.1. **Evaluate existing monitoring programs and identify modifications needed to improve the effectiveness and efficiency of survey methods**. NMFS and its partners will evaluate existing monitoring programs and methods to determine the most appropriate approach, recognizing that the same design may not work in all of the Regions due to differences in black abalone abundance, habitat, and spatial structure. As methods and protocols are developed (e.g., for disease monitoring, genetic analysis, and evaluation of sex and condition; see Recovery Actions 1.2 and 2), they will be incorporated into the long-term monitoring programs. NMFS will also work with partners to identify and incorporate additional data needs to monitor recovery (e.g., data on empty shells, water temperature, habitat quality).

1.1.2. **Evaluate existing monitoring efforts to identify areas of overlapping effort that can be combined and where additional monitoring is needed**. This action addresses gaps in our long-term monitoring, to ensure we are gathering the needed information to inform the recovery actions, address the threats, and prevent extinction. NMFS will work with partners to identify areas of overlapping or missing effort, and to coordinate and prioritize efforts. If needed, we will identify additional sites, or existing sites where focused black abalone surveys are needed. For example, additional monitoring may be needed at Catalina Island to evaluate the presence of black abalone. In particular, we know little about subtidal populations and the use of subtidal versus intertidal habitats, which may differ by location. We need to identify subtidal sites, develop monitoring methods, and conduct pilot studies to evaluate the feasibility of subtidal monitoring and where such monitoring would be most useful. For example, sites at the northern Channel Islands may have subtidal populations that are large enough to monitor.

1.1.3. **Develop a plan and process to manage, analyze, and share population monitoring data**. This plan will ensure that the long-term monitoring data are accessible and used to focus and prioritize recovery efforts on major threats contributing to extinction risk. NMFS will work with partners to develop this plan and process, which should identify minimum information that needs to be tracked; how to report the information to NMFS; how to support sampling compatibility and continued data sharing, analysis, and reporting; and a process for regularly reviewing and updating the species status assessments that form the basis for this Recovery Plan. The annual MARINe meetings may be a venue for this discussion and assessment.

1.2. **Evaluate and monitor the health of wild populations**. Withering syndrome is the primary factor for the species' decline. We should continue to gauge the disease's effects throughout the species' range and better understand how disease expression varies among sites, with latitude, among years, and under different oceanographic conditions,including El Niño/La Niña cycles, decadal cycles (e.g., Pacific Decadal Oscillation, Interdecadal Pacific Oscillation), and long-term climate change. Factors including temperature, food availability and quality, competitors, and predators may influence disease expression, reproductive output, and survival. Conducting periodic standardized observations and sampling will allow us to observe acute changes, identify long-term trends in health, and detect other diseases that may emerge in wild populations.

1.2.1. **Incorporate or continue health observations during long-term monitoring**. The health of black abalone will be evaluated during annual monitoring surveys and will include the percentage of animals encountered that appear visibly shrunken. The Withered Black Abalone Protocol (Ammann 2016) provides guidance on how to identify shrunken abalone, when to sacrifice an animal, and how to process it in the field to obtain maximum information on overall health, genetics, and pathogen presence. Samples will be used to quantify levels of the pathogen in target tissues. This information will inform the degree to which withering syndrome contributed to the observed poor health of the individual and ultimately the continuing effects of withering syndrome on population recovery.

Researchers will apply these protocols during regular monitoring (see Recovery Action 1.1). As needed, protocols will be developed for monitoring other diseases.

1.2.2. **Develop non-lethal methods to quantify infection with the withering syndrome pathogen and its phage in wild populations**. In addition to sampling individuals that appear unhealthy, monitoring levels of the withering syndrome pathogen and its bacteriophage in wild black abalone populations using a standardized non-lethal method would greatly contribute to understanding the disease's effect on population recovery. One way to quantify the pathogen and bacteriophage is to filter standard volumes of seawater collected adjacent to animals (Friedman et al. 2014b). We will develop a standardized protocol that can be used by site surveyors throughout the

species' range. We will take precautions to ensure that monitoring and sampling does not spread disease.

2 EVALUATE GENETIC STRUCTURE AND DIVERSITY OF WILD BLACK ABALONE POPULATIONS ACROSS LOCAL AND BROAD SPATIAL SCALES.

An understanding of genetic structure range-wide, regionally (e.g., study sites north versus south of Point Conception, sites on the southern California mainland versus the Channel Islands), and locally (e.g., within and among sites across a single Channel Island) is crucial to determine over what spatial scales and to what extent black abalone populations may be able to recover naturally. The best available research to date indicates that significant differentiation exists among samples collected on a broad scale (Hamm and Burton 2000, Chambers et al. 2006, Gruenthal and Burton 2008). Significant genetic divergence among samples indicates there may be a lack of connectivity among populations across evolutionary timescales. As a result, severely depleted populations must rely on predominantly local recruitment and will take many generations to – or may never – fully recover on their own. Evaluating genetic structure and diversity will inform our understanding of black abalone population dynamics and how we develop and implement population restoration actions (e.g., translocation, captive breeding, and outplanting; see Recovery Action 3). Additionally, development of genetic methods to evaluate the sex and health of individuals will be critical to assess the reproductive viability of populations and guide population restoration efforts.

2.1. **Develop plan for assessing the genetic structure of black abalone across the species' range**. The genetic structuring of natural black abalone populations can be used to understand the connectivity among groups of individuals, both across and within study sites. Because connectivity is mediated by larval dispersal, evaluating genetic structure across sites (macroscale) and within sites (microscale) could provide a deeper understanding of larval dispersal and recruitment dynamics. NMFS will work with partners to develop this plan, which should address: methods for non-lethal collection of genetic samples (e.g., epipodial clippings [Hamm and Burton 2000] or other methods to be developed), the appropriate sample design (e.g., number of samples per site, size/life stage to sample, frequency of sampling), maintaining and archiving samples, and guidance to coordinate future use of the samples. We should also pursue methods to assess the historical genetic structure of black abalone populations, if samples of sufficient quality and quantity are available.

2.2. **Develop plan for resampling of black abalone for long-term monitoring and temporal studies.** Collection of genetic samples at a representative subset of study sites may be incorporated into long-term monitoring plans, to assess changes in genetic diversity and profile over time. During the 1980s and 1990s, black abalone experienced a population bottleneck in the southern portion of its range due to mortality from withering syndrome. We define a bottleneck as a period of time during which the population size was drastically reduced and may have remained sufficiently small over a sufficiently lengthy time period to risk experiencing a significant reduction in genetic diversity. Comparison of samples

collected prior to this bottleneck and contemporary samples collected from the same sites would provide a deeper understanding of the disease's effect on genetic diversity. For example, if the disease resulted in significant declines in genetic diversity, then this may raise our concern for overall species resilience in the face of environmental change or subsequent disease outbreaks. The plan should include: an inventory of existing samples (e.g., number of samples, collection location, current location of sample) and analysis results; an appropriate sample design for long-term monitoring and for temporal studies; and guidance on maintaining, archiving, and coordinating future use of the samples.

2.3. **Develop genetic methods for identifying sex of individuals** (see Recovery Action 1.1.1). Monitoring sex-ratio is needed to model the reproductive potential at a site and whether external factors (e.g., endocrine disruptors) may be acting to skew sex ratio. The ability to accurately identify the sex of an individual will also be critical to guide population restoration efforts (see Recovery Action 3), such as selecting animals for local aggregation, translocation, and captive propagation. Work is in progress to identify genetic markers linked to sex by comparing genomic sequence data of animals of known sex. Development of such markers will allow us to collect sex ratio data from wild populations using non-lethal samples without removing animals from their substrate, which can cause injury.

2.4. **Develop genetic methods for evaluating the health of individuals** (see Recovery Action 1.1.1). Non-lethal tissue samples can be used to measure overall condition and health. For example, researchers may screen a subset of genes to develop a simple metric of stress, reproductive activity, or other processes related to health. Expression levels of genes such as insulin-like growth factor-1 (IGF-1) are typically related to nutritional status and growth. Similarly, expression levels of heat shock proteins (HSPs) can be used as genetic measures of stress to assess the health of animals across study sites.

3 RESTORE BLACK ABALONE POPULATIONS NOT CURRENTLY MEETING THE DEMOGRAPHIC RECOVERY CRITERIA, BY ENHANCING LOCAL POPULATIONS AND SUPPORTING NATURAL RECOVERY.

In the 1980s and 1990s, withering syndrome reduced black abalone abundances by 80 to 100% at long-term monitoring sites in California south of Monterey County (Neuman et al. 2010). Similar declines may have occurred in Baja California. At a few sites, black abalone numbers have been increasing since the early 2000s, with signs of recent recruitment. At most sites, however, black abalone continue to persist at low densities or remain locally extirpated. NMFS will work with partners throughout the coast to identify these sites and to develop and implement the appropriate actions to support natural recovery or, where needed, increase the abundance and density of local populations through enhancement. These restoration actions aim to reverse declining trends and re-establish locally extirpated populations, to build up the species' redundancy and resiliency and prevent extinction.

3.1 Develop a population restoration plan. NMFS will develop a plan to guide population restoration efforts, incorporating information from the research conducted under Recovery Action 3.2. This plan will include the following components: (a) identification of limiting

factors and information gaps by study site and/or SubRegion; (b) Region-specific guidance on habitat-based density goals (see Demographic Recovery Criterion 2); (c) general guidance for restoration research efforts (see Recovery Action 3.2); (d) site-specific and/or SubRegion-specific plans for applying restoration actions; and (e) guidance for minimizing risks. Risks to address include those associated with moving and collecting animals in the wild; transport of animals; disease and genetic management; predation, competition, and changing ocean conditions; and restoration efforts such as habitat restoration, local aggregation, translocation, captive breeding, and outplanting, and where these can be most effective. NMFS will review and update the population restoration plan as needed.

3.2 Conduct research to develop and evaluate population restoration methods for enhancing populations. These methods include habitat restoration, local aggregation, translocation, and captive propagation and outplanting. An ESA Section 10(a)(1)(A) scientific research permit issued by NMFS would be required to conduct studies, develop methods, and implement these restoration tools. NMFS will work with partners to coordinate research efforts and permitting needs. If found to be effective, then NMFS will work with partners to develop an implementation plan, guided by the population restoration plan discussed in Recovery Action 3.1. Care will be taken to communicate abalone locations in a way that protects these populations from illegal take.

3.2.1 Determine the value and efficacy of habitat restoration to enhance recruitment success, and conduct habitat restoration if appropriate. At long-term monitoring sites, changes to the habitat have been observed following the decline of black abalone. These changes include shifts in the invertebrate and algal community, with increased growth of encrusting organisms that fill in cracks and crevices and reduce the surface area for crustose coralline algae to grow. Habitat restoration activities would involve removing these encrusting organisms, to encourage the growth of crustose coralline algae (an important component of recruitment habitat). PISCO researchers have conducted, and continue to conduct, pilot studies to evaluate the feasibility and effectiveness of habitat restoration efforts to enhance recruitment success.

3.2.2 Determine the value and efficacy of aggregating local low abundance populations to enhance reproductive success, and aggregate if appropriate. Aggregation studies have been done using various abalone species (including limited studies involving black abalone; Ruediger 1999), with mixed results in terms of enhancement effectiveness. Additional studies are needed to evaluate effectiveness and key questions regarding the risk of injury/mortality; the distance and frequency at which individuals move; and what spatial scale and number of animals constitutes an effective aggregation for population enhancement, balancing the potential for increased risk of disease transmission and intraspecific competition. Aggregation studies should occur in localities where: 1) subpopulations are amenable to repeated assessment; 2) existing data suggests that population viability is low if left unmanipulated; 3) predation and

poaching pressures are minimal; and 4) the spatial scale of aggregation conforms to the genetic management plan in Recovery Action 3.1. Aggregation experiments will involve monitoring size structure, abundance, individual movements, and individual growth on a regular basis for an appropriate length of time (e.g., at least annually over five years and then every two years for an additional five years).

3.2.3 Determine the value and efficacy of translocation to establish viable populations, and translocate if appropriate. Similar to aggregation activities, limited translocation studies have been conducted using black abalone and other abalone species (Ruediger 1999). Further studies are needed to evaluate the effectiveness of translocating animals from one area to repopulate another, applying the same research parameters listed for aggregation (above). To conserve the genetic spatial structure of populations, translocation studies and efforts will rely on the guidance provided in the genetic management plan.

3.2.4 Continue research and development of captive propagation and outplanting of black abalone. Development of a captive propagation program would produce captive-bred animals for use in research and to artificially enhance wild populations, if needed. At this time, successful captive spawning has been very limited and difficult to replicate. The first priority is to determine the factors and protocols for conditioning and spawning broodstock on a regular and controlled basis. Once this has been accomplished, we will apply lessons learned from the white abalone captive propagation and outplanting programs to develop such programs for black abalone, including careful consideration of genetic and disease management. Additionally, information from aggregation and translocation studies may be applied to develop effective outplanting methods.

4 DEVELOP A PLAN TO REMOVE BLACK ABALONE IN RESPONSE TO EVENTS SUCH AS OIL SPILLS, LANDSLIDES, AND VESSEL GROUNDINGS.

Removing animals from the wild should only be conducted after adequately weighing the risks and benefits. Once a decision has been made, the removal, handling, and care of the animals should be conducted using best practices to minimize stress and maximize survival. Implementing removal activities involves many logistical challenges and potentially large technical, fiscal, administrative, and political investments, particularly in response to emergency situations such as contaminant spills, landslides, and vessel groundings. Thus, developing a plan and working with partners to prepare for such events is critical. This plan will provide decision-making tools and guidance for deciding when to remove animals from the wild, either before (pre-emptive) or after (non-preemptive) exposure to the effects of an event. The plan will also provide protocols for oiled and non-oiled animal care, protocols for short and long-term holding, guidance for returning animals to the wild, key contacts at the primary agencies (NMFS, CDFW-OSPR, USCG) to notify about events, and potential captive holding facilities for abalone. NMFS will work with partner facilities to develop the plan, coordinate with existing plans (e.g., Regional

Contingency Plans), establish agreements, and obtain needed permits (e.g., ESA permits). This plan may be used to respond to other events as well, such as a large disease event that threatens a population. Care will be taken to communicate abalone locations in a way that protects these populations from illegal take.

4.1 Identify and conduct research to develop the tools, guidance, and protocols needed to remove black abalone from the wild. NMFS will work with partners to compile information from past spill and vessel grounding events that have involved abalone, to evaluate what is known about effects on black abalone and best practices for response activities. Recent events include the Blue Mist vessel grounding in San Luis Obispo County, CA, in 2014 (Lonhart et al. 2014) and the Refugio oil spill in Santa Barbara County, CA, in 2015 (pers. comm. with Jack Engle, UCSB, and Pete Raimondi, UCSC, on 5-6 June 2015). NMFS will then work with partners to identify research needs to inform the development of tools, guidance, and protocols. Other abalone species may serve as a proxy for black abalone or may be used in pilot studies; however, because there may be species-specific differences, studies involving black abalone are preferred (and may rely on the ability to captively breed black abalone). Specific research needs identified by the BART include, but are not limited to, those discussed below. NMFS will work with partners to identify funding needs and sources for conducting this research.

4.1.1 Evaluate the effects of oil and dispersants on black abalone. Little is known about the effects of different oils and dispersants on black abalone. This information is critical to evaluating and weighing the risks of leaving abalone in place or removing them from the wild in the event of a spill or vessel grounding. Studies should evaluate the relative toxicity and effects of different types of oil and dispersants on black abalone at each life stage, preferably using captive-bred black abalone or other abalone species as surrogates.

4.1.2 Evaluate and develop methods for cleaning and caring for abalone exposed to oil and/or dispersants. Little is known about methods to clean and care for abalone that have been exposed to oil and/or dispersants. Studies are needed to evaluate the effectiveness of different methods, their effects on black abalone health and survival, and their applicability to animals in captive facilities as well as in the wild. Research will inform development of protocols for the cleaning and care of black abalone in captive facilities and in the wild (Recovery Action 4.3).

4.2 Develop protocols for removing black abalone from the wild. These protocols should include procedures for removing abalone preemptively and non-preemptively. The protocols should address the following and focus on managing risks to minimize stress and maximize survival: decision-making tools and guidance for deciding when to remove black abalone from the wild; collection guidance (e.g., number to collect per site, size ranges, isolated vs aggregated animals); collection methods; transport methods; holding conditions and holding facilities (e.g., for oiled and non-oiled animals; short-term and long-term

holding facilities); genetic and disease management; guidance on data collection, sampling, and health monitoring; and guidance for returning animals to the wild.

4.3 Develop protocols for cleaning and caring for abalone exposed to oil and/or dispersants. Currently, little is known about the impacts of oil and dispersants on black abalone, and how to clean and care for abalone that have been exposed to oil,dispersants, or both. Once studies have been conducted to assess effects and evaluate different cleaning and care methods (see Recovery Action 4.1), NMFS will work with partners to develop protocols to guide facilities in carrying out these methods. If possible, NMFS will also work with partners to develop methods and protocols for cleaning oiled black abalone in the wild. If an event occurs before these studies and protocols are developed, NMFS will work with partners on best management practices for cleaning and caring for abalone.

5 PROTECT AND RESTORE BLACK ABALONE HABITAT FROM THREATS SUCH AS OIL SPILLS, SEDIMENTATION, AND COMMUNITY SHIFTS THAT OCCUR IN THE ABSENCE OF BLACK ABALONE.

The quality and quantity of habitat available to support black abalone may be affected by episodic events such as oil spills and coastal erosion, as well as by more persistent threats such as coastal development and shifts in the algal and invertebrate community following the decline of black abalone. The ability to reverse these habitat effects varies by the severity, scope, duration, and nature of the effects. NMFS will work with partners to assess habitat quality throughout the species' range, identify areas to prioritize for protection, and identify areas that require habitat restoration. The goals are first to maintain existing, high quality habitat, and second to restore habitats important for species recovery.

5.1 Assess the quality and quantity of black abalone habitat throughout their range. Critical habitat has been designated, but fine-scale mapping of black abalone habitat and habitat quality along much of the coast is needed. Such information would complement existing data layers of rocky habitat along the California coast (e.g., Environmental Sensitivity Index (ESI) maps at https://oceanservice.noaa.gov/facts/esimap.html; Tenera Environmental Inc. 2007). Habitat quality surveys have been completed throughout most of the species' range. Habitat data used to generate expected habitat-based densities (Demographic Recovery Criterion 2) will also inform this action. NMFS will work with partners (including BOEM, MBNMS, CINMS, GFNMS, MARINe, PISCO, Navy, BLM) to identify gaps and conduct habitat assessments, to develop mapping tools for managers and researchers. Additional fine scale mapping of habitat and habitat quality should occur on a regular basis (e.g., every 10 years), and incorporate the risk of armoring or sedimentation in the next 25 years.

5.2 Develop and implement a plan to protect black abalone habitat in response to episodic events, such as oil spills and vessel groundings, and to coastal development plans that may affect black abalone habitat. The plan will include recommendations on

best practices to minimize effects on black abalone habitat as well as guidance for responding to incidents, damage assessment, monitoring, restoration and mitigation. This plan should include contingencies for the loss, addition, and migration of black abalone habitat in response to climate change impacts (e.g., sea level rise, increased storm intensity, coastal erosion). Care will be taken to communicate abalone locations in a way that protects these populations from illegal take.

5.2.1 Work with other Federal and State agencies with jurisdiction over the California coast to ensure consideration of black abalone habitat in permitting. For example, coastal central California is prone to landslide activity, which can bury black abalone habitat for decades. At McWay Cove, the rocky intertidal has been filled with sand since the 1982-83 ENSO event (pers. comm. with Steve Lonhart, NOAA/MBNMS, 28 Feb 2017). The May 2017 landslide at Mud Creek on the Big Sur coast buried approximately 1,700 ft (~518 m) of coastline (Raimondi et al. 2017). The spatial and temporal extent of continued sedimentation effects is being monitored. Emergency Development Permits issued to CalTrans by the California Coastal Commission and authorized by the National Marine Sanctuaries and other agencies (e.g., State Lands Commission, National Forest Service, USACE) should consider black abalone habitat and implement measures to minimize effects on black abalone and their habitat, to the extent possible.

5.2.2 Evaluate the effects of sedimentation on black abalone and identify high risk areas (e.g., areas with a high risk of land slide). In 2015, burial and subsequent re-exposure of a site on San Nicolas Island occurred within a span of several months (pers. comm. with Glenn VanBlaricom, USGS/UW, on 23 Mar 2016, and with John Ugoretz, Navy/CDFW, on 25 May 2016), with apparently precipitous mortalities of black abalone and other intertidal species. How that system recovers may provide insight to other areas of coastal California. NMFS will work with partners to evaluate and identify high risk areas along the coast. For example, the California Coastal Sediment Management Workgroup facilitates regional approaches to sediment management. Several counties have developed Coastal Regional Sediment Management Plans with maps identifying areas that experience severe erosion. For a copy of these plans, see the CA State Parks Division of Boating and Waterways webpage. NMFS will also work with CalTrans on pre-emptive risk minimization measures to assess their effects on black abalone and their habitat.

5.3 Develop and apply methods to restore habitat in areas affected by episodic events such as oil spills, sedimentation events, and community shifts. Methods to restore rocky intertidal habitats should be vetted to ensure they do not further compromise black abalone habitat. For example, in an oil spill, high-pressure hot water to clean rocks might do more harm than the oiling (Houghton et al. 1996, Paine et al. 1996, Shigenaka 2014). When community shifts alter habitat quality, restoration may be necessary, such as removing encrusting organisms or adding specific taxa to the habitat (e.g., crustose coralline algae;

see Recovery Action 3.2.1). NMFS will work with partners to identify, evaluate, develop, and implement methods to restore black abalone habitat where it has been affected.

5.4 Reduce threats to kelp forest health throughout the range of black abalone. Black abalone consume diverse species of macroalgae, many of which are transported from offshore kelp forests adjacent to black abalone habitat. Thus, kelp forest health is important to maintaining a reliable, quality food supply for black abalone populations, as well as for overall ecosystem health. Kelp may also aid in local retention of abalone larvae (McShane 1992) and reduce ocean acidification effects (Pfister et al. 2019, Murie and Bourdeau 2020). NMFS will work with partners to identify threats to kelp forest health (e.g., climate change impacts, warm water events, invasive algal species) and ways to address these threats to maintain healthy kelp forests. This may include supporting the important role of marine reserves (e.g., Sanctuaries, marine protected areas) to protect and enhance black abalone habitat.

6 CONTINUE, REFINE, AND EXPAND RESEARCH ON WITHERING SYNDROME, OTHER DISEASES, AND OCEAN ACIDIFICATION.

Under Recovery Action 1.2, researchers will evaluate and monitor the health of wild black abalone populations and disease impacts. Research efforts should also continue to understand how diseases are transmitted, how they affect individuals and populations, and how physical, biological, and environmental factors influence pathogen transmission dynamics and disease expression. This understanding will be critical to assess and manage disease risks to black abalone. In addition, studies are needed to evaluate the potential effects of changing ocean conditions (e.g., ocean acidification) on black abalone and how to address these effects. If possible, research should use captive-bred black abalone.

6.1 Continue and expand research on withering syndrome and its effects on black abalone. Mass mortalities results from withering syndrome was identified as the primary threat putting black abalone at risk of extinction (VanBlaricom et al. 2009). Although mass mortalities have not been observed in recent years, withering syndrome continues to pose a major threat to black abalone populations. Continued research is needed to assess and identify ways to manage and ameliorate this threat, if possible, to prevent further declines and species extinction. NMFS will work with researchers (e.g., at the University of Washington, CDFW/BML, CICESE) to prioritize and carry out studies to inform understanding of the disease and how to advance species recovery in its presence. Research topics include: Transmission dynamics, factors affecting susceptibility to infection and onset of the disease (e.g., location, size/age, species interactions such as the presence of infected red, pinto, pink, or green abalone), phage distribution and dynamics, thermal modulation of disease expression in the presence of the phage, genetically-based disease resistance, and how infection with both the pathogen and the phage affects fitness, including reproduction.

6.2 Develop model(s) to evaluate withering syndrome transmission dynamics, including the influence of climate, density, genetically-based disease resistance, phage

intervention, and species interactions. Understanding the factors that lead to the start and end of a disease outbreak is crucial to forecasting disease events and species interactions within a natural ecosystem or farm, as well as interactions between these two systems. Withering syndrome causes severe losses in pinto abalone, low level losses in pink abalone, few or no losses in green abalone, and moderate losses in farmed red abalone, as documented by field studies and experimental trials (Crosson et al. 2014, Crosson and Friedman 2018). Factors controlling withering syndrome (e.g., infection, thermal stress) have been well documented in red abalone and, to a lesser extent, other California abalone (e.g. black, pinto, pink, green and white; Crosson et al. 2014, Crosson and Friedman 2018; Vilchis et al. 2005). We lack critical data on how temperature influences shedding of the pathogen, and the pathogen's survival in seawater, dispersal over long distances (e.g., among the Channel Islands), and ability to infect new hosts. We need empirical data on transmission dynamics and driving factors (e.g., temperature) to forecast outcomes of disease scenarios and inform management decisions, such as selecting translocation sites.

6.3 Apply disease research and models to population restoration plans and efforts. Withering syndrome poses a major threat to population restoration efforts, because restored populations will be susceptible to the same mass mortalities experienced in the 1980s and 1990s. To address this threat and prevent extinction, population restoration plans and efforts (see Recovery Action 3) should consider disease management, using information generated from disease research and modeling. For example, to select restoration sites, we must understand species interactions, including how temperature influences infection rates and shedding of the pathogen, and the survival of the pathogen in seawater. We also need to assess the genetic basis of disease resistance or tolerance to infection, the heritability of resistance, and the trade-offs of disease resistance and genetic bottlenecks following mass mortality (see Recovery Action 2 on Genetics). NMFS will work with partners to incorporate such information into disease management protocols (see Recovery Action 3.1). These protocols will be used to guide development of optimal restoration strategies and focus efforts where they will most likely contribute to species recovery. Research and model results should also be incorporated into plans for removing black abalone from the wild (see Recovery Action 4), particularly if such plans are applied to a disease event.

6.4 Evaluate potential susceptibility of black abalone to other abalone diseases, including diagnosing and understanding host-parasite relationships. The principal foreign disease concerns for black abalone include the herpes virus in Australia and Taiwan (herpes virus), the amyotrophia virus in Japan, the shriveling syndrome virus in China, the bacterium *Vibrio harveyi* in France, and the protozoan parasite *Perkinsus olseni*. We should evaluate the susceptibility of black abalone to these pathogens, to develop targeted efforts to exclude them (e.g., focusing on geographic regions or illegal aquarium imports, illegal imports for food markets, ballast water exchange). Evaluating black abalone susceptibility to these pathogens should be done in the source country or a laboratory with strict biosecurity to prevent pathogen release. Conducting these challenges will require several hundred animals but would be relatively straightforward with adequate planning, funding, and collaboration with abalone health professionals worldwide.

6.5 Review existing regulations regarding live trade of abalone and other marine species, and revise regulations as needed to minimize the risk of transmitting pathogens. In California, a valid CDFW importation permit is generally needed to import live aquatic animals from any other state or country (CCR Title 14 Section 236 (c)), but not for mollusks and crustaceans intended to go directly into the seafood market with no contact with state waters, or for ornamental tropical marine organisms maintained in closed systems for personal, pet industry, or hobby purposes (CCR Title 14 sections 236 (b) (1) and (2)). In 2008, abalone disease concerns led CDFW to list all non-native abalone species as Restricted Species (CCR Title 14 Section 671 (c) (9) (D)), requiring a specific Restricted Species permit to import for any use, including hobby aquarium and terminal food markets. Through 2020 no entity has applied for such a permit. However, native species farmed overseas, such as red abalone (*H. rufescens*), may be imported into California without such a permit, presenting a potential mechanism for introduction of foreign pathogens and pests. Research is needed to identify and support changes, such as requiring permits for all abalone imports regardless of species or intended use. In addition, foreign diseases may emerge in Mexico or potentially Oregon, Washington, British Columbia, or Alaska, and spread throughout this range. Regulators and researchers throughout the coast should coordinate to prevent the introduction of foreign disease agents.

6.6 Evaluate pH tolerance and the effects of decreasing pH on various life stages of black abalone. In particular, larval and post-settlement stages may be more susceptible to ocean acidification than adults. Studies can include exposing animals to levels of dissolved carbon dioxide that span the range of those experienced and/or predicted in the species' range. Study goals include evaluating the development (e.g., metamorphosis, shell formation), survival, growth, and condition of different life stages of black abalone under relevant conditions. The effects of other stressors in combination with ocean acidification should be evaluated. In addition, studies should examine the degree to which black abalone possess phenotypic plasticity or genetic variation that may promote adaptation to changing oceanographic conditions. If possible, captive-bred black abalone or surrogates (other abalone species) should be used for these studies.

7 MAINTAIN AND ENHANCE BINATIONAL COORDINATION WITH MEXICO.

To adequately assess the status and recovery of black abalone, we need a broad understanding of their historical and current status in Mexico and efforts to conserve and protect the species. The available information is limited but indicates that black abalone populations have declined significantly in Baja California, although anecdotal reports in recent years suggest increased numbers at some mainland sites (pers. comm. with Ricardo Searcy-Bernal, Universidad Autonoma de Baja California, 16 Aug 2016; pers. comm. with Fabiola Lafarga de la Cruz, CICESE, 18 Aug 2016). Collaboration on research, monitoring, and sharing of information will be critical to understand and assess the species' status and recovery in Mexico.

7.1 Develop opportunities for information exchange on a regular basis, such as annual or biennial workshops/meetings. NMFS will work with partners in the U.S. and Mexico to develop opportunities where researchers and managers from both nations can meet to share data and information; provide updates on research, monitoring, conservation efforts, and management; and develop collaborations. In 2016, researchers at CICESE hosted an abalone workshop as part of the joint Western Society of Malacologists/American Malacological Society annual meeting in Ensenada. In addition, representatives of both nations participate in binational science and policy meetings where species such as black abalone are discussed. NMFS will continue to seek out and develop such opportunities, with the goal to enhance communication, collaboration, and coordination between researchers and managers in the U.S. and Mexico for black abalone recovery.

7.2 Coordinate and collaborate on monitoring, research, and funding opportunities. NMFS will work with partners in the U.S. and Mexico to identify and pursue opportunities to work together on black abalone monitoring and research, to improve understanding of black abalone populations throughout their range and collaborate on conservation and management. Opportunities include collaborating on genetic, disease, and captive breeding research, and establishing and expanding long-term black abalone monitoring programs in Baja California. In 2016, researchers at CICESE collected black abalone broodstock for captive research studies and identified sites where long-term monitoring may be established (pers. comm. with Fabiola LaFarga, CICESE, 9 Nov 2016). Coordination with the long-term monitoring program in California will be important as this program develops in Baja California.

8 DEVELOP AND IMPLEMENT ENFORCEMENT, PUBLIC OUTREACH, AND EDUCATION PLANS.

Enforcement, public outreach, and education are vital to black abalone recovery, to raise awareness and promote individual responsibility and stewardship. NMFS will work with the NOAA Office of Law Enforcement (OLE) and CDFW enforcement to enforce laws and regulations, and educate the public. NMFS will also work with partners to develop and implement outreach and education in multiple ways, such as at place-based centers (e.g., visitor centers, aquaria) and via indirect outlets such as digital media (e.g., social media, web sites, emails).

8.1 Coordinate on enforcement issues to enforce existing State and Federal protections and recommend new protections, if needed. In recent years, enforcement cases involving black abalone include illegal take and vessel groundings, affecting both individuals and their habitat. Coordination is needed among multiple agencies (e.g., NOAA OLE, CDFW, NMS, USCG, US Customs and Border Protection, USFWS, State Parks, NPS, NOAA's National Marine Sanctuaries) and with Mexico and Canada. This can include regular information exchange meetings, evaluation of potential gaps in existing protections and patrols, technology and asset sharing, and prosecution of cases at both State and Federal levels.

8.1.1 Refine CDFW database to track past and current illegal take cases and violations. CDFW has an existing database to track illegal take cases in California. NMFS will work with CDFW to identify additional information to include in the database, such as the number taken per species, and the condition, status, and disposition of the abalone (e.g., returned to the wild or brought into captivity; location/facility). NMFS will also coordinate with CDFW to develop guidance for the disposition of dead and live black abalone confiscated during illegal take cases.

8.1.2 Develop materials to inform relevant entities and the public about regulations and resources to minimize disease risks to abalone and address illegal take. This may include education and outreach to shellfish importers and exporters and the public regarding responsible live trade practices to emphasize disease risks, as well as regarding State abalone harvest regulations and resources for notifying wardens about violations (e.g., poaching hotline).

8.1.3 Develop coordination with Mexico and Canada to identify and address illegal abalone trade. NMFS will work with partners in the U.S., Mexico, and Canada to identify, evaluate, and address the main issues regarding illegal trade of black abalone. This will require identifying the appropriate organizations and individuals, understanding the status of black abalone and its protections in each country, and developing and implementing strategies to address illegal take and illegal trade.

8.2 Develop key, unified messaging in collaboration with partners to share in public outreach and education efforts, highlighting the biological, cultural, and economic importance of abalone in California and Mexico. NMFS will work with partners and experts to develop consistent, unified messaging to be used in outreach and education. The messaging will include key points and high quality images to be shared by partners interacting directly with the public (e.g., visitor centers) and indirectly via electronic media (e.g., e-newsletters, blogs, social media). The messaging will also include information about threats to black abalone and actions the public can take to reduce those threats (e.g., simple actions and behaviors to address the emerging threat of ocean acidification). NMFS will work with partners to establish outreach and education goals and evaluate the effectiveness of efforts to meet these goals.

8.2.1 Evaluate public perception of black abalone and their cultural and ecological importance. Gathering information about the public's perception of black abalone, their ecological and social importance, and their recovery is key to creating strategic messages that will educate and inform the public about abalone conservation and what they can do to protect abalone (e.g., report poachers, minimize accidental harm to individuals). Such information can be collected in-person (e.g., at rocky intertidal locations visited by the public that were or are currently occupied by black abalone) and electronically (e.g., questionnaires). It should also involve talking with Native American communities (such as the Chumash community) regarding the historical cultural importance of abalone.

8.2.2 Identify and bring together key partners through an outreach workshop to review existing resources and to discuss and develop signage, educational displays, and other outreach materials. Workshop objectives would include incorporating black abalone messaging into existing outreach and education efforts, programs, and materials; identifying outreach and education gaps; and developing new materials as needed. Participants in the workshop would include, but are not limited to, NMFS, NOAA's National Marine Sanctuaries, National Park Service, California Coastal Commission, CDFW, MARINe/PISCO, State Parks, Tribes, UC Davis Bodega Marine Lab, the University of Washington, and local aquaria.

8.2.3 Update and develop signage and educational materials for display at public aquaria and other facilities and for public outreach through digital media. Three major categories of outreach and education include: printed materials (e.g., signs, brochures, displays); personal contact (e.g., docents, educators); and digital media (e.g., web sites, blogs, social media). NMFS will work with partners to update and develop materials and best strategies for their use. For example, public aquaria that currently (or plan to) have black abalone on display can incorporate the key messages and use red abalone as surrogates for interactive displays (e.g., touch tanks, opportunities to feed abalone). Facilities may work with media contacts to develop a social media campaign. Materials should be provided in languages common in the area (e.g., English, Spanish, Mandarin) to reach diverse communities.

8.2.4 Incorporate black abalone key messaging points into existing programs for K-12 schools (e.g., "Island of the Blue Dolphins" book discussion, fishery harvest activities), docent training programs (e.g., state parks, NPS, NOAA's National Marine Sanctuaries), and citizen science groups working in the rocky intertidal. A narrative about long-term monitoring of black abalone, the history of withering syndrome, the decline that led to the ESA-listing, and efforts to recover black abalone should be developed and accompany the key messages, to provide context for the public and interested parties. A mobile or online display of this content could be shared among partners and travel up and down the coast on a regular basis, to maintain a consistent message and reduce the costs associated with developing their own outreach tools. NMFS will work with outreach and education partners to develop these materials and incorporate them into existing programs.

5 TIME AND COST ESTIMATES (Implementation Schedule)

The Implementation Schedule outlines the recovery actions and estimated costs for the black abalone recovery program. It is a guide for meeting the recovery goals outlined in this Recovery Plan. This schedule indicates action priorities, duration, responsible parties (for funding or carrying out actions), and estimated costs. It identifies parties with authority, responsibility, or expressed interest to implement a specific recovery action. When more than one party has been

identified, the proposed lead party is indicated by an asterisk (*). The listing of a party in the Implementation Schedule does not require the identified party to implement the action(s), or to provide or secure funding. Also, implementation is not limited to the parties identified in this schedule. During implementation, we may identify additional parties that are interested in implementing a specific recovery action or actions.

The Implementation Schedule provides estimated costs for the first five years of recovery implementation (FY1 – FY5). We developed these cost estimates based on estimates from past projects, as well as estimates gathered from partners that may be involved in implementing the recovery actions. Many of the actions are expected to continue beyond year five, until the species is recovered and delisted. The total time needed to recover black abalone cannot be estimated with much certainty, although recovery will likely take decades. Reasons for this uncertainty include threats that are difficult to manage, such as diseases and contaminant spills, making it difficult to estimate the time needed to address these threats and to achieve a level of resiliency that is sufficient to ensure the species' viability over the long term.

The Implementation Schedule estimates the total cost of recovery based on a minimum time frame of 20 years. Recovery could occur at a faster rate (e.g., if significantly large recruitment events occur over a period of a few years) or at a slower rate (e.g., if catastrophic declines occur over a period of a few years). For example, in 2016-2017, numbers at one study site on San Nicolas Island increased by an order of magnitude in one season due to a large recruitment event (VanBlaricom 2017, unpublished data). During the same time period, numbers declined by 75% at a site on Santa Cruz Island that had been increasing for several years (Whitaker 2017, MARINe unpublished data). The total time to recovery will also depend on the availability of funding to carry out the recovery actions and the effectiveness of the recommended actions to achieve the Recovery Criteria. This Recovery Plan may be used by NMFS and other partners to prioritize and secure funding to support the recovery actions.

For each recovery action, we have assigned a priority based on the following definitions (84 FR 18243; 30 April 2019). Assigning priorities does not imply that some actions are of low importance. Rather, the priorities imply that some actions may be deferred while higher priority recovery actions are being implemented.

Priority 1: Actions that must be taken to remove, reduce, or mitigate major threats and prevent extinction and often require urgent implementation. This may include research needed to provide critical information to initiate the action.

Priority 2: Actions to remove, reduce, or mitigate major threats and prevent continued population decline, or research needed to fill knowledge gaps to prevent continued population decline. The implementation of these actions is less urgent than Priority 1 actions.

Priority 3: Actions that should be taken to remove, reduce, or mitigate any remaining, non-major threats and ensure the species can maintain an increasing or stable population to achieve delisting criteria, including research needed to fill knowledge gaps and monitoring to demonstrate achievement of recovery criteria.

Implementation Schedule, with duration and costs estimated for the first five years following publication of the final Recovery Plan and for the minimum time (20 years) projected to achieve full species recovery.

IMPLEMENTATION SCHEDULE **Black Abalone (*Haliotis cracherodii*)**												
Recovery Action #	**Action Description**	**Priority Number**	**Action Duration**	**Potential Partners**	**Estimated Fiscal Year Costs $ K**							**Comments**
					1	**2**	**3**	**4**	**5**	**FY1-5**	**FY1-20**	
1.1	Continue and/or expand long-term monitoring program to evaluate population trends	1	FY1-FY5 & beyond	NMFS, BOEM, CDFW, CICESE, CMA, CPP, CSUF, MARINe*, Navy, NPS, PISCO, UCLA, UCSC, USGS, UW	189	194	200	206	212	1,001	4,000	Annual monitoring for California (~ 103 sites) at ~$200K per year
1.1.1	Evaluate existing black abalone monitoring programs and implement modifications as needed	2	FY1-FY2 & beyond		10	10			10	30	60	Estimated costs for a workshop in FY1-2, FY5, FY10, FY15, and FY20, at $10K per workshop.
1.1.2	Evaluate monitoring efforts to identify overlap or where more efforts are needed	1	FY1-FY2 & beyond		See costs above for 1.1.1 (workshop to discuss 1.1.1, 1.1.2, and 1.1.3)							
1.1.3	Develop a plan/process for data management, analysis, and sharing	1	FY1-FY2 & beyond		See costs above for 1.1.1 (workshop to discuss 1.1.1, 1.1.2, and 1.1.3)							
1.2	Evaluate and monitor the health of wild populations	2	FY1-FY5 & beyond		See costs outlined below							
1.2.1	Incorporate or continue health observations during long-term monitoring	2	FY1-FY5 & beyond		No additional costs; incorporated into Action 1.1							
1.2.2.	Develop non-lethal methods to quantify WS-RLO infection and its phage in wild populations	2	FY1-FY5	UW*, BML/ CDFW*	150	50	50	50	50	350	350	FY1: qPCR validation, sample 15 sites twice. FY2-FY5: sample 15 sites per year
TOTALS FOR RECOVERY ACTION 1					**349**	**254**	**380**	**386**	**272**	**1,641**	**4,670**	

IMPLEMENTATION SCHEDULE Black Abalone (*Haliotis cracherodii*)												
Recovery Action #	**Action Description**	**Priority Number**	**Action Duration**	**Potential Partners**	**Estimated Fiscal Year Costs $ K**							**Comments**
					1	**2**	**3**	**4**	**5**	**FY1-5**	**FY1-20**	
2.1	Develop plan for assessing genetic structure of wild populations across range	2	FY1-FY3 (baseline) & every 10 years	NMFS*, UW	25	100	80	0	0	205	615 (Three 3-year studies)	FY1: Sample curation/preparation; FY2: genotype 50-100 abalone/site (≥ 1 site per SubRegion); FY3: data analysis.
2.2	Develop plan for long-term monitoring and temporal studies on genetics	3	FY4-FY5	NMFS*, UW	0	0	0	25	25	50	50	Additional sample curation and study preparation
2.3	Develop genetic methods to identify sex of individuals	3	FY1-FY5	NMFS*, UW	50	25	10	10	10	105	105	FY1-2: Basic research & development; FY3-5: sample processing
2.4	Develop genetic methods to evaluate condition	3	FY1-FY5	NMFS*, UW	50	25	25	25	25	150	150	
TOTALS FOR RECOVERY ACTION 2					**125**	**150**	**115**	**60**	**60**	**510**	**920**	
3.1	Develop population restoration plan	1	FY1-FY5	NMFS*, CDFW, CICESE, MARINe, Navy, NPS, PISCO, UW	No additional costs; see costs outlined below							Update plan with research results
3.2	Research to develop and evaluate population restoration methods	1	FY1-FY4 & beyond		65	65	65	65		260	260	Initial studies to evaluate restoration tools to inform Actions 3.2.1 – 3.2.3
3.2.1	Determine value of habitat restoration	1	FY4-FY5	PISCO				114	114	227	456	Estimated costs for a 2-year study conducted in FY1-FY5 and a second study conducted after FY5
3.2.2	Determine value of local aggregation	1	FY4-FY5	PISCO, CDFW				59	59	118	236	
3.2.3	Determine value of translocation	1	FY4-FY5	PISCO, CDFW				32	32	64	128	
3.2.4	Research and develop captive propagation methods	1	FY1-FY5 & beyond	NMFS (SWFSC)	25	25	25	25	25	125	500	Annually $25K to maintain program
TOTALS FOR RECOVERY ACTION 3					**90**	**90**	**90**	**295**	**230**	**794**	**1580**	

IMPLEMENTATION SCHEDULE Black Abalone (*Haliotis cracherodii*)													
Recovery Action #	**Action Description**	**Priority #**	**Action Duration**	**Potential Partners**	**Estimated Fiscal Year Costs $ K**							**Comments**
					1	**2**	**3**	**4**	**5**	**FY1-5**	**FY1-20**	
4.1	Develop tools, guidance, and protocols for removal of black abalone from the wild	2	FY1-FY5 & beyond	NMFS*, CDFW, NMS, USCG, UW	See cost breakdown below.							Cost estimates are for initial studies and development of protocols. Additional studies may be needed beyond FY5 (not included in FY1-20 column).
4.1.1	Evaluate the effects of oil and dispersants on abalone	2	FY3-FY5	NMFS, UCD			122	122	122	366	366	
4.1.2	Evaluate cleaning/care methods for oiled abalone	2	FY3-FY5	NMFS, UCD			33	33	33	99	99	
4.2	Develop protocols for removing wild abalone	2	FY1-FY5	NMFS, CDFW	No additional costs; see costs under 4.1.1 and 4.1.2							
4.3	Develop cleaning/care protocols for oiled abalone	2	FY1-FY5	NMFS, CDFW	No additional costs; see costs under 4.1.1 and 4.1.2							
TOTALS FOR RECOVERY ACTION 4					**0**	**0**	**155**	**155**	**155**	**465**	**465**	
5.1	Assess quality and quantity of black abalone habitat	2	FY1-FY3 & beyond	NMFS,CDFW, MARINe*, PISCO, Navy, CINMS, MBNMS, GFNMS	57	57	57			171	684	Three 3yr surveys (every 10 years)
5.2	Develop and implement plan to protect habitat	2	FY1-FY3 & beyond		No additional costs; incorporate into project review							
5.2.1	Work with Federal and State agencies to consider black abalone habitat in permitting	2	FY1-FY5 & beyond	NMFS*, State/ Fed agencies (e.g., CT, NMS, Navy, USACE)	No additional costs; incorporate into project review							
5.2.2	Evaluate sedimentation effects and high risk areas	2	FY1-FY5		No additional costs; incorporate into project review							
5.3	Develop and apply habitat restoration methods	2	FY3-FY5 & beyond	NMFS, CDFW, MARINe*, PISCO, Navy			158	25	25	208	1532	Four one-acre projects, monitor over 10 years (383K/project)
5.4	Reduce threats to kelp forests	2	FY1-FY5 & beyond		Support ongoing kelp restoration efforts; costs unknown at this time.							
TOTALS FOR RECOVERY ACTION 5					**57**	**57**	**215**	**25**	**25**	**379**	**2216**	

IMPLEMENTATION SCHEDULE Black Abalone (*Haliotis cracherodii*)												
Recovery Action #	**Action Description**	**Priority Number**	**Action Duration**	**Potential Partners**	**Estimated Fiscal Year Costs $ K**							**Comments**
					1	**2**	**3**	**4**	**5**	**FY1-5**	**FY1-20**	
6.1	Continue/expand withering syndrome research	1	FY1-FY5 & beyond	BML/ CDFW*, CICESE*, UW*	200	200	200	200	200	1000	2000	Estimate for 10 years at 200K/year
6.2	Develop models to evaluate withering syndrome transmission dynamics	2	FY2-FY3			200	200			400	400	Estimate for one 2-yr project in FY1-5
6.3	Apply disease research and models to population restoration plans and efforts	1	FY4-FY5 & beyond	NMFS				200		200	600	Review plans in FY1-5 and at FY10 and FY20
6.4	Evaluate susceptibility of black abalone to other abalone diseases	2	FY2-FY4 & every 10 years	BML/ CDFW, CICESE, UW*		250	250	250		750	2500	Conduct initial 3-year study and two additional 3-year studies (750K/study)
6.5	Review/revise regulations on live trade of marine species to minimize disease risks	3	FY1	BML/ CDFW*, UW	125						125	Costs for initial review/revisions; additional review may be needed
6.6	Evaluate pH tolerance and effects of decreasing pH on different life stages	2	FY3-FY4	UW			130	130		260	260	Two-year project to test pH tolerance of 3 life stages
TOTALS FOR RECOVERY ACTION 6					**325**	**650**	**780**	**780**	**200**	**2735**	**5885**	
7.1	Develop opportunities for researchers and managers in U.S. and Mexico to share information regularly	2	FY1-FY5 & beyond	NMFS, CICESE	5	5	5	5	5	25	100	Estimated costs to hold annual workshop at 5K per year
7.2	Coordinate and collaborate on monitoring, research, and funding between researchers in the U.S. and Mexico	2	FY2-FY5 & beyond	NMFS, CICESE		42	42	17	17	118	490	Estimates for three 2-yr habitat surveys (25K/year) and annual population surveys (17K/year)
TOTALS FOR RECOVERY ACTION 7					**5**	**47**	**47**	**22**	**22**	**143**	**590**	

IMPLEMENTATION SCHEDULE Black Abalone (*Haliotis cracherodii*)												
Recovery Action #	**Action Description**	**Priority #**	**Action Duration**	**Potential Partners**	**Estimated Fiscal Year Costs $ K**							**Comments**
					1	**2**	**3**	**4**	**5**	**FY1-5**	**FY1-20**	
8.1	Enforcement: Coordinate at State/Fed level to enforce existing laws, recommend new protections	2	FY1-FY5 & beyond	NOAA OLE*, NMFS, CDFW, NMS, NPS, State Parks, USFWS, USCBP, USCG	See cost breakdown below.							
8.1.1	Refine CDFW database to track poaching cases	2	FY1-FY2		2	2	2		2	8	22	Initial 6K; 2K to update every 2 yrs
8.1.2	Develop outreach materials on disease and poaching	3	FY1-FY2 & beyond		1	1				2	6	Printing costs: FY1-2 & every 5 years
8.1.3	Coordinate with Mexico and Canada to address illegal abalone trade	2	FY1-FY3 & beyond	NMFS*, CDFW, CAN, MX	2		2		2	6	40	Travel costs to attend meetings every 2 years
8.2	Collaborate with partners to develop and disseminate key, unified message	3	FY1-FY5 & beyond	NMFS* and all partners	See cost breakdown below							
8.2.1	Evaluate public perception of black abalone status	3	FY1-FY2 & beyond	NMFS*, CDFW, NMS	5	5				10	30	Intern/contract: Three 2-yr studies (i.e., every 10 yrs)
8.2.2	Outreach workshop to discuss/develop materials	3	FY1-FY5 & beyond	NMFS* and all partners	10	10			10	30	60	Host workshops in FY1-2, 5, 10, 15, 20
8.2.3	Develop signage and educational material for display and digital media	3	FY1-FY5 & beyond		5	5	2	2	2	16	43	Costs to develop & print materials and update/maintain displays annually
8.2.4	Incorporate key messages into educational/training programs	3	FY1-FY5 & beyond		5	5	2	2	2	16	43	Costs to incorporate and update annually
TOTALS FOR RECOVERY ACTION 8					**28**	**25**	**6**	**4**	**16**	**80**	**202**	
TOTALS FOR ALL RECOVERY ACTIONS (first 5 years and to recovery, estimated to at least 20 years)					**979**	**1274**	**1658**	**1597**	**980**	**6487**	**16268**	

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APPENDIX A: EXISTING BLACK ABALONE STUDY SITES

The table below lists the existing study sites where long-term monitoring of black abalone is conducted at least annually. These study sites are the basic unit for evaluating the Demographic Recovery Criteria (Section 3.3 of this Plan). To protect the location of these sites, they are listed by an assigned numeric code, rather than the site name. We summarize the following information for each study site: entities involved in monitoring, major funders, frequency of monitoring, the site establishment date, site dimensions/area covered (m^2), and survey methods. Information is not available for some sites (blank cells). Data for most MARINe sites are available by request (https://marine.ucsc.edu/explore-the-data/contact/index.html).

Black abalone surveys are also conducted at sites that are monitored less frequently or have only been surveyed once. These sites would not be used to evaluate the Demographic Recovery Criteria and are not included in this table.

Descriptions and Codes used in the Table:

Site Code = a numerical sorting code used in the MARINe database.

Entity = group(s) currently in charge of monitoring

- CINP = Channel Islands National Park
- CMA = Cabrillo Marine Aquarium
- CNM = Cabrillo National Monument
- CPP = California State Polytechnic University, Pomona
- CSUF = California State University at Fullerton
- CSULB = California State University at Long Beach
- GGNP = Golden Gate National Parks
- Navy = U.S. Navy
- PRNS = Point Reyes National Seashore
- Tenera = Tenera Consulting
- UABC = Universidad Autónoma de Baja California
- UCSB = University of California at Santa Barbara
- UCSC = University of California at Santa Cruz
- USGS = U.S. Geological Survey
- UW = University of Washington

Current PI initials:

- BB = Ben Becker
- BJA = Bengt J. Allen
- DF= Darren Fong
- GVB = Glenn Van Blaricom
- JB = Jessica Bredvik
- JEC = Jenn Caselle
- JKP = Julianne Kalman Passarelli
- JLB = Jennifer Burnaford
- JME = Jack Engle
- JRS = Jayson Smith

- JS = John Steinbeck
- KL = Keith Lombardo
- MK = Mike Kenner
- PTR = Pete Raimondi
- RB = Rodrigo Beas
- SGW = Stephen Whitaker

Major Funders = Funding agencies that have contributed to the cost of monitoring (could be partial or short-term support).

Codes:

- ASIL = Asilomar State Beach
- BOEM = Bureau of Ocean Energy Management
- CASG = California Sea Grant
- CASP = California State Parks
- CCC = California Coastal Commission
- CMA = Cabrillo Marine Aquarium, City of Los Angeles Department of Recreation and Parks
- CSULB = California State University at Long Beach
- DOD = U.S. Department of Defense, Legacy Resource Management Program
- MBNMS = Monterey Bay National Marine Sanctuary
- NAVY = Navy
- NMFS = National Marine Fisheries Service
- NBSv = National Biological Service
- NBSy = National Biological Survey
- NPS = National Park Service
- OPC = Ocean Protection Council (MPA funding through California Sea Grant)
- PG&E = Pacific Gas & Electric
- PISCO = Partnership for Interdiciplinary Studies of Coastal Oceans; funded primarily by David and Lucile Packard Foundation and Gordon and Betty Moore Foundation
- SBC = Santa Barbara County
- SCCWRP = Southern California Coastal Water Research Project
- SERP = San Elijo Restoration Project
- SLO = San Luis Obispo County
- TAT = Tatman Foundation
- TNC = The Nature Conservancy
- UCM = UC Mexus
- UCSC = University of California at Santa Cruz
- USFWS = U.S. Fish and Wildlife Service
- USGS = U.S. Geological Survey
- UW = University of Washington
- VAFB = Vandenberg Air Force Base

Freq per year: Number of times site is currently sampled per year. Many sites in the MARINe consortium were historically sampled twice per year, but were reduced to once per year in 2017.

Dimensions:

- For sites with permanent plots, the plot area is given in m^2. For sites with two survey methods, the total plot area for each method is given, separated by a slash (/). A question mark (?) is used where plot area is not known.
- For sites with fixed band transects, the dimensions and total area of the band transects are given in meters and m^2.
- For sites without permanent plots for black abalone, but where 30 minute "whole site" searches are done, "site" is listed as the dimension. These sites vary from about 30 x 50 m to 75 x 200 m. Sites where "whole site" searches are done may miss black abalone when they are very rare.
- For San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara islands: The search area is delineated by the estimated length of the shoreline and the estimated width of the intertidal (L x W) in meters.
- Sites with no dimension listed are those where there are no abalone plots, and where timed searches are not done. Black abalone are noted if observed. Targeted searches for black abalone could be implemented with additional funding.

Survey Method Codes:

- AHA = abalone habitat surveys, conducted one time. These plots are not considered study sites, but dimensions are included here for informational purposes.
- GSES = general site search, typically 30 min, surveyed annually.
- IP = irregular shaped, permanent plots, surveyed annually.

Study Sites Table

Region	SubRegion	Site Code	Entity	PI	Major Funder	Freq per year	Start Date	Dimensions	Methods	In MARINe database?
North-Central CA	Del Mar Landing Ecological Reserve to Bodega Head	5110	UCSC	PTR	OPC, PISCO, NMFS, TNC	1X	2001	214 / 2740	IP & AHA	Y
		5150	UCSC	PTR	OPC, PISCO, NMFS	1X	2004	62	IP	Y
		5200	UCSC	PTR	OPC, PISCO, NMFS	1X	2001	71 / 1370	IP / AHA	Y
	Bodega Head to Point Bonita, including Farallon Islands	5220	PRNS, UCSC	BB	NPS	1X	2006	? / 690	? / AHA	Y
		5240	PRNS, UCSC	BB	NPS	1X	2005	? / 8290	? / AHA	Y
		5270	PRNS, UCSC	BB	NPS	1X	2006	? / 1330	? / AHA	Y
		5280	GGNP	DF	NPS	1X	2006			Y
Central CA	Pescadero State Beach to Natural Bridges State Beach	5540	UCSC	PTR	PISCO, MBNMS, OPC	1X	2004	110 / 1655	IP / AHA	Y
		6000	UCSC	PTR	PISCO, MBNMS, OPC	1X	2002	2768	IP	Y
		6010	UCSC	PTR	PISCO, MBNMS, OPC	1X	2004	85 / 780	IP / AHA	Y
		6030	UCSC	PTR	PISCO, MBNMS, OPC	1X	1999	384	IP	Y
		6050	UCSC	PTR	PISCO, MBNMS, OPC	1X	1999	site	GSES	Y

Region	SubRegion	Site Code	Entity	PI	Major Funder	Freq per year	Start Date	Dimensions	Methods	In MARINe database?
		6070	UCSC	PTR	PISCO, MBNMS, OPC	1X	1999		IP / GSES	Y
	Pacific Grove to Monterey/San Luis Obispo County Line	6090	UCSC	PTR	PISCO, MBNMS, OPC	1X	1999	284	IP	Y
		6100	UCSC	PTR	OPC, PISCO	1X	2007	125	IP	Y
		6105	UCSC	PTR	CASP, ASIL	1X	2005		IP	Y
		6110	UCSC	PTR	OPC, PISCO	1X	2007	47	IP	Y
		6120	UCSC	PTR	OPC, PISCO	1X	2008	73	IP	Y
		6130	UCSC	PTR	PISCO, MBNMS, OPC	1X	2000	256	IP	Y
		6140	UCSC	PTR	PISCO, MBNMS, OPC	1X	2004	118	IP / AHA	Y
		6150	UCSC	PTR	PISCO, MBNMS, OPC	1X	1999	53 / 830	IP / AHA	Y
		6170	UCSC	PTR	OPC, PISCO	1X	2000	110	IP	Y
		6180	UCSC	PTR	PISCO, MBNMS, OPC	1X	2004	85 / 725	IP / AHA	Y
		6190	UCSC	PTR	PISCO, MBNMS, OPC	1X	1999	64	IP	Y
		6200	UCSC	PTR	PISCO, MBNMS, OPC	1X	2004	76	IP	Y

Region	SubRegion	Site Code	Entity	PI	Major Funder	Freq per year	Start Date	Dimensions	Methods	In MARINe database?
		6220	UCSC	PTR	PISCO, MBNMS, OPC	1X	1999	133 / 545	IP / AHA	Y
		6230	UCSC	PTR	PISCO, MBNMS, OPC	1X	2004	66	IP	Y
Central CA	Monterey/San Luis Obispo County Line to Cayucos	6250	UCSC	PTR	BOEM, SLO, MBNMS	1X	1995	76 / 1185	IP / AHA	Y
		6260	UCSC	PTR	BOEM, MBNMS, OPC	1X	1997	67	IP	Y
		6280	UCSC	PTR	PISCO, MBNMS, OPC	1X	2004	80	IP	Y
		6290	UCSC	PTR	BOEM, SLO, OPC	1X	2001	32	IP	Y
		6310	UCSC	PTR	BOEM, SLO, OPC	1X	1995	21 / 1430	IP / AHA	Y
	Montaña de Oro State Park to Government Point	6320	UCSC	PTR	BOEM, SLO, OPC	1X	1995		GSES	Y
		NC1	Tenera	JS	PG&E	4X	1976	2 - 30mx2m transects	10 - m2 abalone quadrats per transect	N
		NC2	Tenera	JS	PG&E	4X	1976	2 - 30mx2m transects	10 - m2 abalone quadrats per transect	N
		FC1	Tenera	JS	PG&E	4X	1976	2 - 30mx2m transects	10 - m2 abalone quadrats per transect	N
		FC2	Tenera	JS	PG&E	4X	1976	2 - 30mx2m transects	10 - m2 abalone quadrats per transect	N
		FC3	Tenera	JS	PG&E	4X	1976	2 - 30mx2m transects	10 - m2 abalone quadrats per transect	N

Region	SubRegion	Site Code	Entity	PI	Major Funder	Freq per year	Start Date	Dimensions	Methods	In MARINe database?
		NDC1	Tenera	JS	PG&E	4X	1976	2 - 30mx2m transects	10 - m2 abalone quadrats per transect	N
		NDC2	Tenera	JS	PG&E	4X	1976	2 - 30mx2m transects	10 - m2 abalone quadrats per transect	N
		NDC3	Tenera	JS	PG&E	4X	1976	2 - 30mx2m transects	10 - m2 abalone quadrats per transect	N
		SDC1	Tenera	JS	PG&E	4X	1976	2 - 30mx2m transects	10 - m2 abalone quadrats per transect	N
		SDC2	Tenera	JS	PG&E	4X	1976	2 - 30mx2m transects	10 - m2 abalone quadrats per transect	N
		SDC3	Tenera	JS	PG&E	4X	1976	2 - 30mx2m transects	10 - m2 abalone quadrats per transect	N
		SDP1	Tenera	JS	PG&E	4X	1976	1 - 30mx2m transects	10 - m2 abalone quadrats per transect	N
		SDP2	Tenera	JS	PG&E	4X	1976	1 - 30mx2m transects	10 - m2 abalone quadrats per transect	N
		SC1	Tenera	JS	PG&E	4X	1976	2 - 30mx2m transects	10 - m2 abalone quadrats per transect	N
		6340	UCSC	PTR	BOEM, SLO, OPC	1X	1995	site	GSES	Y
		6360	UCSC	PTR	BOEM, SBC, VAFB, OPC	1X	1993	45 /1390	IP / AHA	Y
		6370	UCSC	PTR	BOEM, SBC, VAFB, OPC	1X	1992	30 / 954	IP / AHA	Y
		6390	UCSC	PTR	BOEM, SBC, VAFB, OPC	1X	1992	56 / 1663	IP / AHA	Y
		6400	UCSC	PTR	BOEM, SBC, OPC	1X	1992	57	IP	Y

Region	SubRegion	Site Code	Entity	PI	Major Funder	Freq per year	Start Date	Dimensions	Methods	In MARINe database?
Southern CA mainland	Government Point to Malibu Pier	6420	UCSB	JEC	BOEM, SBC, OPC	1X	1992	site	GSES / AHA	Y
		6440	UCSB	JEC	BOEM, SBC, OPC	1X	1992	site	GSES	Y
		6460	UCSB	JEC	BOEM, SBC, OPC	1X	1992	site	GSES	Y
		6480	UCSB	JEC	BOEM, SBC, OPC	1X	1992	site	GSES	Y
		6500	UCSB	JEC	BOEM, CCC, OPC	1X	1994	site	GSES	Y
		6520	CSUF, CPP	JLB, JRS	BOEM, CCC, OPC	1X	1994	site	GSES	Y
		6580	CSUF, CPP	JLB, JRS	BOEM, CCC, OPC	1X	1994	site	GSES	Y
Southern CA mainland	Palos Verdes Peninsula from the Palos Verdes/Torrance border to Los Angeles Harbor	6585	CSULB, CMA	JKP, BJA	CMA, CSULB	1X	1975			N
		6595	CSULB, CMA	JKP, BJA	CMA, CSULB	1X	1975			N
			CSULB, CMA	JKP, BJA	CMA, CSULB	1X	1975			
		6600	CSUF, CPP	JLB, JRS	BOEM, CCC, OPC	1X	1994	site	GSES	Y
		6620	CSUF, CPP	JLB, JRS	BOEM, OPC	1X	1999	site	GSES	Y
	Corona Del Mar State Beach to Dana Point	6660	CSUF, CPP	JLB, JRS	BOEM, OPC	1X	1996	site	GSES	Y
		6680	CSUF, CPP	JLB, JRS	BOEM, OPC	1X	1996	site	GSES	Y
		6720	CSUF, CPP	JLB, JRS	BOEM, OPC	1X	1996	site	GSES	Y

Region	SubRegion	Site Code	Entity	PI	Major Funder	Freq per year	Start Date	Dimensions	Methods	In MARINe database?
		6740	CSUF, CPP	JLB, JRS	BOEM, OPC	1X	1996	site	GSES	Y
	Cardiff State Beach to US-Mexico Border	6760	CSUF, CPP, CNM	JLB, JRS, KL	SERP, NAVY, NPS	1X	1997	site	GSES	Y
		6780	CSUF, CPP, CNM	JLB, JRS, KL	SERP, NAVY, NPS	1X	1997	site	GSES	Y
		6820	UCSB, Navy	JB	NAVY	1X	1995	site	GSES	Y
		6840	UCSB, Navy	JB	NAVY	1X	1995	site	GSES	Y
		6860	CNM	KL	NPS	1X	1990	site	GSES	Y
		6880	CNM	KL	NPS	1X	1990	site	GSES	Y
		6900	CNM	KL	NPS	1X	1990	site	GSES	Y
Channel Islands	San Miguel Island	7000	CINP	SGW	NPS, NMFS, OPC	1X	1985	275m x 10m	IP (5 plots), timed site-wide count	Y
		7010	CINP	SGW	NPS, NMFS, OPC	1X	1985	130m x 10m	IP (5 plots), timed site-wide count	Y
		7020	CINP	SGW	NPS, NMFS, OPC	1X	1985	50m x 4m	Timed site-wide count	Y
		7030	CINP	SGW	NPS, NMFS, OPC	1X	1985	90m x 8m	IP (5 plots), timed site-wide count	Y
	Santa Rosa Island	7100	CINP	SGW	NPS, NMFS, OPC	1X	1988	212m x 6m	IP (5 plots), timed site-wide count	Y
		7110	CINP	SGW	NPS, NMFS, OPC	1X	1986	100m x 18m	IP (5 plots), timed site-wide count	Y
		7120	CINP	SGW	NPS, NMFS, OPC	1X	1986	45m x 4m	Timed site-wide count	Y

Region	SubRegion	Site Code	Entity	PI	Major Funder	Freq per year	Start Date	Dimensions	Methods	In MARINe database?
		7130	CINP	SGW	NPS, NMFS, OPC	1X	1985	90m x 5m	Timed site-wide count	Y
		7140	CINP	SGW	NPS, NMFS, OPC	1X	1985	100m x 5m	IP (5 plots), timed site-wide count	Y
	Santa Cruz Island	7200	CINP	SGW	NPS, SBC, CCC, NMFS, OPC	1X	1994	70m x 9m	Timed site-wide count	Y
		7220	CINP	SGW	NPS, SBC, CCC, NMFS, OPC	1X	1994	74m x 8m	Timed site-wide count	Y
		7230	CINP	SGW	NPS, SBC, CCC, NMFS, OPC	1X	1994	56m x 3m	Timed site-wide count	Y
		7240	CINP	SGW	NPS, SBC, CCC, NMFS, OPC	1X	1994	70m x 3m	Timed site-wide count	Y
		7250	CINP	SGW	NPS, SBC, CCC, NMFS, OPC	1X	1994	27m x 4m	Timed site-wide count	Y
		7280	CINP	SGW	NPS, SBC, CCC, NMFS, OPC	1X	1994	60m x 6m	Timed site-wide count	Y
Channel Islands	Anacapa Island	7300	CINP	SGW	NPS, NMFS, OPC	1X	1982	135m x 15m	5 irregular fixed plots, timed site-wide count	Y
		7310	CINP	SGW	NPS, NMFS, OPC	1X	1982	95m x 6m	Timed site-wide count	Y
		7330	CINP	SGW	NPS, NMFS, OPC	1X	1982	15m 32m	Timed site-wide count	Y
	Santa Barbara Island	7400	CINP	SGW	NPS, NMFS, OPC	1X	1985	36m x 9m	Timed site-wide count	Y
		7410	CINP	SGW	NPS, NMFS, OPC	1X	1985	53m x 42m	5 irregular fixed plots, timed site-wide count	Y

Region	SubRegion	Site Code	Entity	PI	Major Funder	Freq per year	Start Date	Dimensions	Methods	In MARINe database?
	San Nicolas Island	7545	UW/USGS	GVB, MK	NMFS, Navy, USFWS, NBSv, NBSy, USGS, DOD, UCSC, UW	1X	1981	360	6 fixed band transects, each 2m x 30m	N
		7550	UW/USGS	GVB, MK	NMFS, Navy, USFWS, NBSv, NBSy, USGS, DOD, UCSC, UW	1X	1981	274	6 fixed band transects; 2m x 30m (n=3), 2m x 25m; 1m x 17m; and 1m x 27m	N
		7513	UW/USGS	GVB, MK	NMFS, Navy, USFWS, NBSv, NBSy, USGS, DOD, UCSC, UW	1X	1981	252	7 fixed band transects; 2m x transect length (7, 8, 15, 18, 31, 35, and 36m)	N
			UW/USGS	GVB, MK	NMFS, Navy, USFWS, NBSv, NBSy, USGS, DOD, UCSC, UW	1X	1981	52	2 fixed band transects; 2m x 12m and 2m x 14m	N
		7518	UW/USGS	GVB, MK	NMFS, Navy, USFWS, NBSv, NBSy, USGS, DOD, UCSC, UW	1X	1981	70	3 fixed band transects; 2m x transect length (8, 12, and 15m)	N
		7519	UW/USGS	GVB, MK	NMFS, Navy, USFWS, NBSv, NBSy, USGS, DOD, UCSC, UW	1X	1981	252	4 fixed band transects; 2m x transect length (26, 30, 30, and 40m)	N
		7521	UW/USGS	GVB, MK	NMFS, Navy, USFWS, NBSv, NBSy,	1X	1981	270	5 fixed band transects; 2m x 30m (n=2) and 2m x 25m (n=3)	N

Region	SubRegion	Site Code	Entity	PI	Major Funder	Freq per year	Start Date	Dimensions	Methods	In MARINe database?
					USGS, DOD, UCSC, UW					
		7530	UW/USGS	GVB, MK	NMFS, Navy, USFWS, NBSv, NBSy, USGS, DOD, UCSC, UW	1X	1981	278	5 fixed band transects; 2m x 30m (n=3), 2m x 25m, and 2m x 24m	N
		7535	UW/USGS	GVB, MK	NMFS, Navy, USFWS, NBSv, NBSy, USGS, DOD, UCSC, UW	1X	1981	198	6 fixed band transects; 2m x transect length (7, 10, 17, 18, 20, and 27m)	N
		7500	NAVY	JB	NAVY	1X	2015	35/51/42	IP (3 plots), timed site-wide count	Y
		7511	NAVY	JB	NAVY	1X	2016		Timed site-wide count	Y
		7520	NAVY	JB	NAVY	1X	2015	70/50/39	IP (3 plots), timed site-wide count	Y
		7540	NAVY	JB	NAVY	1X	2015	26/41/63	IP (3 plots), timed site-wide count	Y
	Santa Catalina Island	7610		JME	TAT	1X	1982	site	GSES	Y
		7650		JME	TAT	1X	1995	site	GSES	Y
	San Clemente Island	7700	NAVY	JB	NAVY	1X	2011		IP (1 plot); timed site-wide count	Y
		7710	NAVY	JB	NAVY	1X	2011		Timed site-wide count	Y
		7720	NAVY	JB	NAVY	1X	2011		IP (2 plots), timed site-wide count	Y
		7730	NAVY	JB	NAVY	1X	2011		Timed site-wide count	Y
Mexico	Baja California	8010	UABC	RB	UCM	1X	2018		AHA	N
		8012	UABC	RB	UCM	1X	2018		AHA	N

Region	SubRegion	Site Code	Entity	PI	Major Funder	Freq per year	Start Date	Dimensions	Methods	In MARINe database?
		8016	UABC	RB	UCM	1X	2018		AHA	N
		8022	UABC	RB	UCM	1X	2019		IP (3 plots)	N
		8045	UABC	RB	UCM	1X	2019		AHA	N
		8049	UABC	RB	UCM	1X	2018		AHA	N
		8051	UABC	RB	UCM	1X	2018		AHA	N
		8053	UABC	RB	UCM	1X	2018		AHA	N
		8071	UABC	RB	UCM	1X	2018		AHA	N
		8100	UABC	RB	UCM	1X	2019		IP (3 plots)	N
		8101	UABC	RB	UCM	1X	2018		AHA	N
		8107	UABC	RB	UCM	1X	2018		AHA	N
		8150	UABC	RB	UCM	1X	2018		AHA	N
		8170	UABC	RB	UCM	1X	2018		AHA	N
		8325	UABC	RB	UCM	1X	2018		AHA	N
		8400	UABC	RB	UCM	1X	2018		AHA	N
		8430	UABC	RB	UCM	1X	2018		AHA	N

APPENDIX B: DEMOGRAPHIC RECOVERY CRITERIA-INITIAL ANALYSIS RESULTS

We assessed the status of black abalone based on the Demographic Recovery Criteria (Section 3.3 of this Plan), using the available long-term monitoring data through 2015/2016. This allowed us to evaluate whether our proposed methods are appropriate for assessing the Criteria. We summarize the analysis and results below and in the following table. Overall, none of the SubRegions or Regions met all of the criteria. Only the SubRegion from Pacific Grove to the Monterey/San Luis Obispo County Line (in the Central California Region) met four of the five criteria evaluated. Although populations in this SubRegion are considered healthy, they are subject to threats such as illegal take. The Baja California Region is not included in the summary table below, because we do not currently have study sites within this Region.

- **# Study Sites**: The number of study sites within each SubRegion sampled at least annually. Within some SubRegions, historical data are available for additional sites that were only sampled sporadically (e.g., sites on Año Nuevo Island).
- **Yes/No**: Indicates whether the SubRegion met the criterion (YES) or not (NO).
- **Presence**: This criterion is met if black abalone were present in the SubRegion in each year for the last five years. The table indicates the number of years over which black abalone were present over the last five years. Several SubRegions in the Central California and Channel Islands Regions met this criterion. No SubRegions in the North-Central and Southern California Regions met this criterion, but current monitoring efforts may not be sufficient to evaluate presence of black abalone in these two Regions.
- **Population Density, Structure, and Growth**: For these criteria, the table indicates the number of study sites within each SubRegion that met the criterion. Blank cells indicate where we did not have enough information to fully evaluate the criterion. For example, for manysites, we did not have data to evaluate the Density criterion. In addition, many sites did not have sufficient numbers of black abalone to evaluate the Recruitment, Size Structure, or Population Trend criteria.
    - **Density**: This criterion is met if the observed density is equal to or greater than the expected habitat-based density at 50% or more of the study sites within the SubRegion, in each year for the last five years. Expected densities may differ among Regions and SubRegions. For this initial analysis, we estimated the expected densities based on densities observed during habitat surveys conducted in the SubRegion from Pacific Grove to the Monterey/ San Luis Obispo County line in Central California. Only this SubRegion met this criterion.
    - **Recruitment**: This criterion is met if at least 50% of the study sites within the SubRegion show evidence of recruitment events in at least two non-consecutive years of the last ten years. Only the SubRegion from Pacific Grove to the Monterey/San Luis Obispo County line in Central California met this criterion.

- **Size Structure**: This criterion is met if at least 50% of the study sites within the SubRegion have at least 50 black abalone and, for the last five years, at least 40% are small (50-100 mm SL) and 10% are large (>100 mm SL). Only one SubRegion in Central California (from Pacific Grove to the Monterey/San Luis Obispo County line) and one SubRegion in the Channel Islands (San Nicolas Island) met this criterion.
- **Population Trend**: This criterion is met in a SubRegion if, over the last ten years, the average population growth rate for individuals >50 mm SL is (a) stable or increasing when averaged across all study sites within the SubRegion (overall SubRegion-wide average); (b) stable or increasing for at least 50% of the individual study sites (individual site averages); and (c) greater than or equal to the minimum (e.g., -0.05) in each individual study site. Only one SubRegion (Anacapa Island) in the Channel Islands Region met this criterion.

Summary of analysis results applying the Demographic Recovery Criteria to the SubRegions and Regions, using existing long-term monitoring data through 2015/2016.

Region	SubRegion	# Study Sites	Presence		Density		Recruitment		Size Structure		Population Growth	
			# Years	Yes/ No	# Sites	Yes/ No	# Sites	Yes/ No	# Sites	Yes/ No	# Sites	Yes/ No
North-Central California	Del Mar Landing Ecological Reserve to Bodega Head	2	1	NO	0	NO		NO		NO		NO
	Bodega Head to Point Bonita, including Farallon Islands	4	1	NO	0	NO		NO		NO		NO
	San Francisco Bay (southern point at mouth) to Pescadero State Beach	0										
Central California	Pescadero State Beach to Natural Bridges State Beach	6	5	YES	0	NO	0	NO		NO	1	NO
	Año Nuevo Island	0										
	Pacific Grove to Monterey/San Luis Obispo County Line	14	5	YES	7	YES	12	YES	11	YES	4	NO
	Monterey/San Luis Obispo County Line to Cayucos	5	5	YES	2	NO	0	NO	2	NO	0	NO
	Montana de Oro State Park to Government Point	20	5	YES	0	NO	0	NO		NO	0	NO
Southern California	Government Point to Malibu Pier	7	1	NO	0	NO		NO		NO		NO
	Palos Verdes Peninsula from the Palos Verdes/Torrance border to Los Angeles Harbor	5	0	NO	0	NO		NO		NO		NO
	Corona Del Mar State Beach to Dana Point	4	0	NO	0	NO		NO		NO		NO
	Cardiff State Beach to US-Mexico Border	7	0	NO	0	NO		NO		NO		NO
Channel Islands	San Miguel Island	4	5	YES	1	NO	0	NO	1	NO	0	NO
	Santa Rosa Island	5	5	YES	0	NO	0	NO		NO	2	NO
	Santa Cruz Island	6	5	YES	1	NO	1	NO	1	NO	0	NO
	Anacapa Island	3	5	YES	0	NO	0	NO		NO	2	YES
	Santa Barbara Island	2	4	NO	0	NO	0	NO		NO		NO
	San Nicolas Island	9	5	YES	2	NO	4	NO	5	YES	4	NO
	Santa Catalina Island	2	0	NO	0	NO		NO		NO		NO
	San Clemente Island	4	4	NO	0	NO	0	NO		NO		NO
	TOTALs	109	56		13		17		20		13	